Document WRC-23-IRW-22/15-E
23 November 2022
English only

ITUEvents

2nd ITU Inter-regional Workshop on WRC-23 Preparation

29 November – 1 December 2022
Geneva, Switzerland

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The Coordinated Universal Time as international reference for timekeeping

Patrizia TAVELLA
Director of BIPM Time Department

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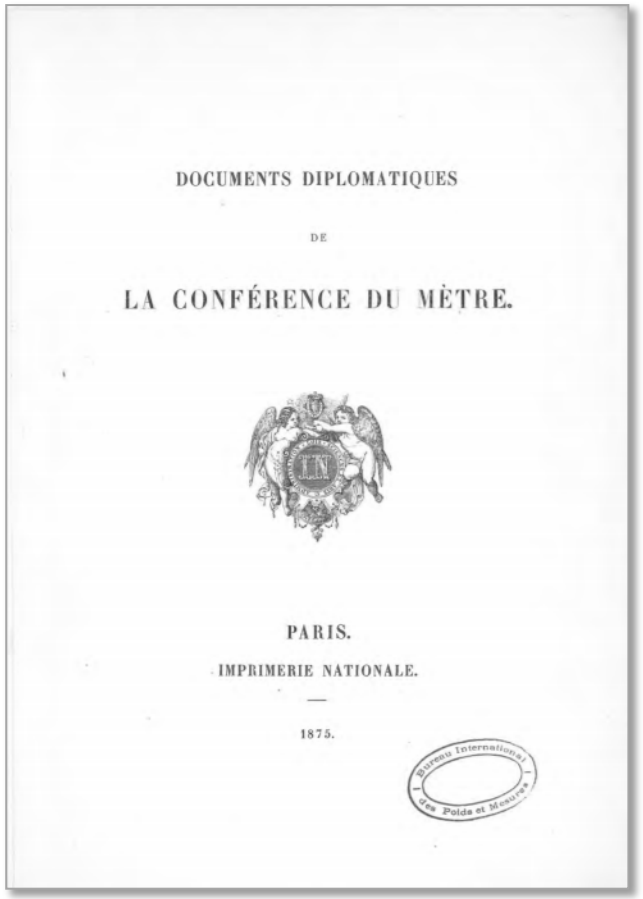
Bureau International des Poids et Mesures

The Metre Convention



DOCUMENTS DIPLOMATIQUES

DE

LA CONFÉRENCE DU MÈTRE.

PARIS.

IMPRIMERIE NATIONALE.

1875.

20 May 1875 - The Metre Convention was signed in Paris by representatives of 17 States

ARTICLE PREMIER (1875)

Les Hautes Parties contractantes s'engagent à fonder et entretenir, à frais communs, un *Bureau international des poids et mesures*, scientifique et permanent, dont le siège est à Paris[1].

The First Article creates the International Bureau of Weights and Measures (BIPM).

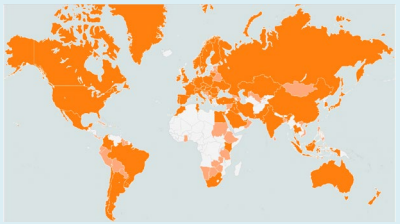
ART. 3 (1875)

Le Bureau international fonctionnera sous la direction et la surveillance exclusives d'un *Comité international des poids et mesures*, placé lui-même sous l'autorité d'une *Conférence générale des poids et mesures*, formée de délégués de tous les Gouvernements contractants.

Article 3 states that the BIPM shall operate under the authority of the General Conference on Weights and Measures (CGPM) and the supervision of the International Committee for Weights and Measures (CIPM).

Bureau International des Poids et Mesures

The BIPM – an international organization



CGPM – Conférence générale des poids et mesures

Official representatives of Member States.

CIPM – Comité international des poids et mesures

Eighteen individuals of different nationalities elected by the CGPM.

Scientific and technical secretariat (in Sèvres)

- *International coordination and liaison*
- *Technical coordination – laboratories*
- *Capacity building*

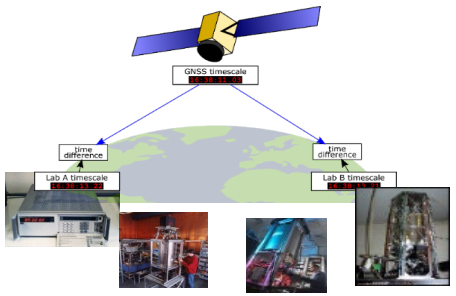
Consultative Committees (CCs)

CCAUV – Acoustics, US & Vibration
CCEM – Electricity & Magnetism
CCL – Length
CCM – Mass and related quantities
CCPR – Photometry & Radiometry
CCQM – Amount of substance
CCRI – Ionizing Radiation
CCT – Thermometry
CCTF – Time & Frequency
CCU - Units

Established in 1875 when 17 States signed the Metre Convention, now with 64 Member States and 36 Associate States and Economies.

Bureau International des Poids et Mesures

Construction of the Coordinated Universal Time



National time laboratories realize real-time approximations **UTC(k)**

≈ 450 atomic clocks
≈ 10 primary frequency standards

in ~ 85 laboratories

TAI

International Atomic Time

leap seconds

Measurement of Earth's rotation (IERS)

UTC

Coordinated Universal Time

The offset [***UTC*** - ***UTC(k)***] is published in **BIPM *Circular T***

Bureau International des Poids et Mesures

Coordinated Universal Time UTC is in agreement with the rotational angle of the Earth UT1

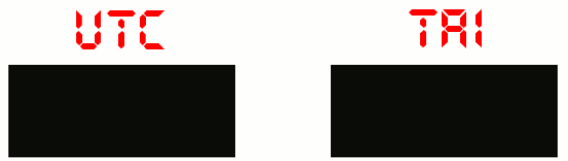
Timekeeping is related to the rotation of the Earth.

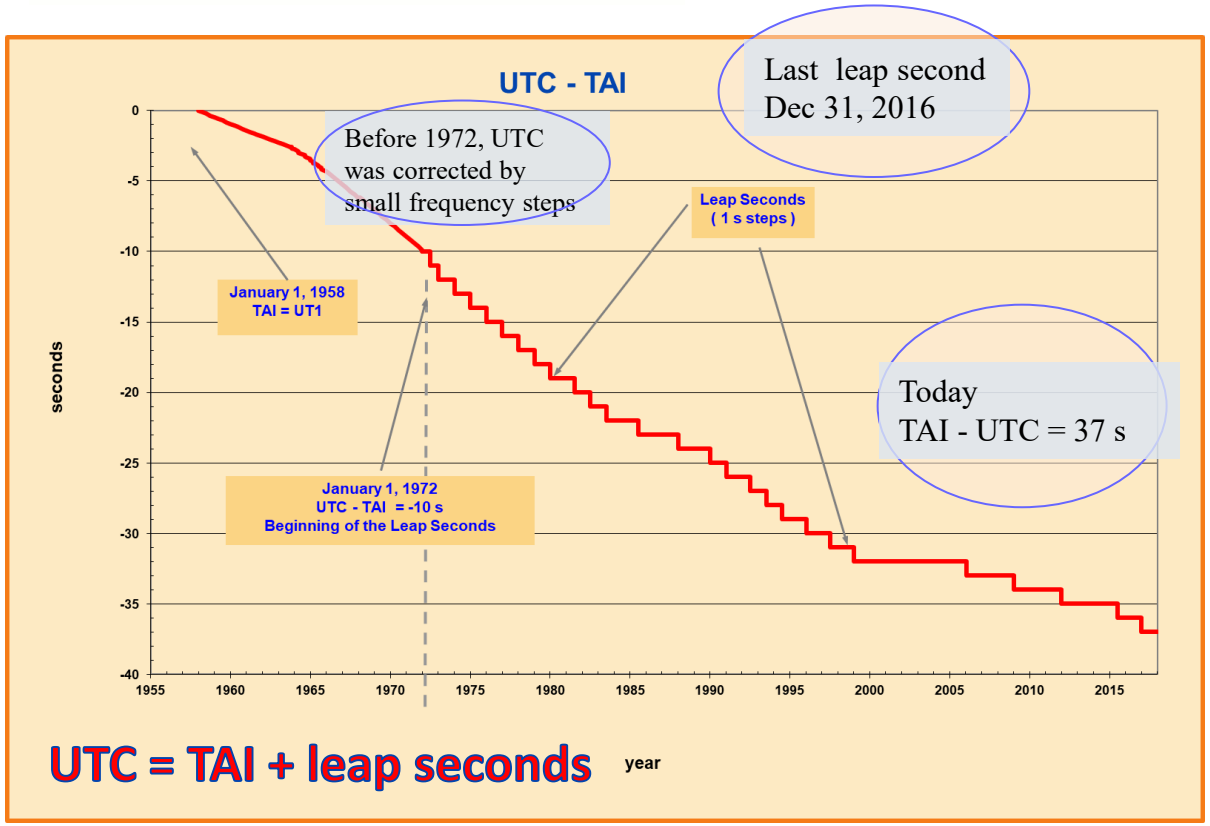
The real time timekeeping is based on atomic clocks and, since 1972, UTC is obtained from the International Atomic Time (TAI) plus leap seconds.

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

$|UTC - UT1| < 1$ second

UTC = TAI + n seconds





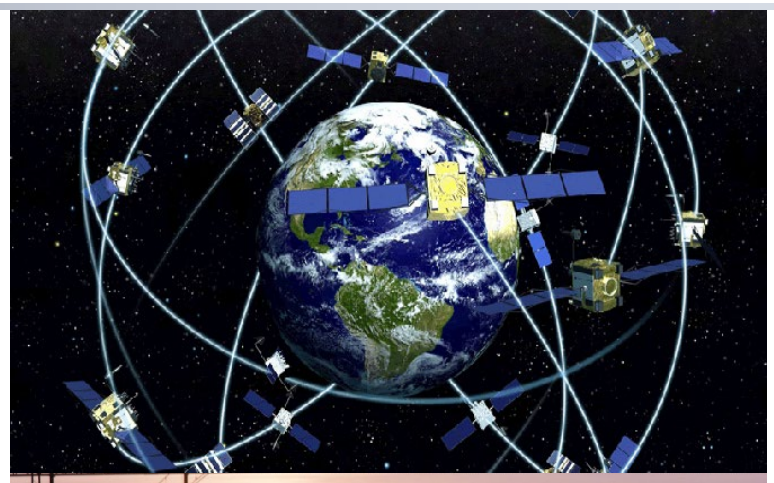
23:59:59
23:59:60
00:00:00

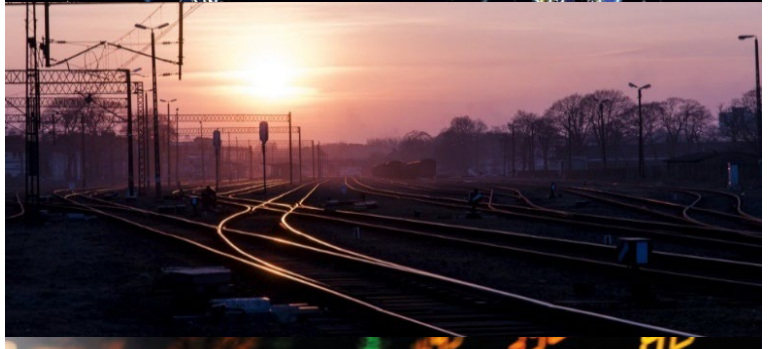
The process to insert the leap second and the code to transmit DUT1= UT1-UTC are described in Rec ITU-R TF 460-6

Current situation

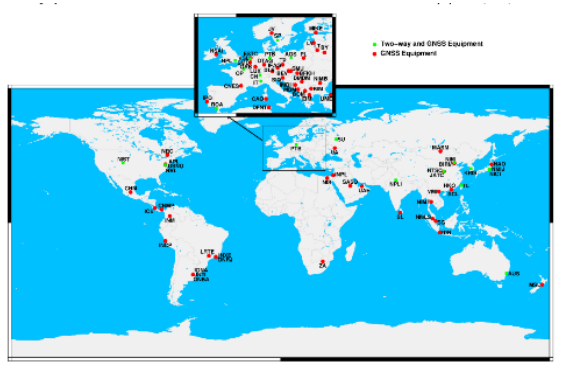
Technological and digital applications which underpin national critical infrastructures are based on an overall synchronization.

The main requirements for the common time scale is that it be continuous, monotonic, reliable, and easily available.





Coordinated Universal Time UTC is the international time standard



UTC is supported by the work of:

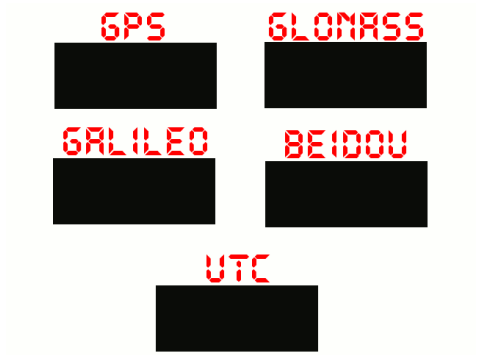
- **BIPM** and the 85 time laboratories providing data and realizing real-time traceability under the authority of the General Conference of Weights and Measures, where all states are represented
- the International Earth Rotation and Reference Systems Service - **IERS** computing and publishing the difference versus the Earth rotation angle UT1-UTC,
- the International Telecommunication Union, **ITU-R**, to ensure it is used and correctly transmitted (ITU-R TF.460-6 (2002): *Standard-frequency and time-signal emissions)*

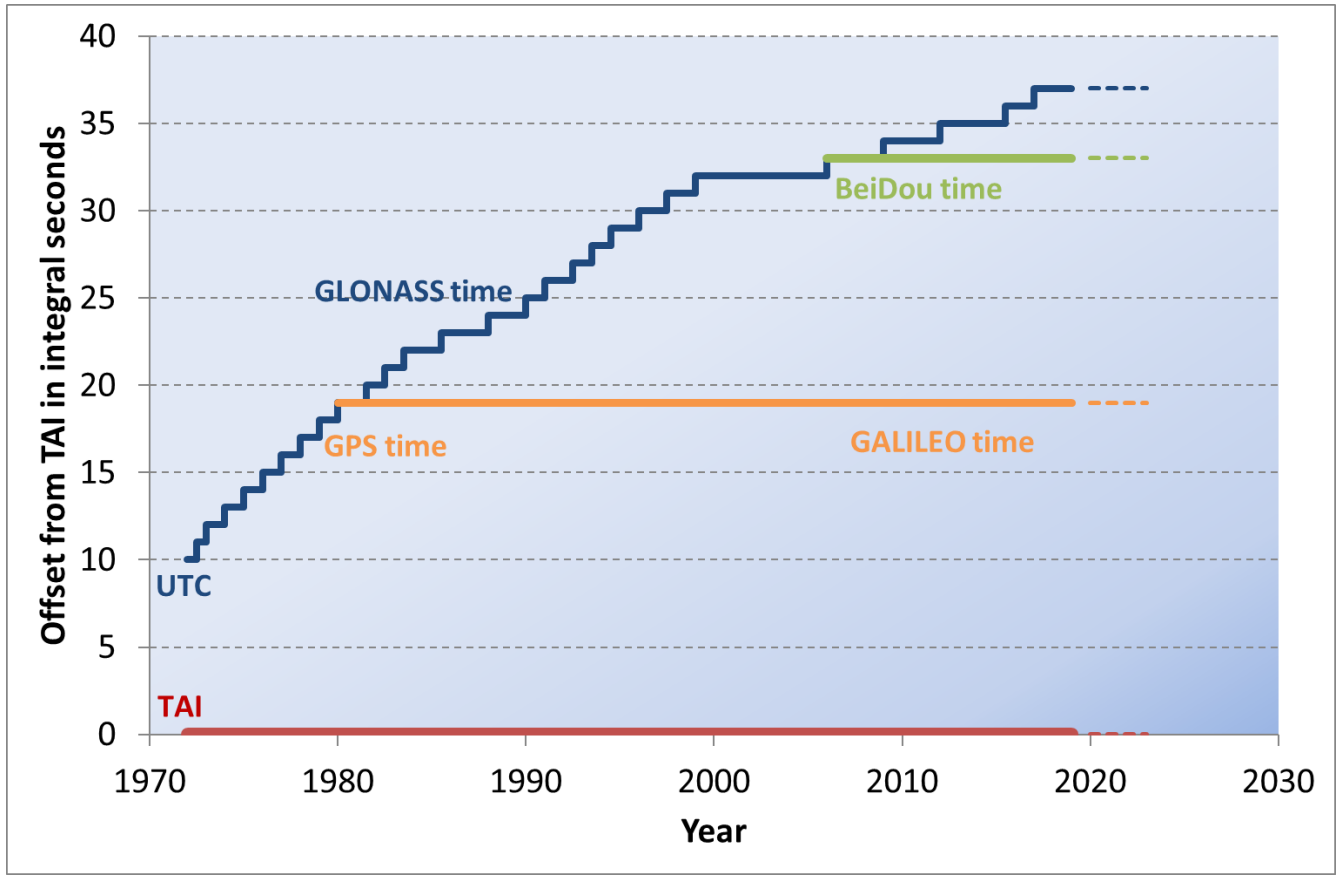
→ But, users underpinning critical infrastructures, need a continuous and unique timescale.
Increasingly UTC is not being used by:

- **most of the GNSSs,**
- **the digital network giants (eg GAFA and Alibaba),**
- **the most widely used Internet time synchronization protocols as NTP and PTP**

Leap seconds in Global Navigation Satellite System time scales

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





The digital networks cannot cope with unpredictable leap seconds

WIRED

The Inside Story of the Extra Second That Crashed the W

BUSINESS | CULTURE | GEAR | IDEAS | SCIENCE

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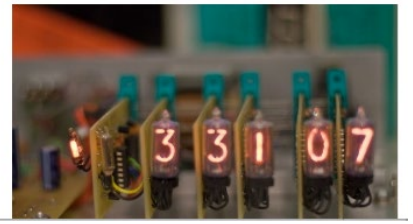
The Inside Story of the Extra Second That Crashed the Web



自由時報 Liberty Times Net

https://3c.ltn.com.tw/news/18985/2

61 seconds in a minute? Understand the computer and the stock market enemy "leap second"

2015/07/01 06:27

Text/Reporter Liu Jiqing

The impact of leap seconds-computer systems, financial market preparations

The Telegraph

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Leap Second confuses Twitter and Android

Users reported problems with Android and Twitter as the leap second was added to atomic time

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How and why the leap second affected Cloudflare DNS

Share Like 1K Tweet

John Graham-Cumming

01/01/2017 à 11:40:26 PM UTC+1

At midnight UTC on New Year's Day, deep inside Cloudflare's custom RRDNS software, a number went negative when it should always have

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'Leap second' snafu affects Oracle clusterware

By Chris Kanaracus

U.S. Correspondent, IDG News Service | JANUARY 06, 2009 12:00 AM PT

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By Joab Jackson

U.S. Correspondent, IDG News Service | JULY 02, 2012 08:00 AM PT

Time travels on the network

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

Consultative Committee on Time and Frequency User Survey (2021)

- > 200 answers
- The large majority asks to get rid of discontinuities in UTC
- Other time scales are used, instead of UTC, as continuous time scales

Several “ah hoc” methods have been developed to avoid leap seconds

- **Ignore leap seconds after an initial synchronization**
  - GPS, Galileo, BeiDou system times.
  - Most current versions of Windows (till next synchronization)
- **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) …
  - Google smear is now being proposed as a new « international standard »

→ 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
GPS system time, which is continuous and easily accessible, is already considered as a time and frequency reference and could become, de facto, the international standard time.

It is urgent to revise the leap second process in UTC

Solution to progress towards a continuous UTC

Increase the tolerance in|UT1 - UTC| to a new limit (e.g. 1 min reached after 1 century or 1 hr reached after 5000 yrs) or to an unlimited value (= the difference UT1 – UTC will be let growing with no limit).

→ **UTC remains linked to UT1**, the Earth's rotation angle, whose origin is the reference meridian of Greenwich.

In the daily life, there is no change for the general public since the evolution of |UT1 - UTC| will remain negligible compared to the +/- 15 min seasonal day variations, for centuries. The general perception of conformity to astronomical phenomena is not challenged.

Users needing the knowledge of UT1-UTC find accurate and real time estimations by the services of IERS, NASA, GNSS, ITU-R broadcast signals

In the '70s UTC was used as approximation to UT1 mostly for navigation with traditional optical instruments.

Approximation UTC ≈ UT1 corresponds to an uncertainty in the position up to 400 m (at the equator). It is used only in low accuracy applications (as amateurs telescope pointing).

But it is not adapted for high precision applications (as high accuracy astronomy and space applications) that are already using the IERS and NASA estimates with 10 microsecond uncertainty, corresponding to about 0.3 cm uncertainty in the position

CGPM resolution D/4 - On the use and future development of Coordinated Universal Time (UTC)

Overall consensus on the technical need of enlarging the tolerance: *CCTF, CIPM, ITU-T, ITU-R, IAU, IUGG, URSI, IGS, GAFA, GNSS providers, IT stakeholders, …*

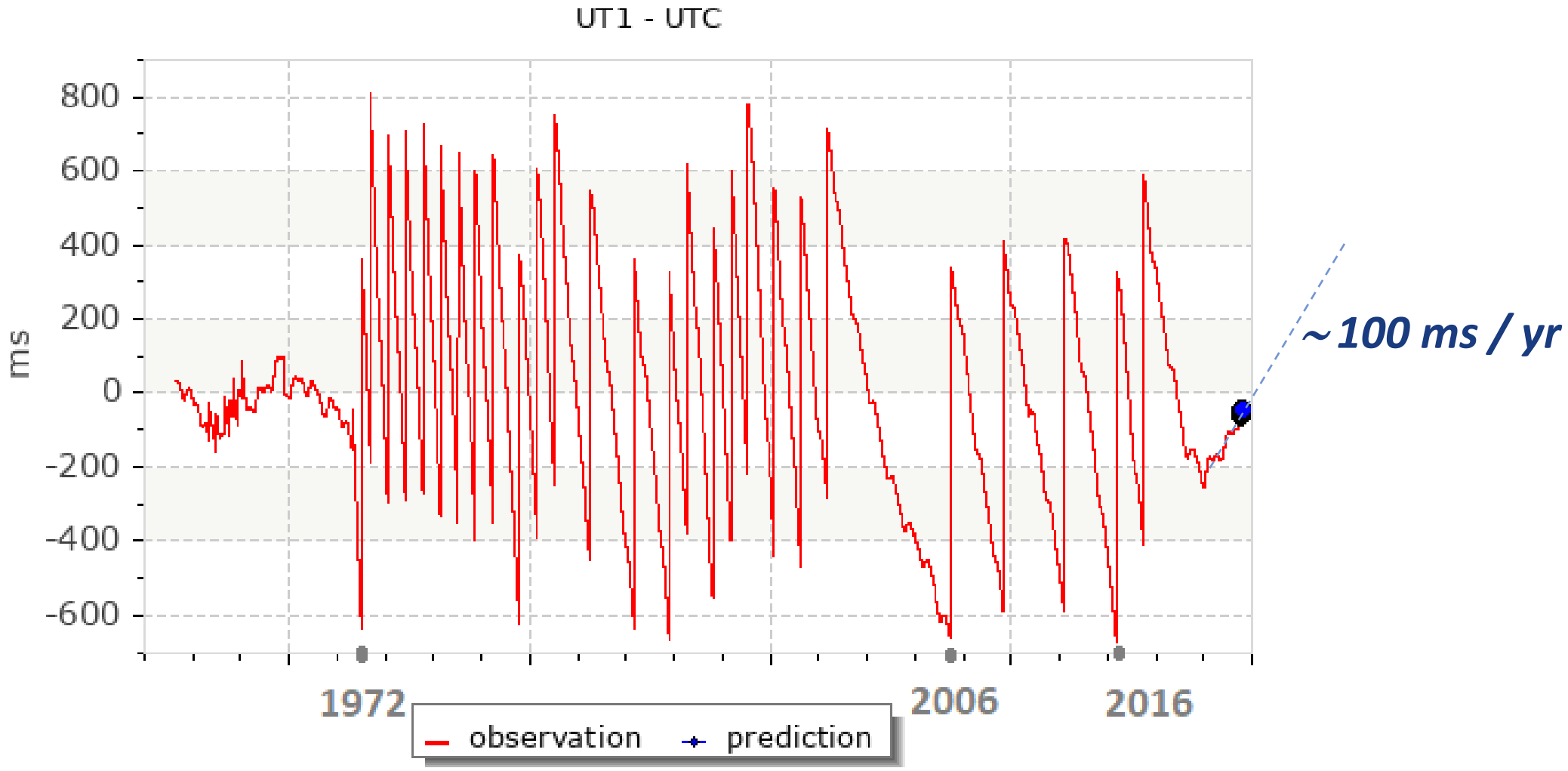
Process in two steps:

1. *decision in CGPM 2022 to enlarge UT1-UTC tolerance*
2. *details for the new tolerance, its implementation and periodic review process at CGPM in 2026*

Trade-off on the implementation date between:

- *the need of updating systems*
- *the important issues that*
  - *discontinuities in UTC and different ad-hoc solutions currently implemented (Google / Facebook / Alibaba smears, NTP, Microsoft, …) cause confusion and put at risk the resilience of critical national infrastructures,*
  - *the current Earth acceleration may lead to a possible negative leap seconds in the next decade,*
  - *one of the GNSS time scales may be use de facto as the international standard*

Possible negative leap second in 10 years?



Difference between Earth rotation UT1 and UTC.
The current leap second system was initialized in 1972, and a positive step in UT1-UTC was introduced each time the difference approached approximately -500 ms.
https://eoc.obspm.fr/index.php?index=realtime&lang=en

Overall acceptability and support to the enlargement of the tolerance in|UT1 - UTC|

CCTF, CIPM, ITU-T, ITU-R, IAU, IUGG, URSI, IGS, GAFA, GNSS providers, IT stakeholders, Vatican,… …

The Vatican expert helped in understanding the principle of astronomical conformity historically linked to civil timekeeping:

- Some irregularities in the Earth rotation can be observed but not predicted with sufficient uncertainty.
- Need of more and better data (and better models) to predict more accurately the agreement of UTC with the Earth rotation (work of future generations)

URSI

INTERNATIONAL UNION OF RADIO SCIENCE
UNION RADIO-SCIENTIFIQUE INTERNATIONALE
info@ursi.org www.ursi.org

XXXIVth General Assembly and Scientific Symposium
Rome 2021

Council IV
Vote on URSI Resolutions

GASS 2021 : Vote on URSI Resolutions and Recommendation

R1. Resolution on the need for a continuous reference time scale

The URSI Council,

INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2017-2020

SG15-TD780/PLEN

STUDY GROUP 15

Original: English

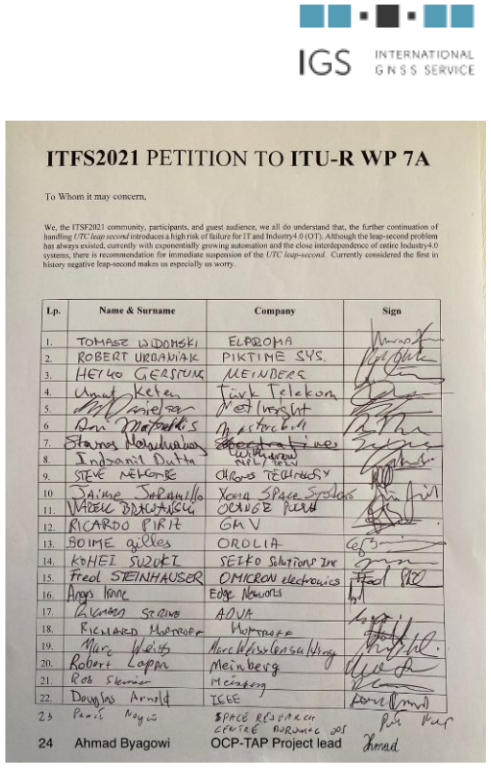
Question(s): 10, 11, 12, 13, 14/15 E-Meeting, 6-17 December 2021

TD

Source: Chairman WP3/15

Title: WP3 liaison statements

Purpose: Admin



IGS INTERNATIONAL GNSS SERVICE

ITFS2021 PETITION TO ITU-R WP 7A

To Whom it may concern,

We, the ITSF2021 community, participants, and guest audience, we all do understand that, the further continuation of handling *UTC leap second* introduces a high risk of failure for IT and Industry4.0 (OT). Although the leap-second problem has always existed, currently with exponentially growing automation and the close interdependence of entire Industry4.0 systems, there is recommendation for immediate suspension of the *UTC leap-second*. Currently considered the first in history negative leap-second makes us especially us worry.

Lp.	Name & Surname	Company	Sign
1.	TOMASZ WIDOMSKI	ELPROMA	
2.	ROBERT URBANIAK	PIKTIME SYS.	
3.	HEIKO GERSTUK	MEINBERG	
4.	Ugur Keten	Türk Telekom	
5.	[illegible]	Net Insight	
6.	[illegible]	[illegible]	
7.	[illegible]	[illegible]	
8.	Indranil Dutta	[illegible]	
9.	STEVE MEHORE	CISCO TECHNOLOGY	
10.	JAIME JARAMILLO	XONA SPACE SYSTEMS	
11.	MIKEL DRAUTSKI	ODYSSEY PNT	
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14.	KOHEI SUZUKI	SEIKO Solutions Inc	
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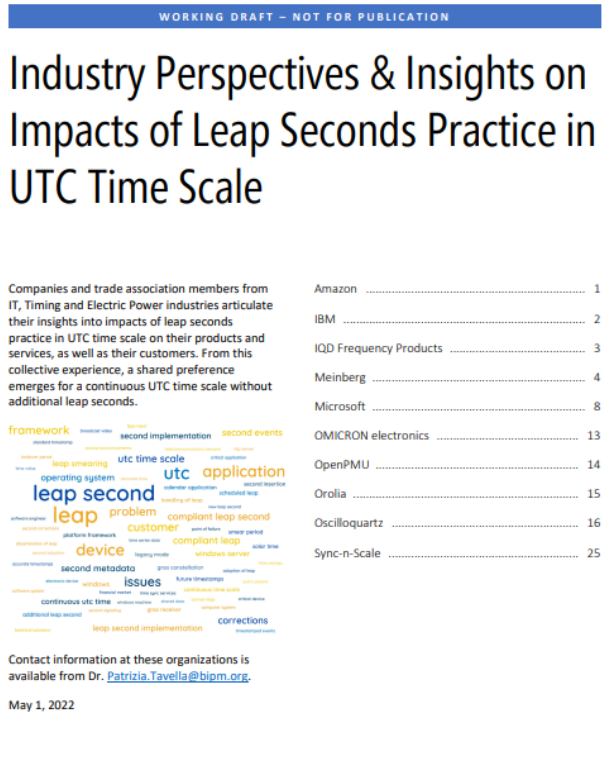
16.	Arpo Ilme	Edge Networks	
17.	[illegible]	ADVA	
18.	RICHARD MURPHY	Huawei	
19.	Marc Weiss	Marc Weiss Consulting	
20.	Robert Lapan	Meinberg	
21.	Rob Skinner	Meinberg	
22.	Douglas Arnold	IEEE	
23.	Pawel Nogus	SPACE RESEARCH CENTRE PAN	
24	Ahmad Byagowi	OCP-TAP Project lead	

Statement on Leap Second



WORKING DRAFT – NOT FOR PUBLICATION

Industry Perspectives & Insights on Impacts of Leap Seconds Practice in UTC Time Scale

Companies and trade association members from IT, Timing and Electric Power industries articulate their insights into impacts of leap seconds practice in UTC time scale on their products and services, as well as their customers. From this collective experience, a shared preference emerges for a continuous UTC time scale without additional leap seconds.

Contact information at these organizations is available from Dr. Patrizia.Tavella@bipm.org.

May 1, 2022

BIPM and ITU-R working together

ITU is a liaison to the CCTF, BIPM is a sector member of ITU-R
Develop a common way forward so that both organisations continue to address the needs for internationally-recognised timing and synchronisation by

Ensuring a Continuous UTC + Efficient protocols for the transmission of UTC and (UT1- UTC) for end-users

- **1972**: the practice of inserting leap second was introduced in a ITU-R Rec (UTC was corrected before by frequency steps)
- **2000**: start of the discussion on continuous UTC
- **2015**: ITU WRC *Resolution 655 recommends "*To strengthen the cooperation between ITU-R and BIPM, CIPM, CGPM, as well as other relevant organizations, and to carry out a dialogue concerning the expertise of each organization"
- **2018**: *Resolution 2 of the 26th CGPM "On the definition of time scales"* :
  - confirms UTC is a time scale produced by the BIPM with the same rate as TAI, but differing from TAI only by an integral number of seconds,
  - recommends that all relevant unions and organizations work together to develop a common understanding
- **2020**: the BIPM and ITU-R signed an MoU for mutual assistance
  - to the ITU-R in its role to set standards concerning time signals and frequency standard emissions, protocols, and dissemination procedure,
  - to the BIPM in its role of defining and realizing measurement standards and reference time-scales
- Preparation to the ITU WRC in **2023**: BIPM/NMIs contribute to the ITU-R WP7A activity that has recently published a report on UTC *(https://www.itu.int/pub/R-REP-TF/en)*

CGPM resolution D/4 - On the use and future development of Coordinated Universal Time (UTC)

https://www.bipm.org

recognizing that the use of UTC as the unique reference time scale for all applications, including advanced digital networks and satellite systems,

calls for its clear and unambiguous specification as a continuous time scale, with a well-understood traceability chain,

decides that the maximum value for the difference (UT1-UTC) will be increased in, or before, 2035,

Approved by the CGPM on Nov 18, 2022

requests that the CIPM consult with the ITU, and other organizations that may be impacted by this decision in order to

- propose a new maximum value for the difference (UT1-UTC) that will ensure the continuity of UTC for at least a century,
- prepare a plan to implement by, or before, 2035 the proposed new maximum value for the difference (UT1-UTC),
- propose a time period for the review by the CGPM of the new maximum value following its implementation, so that it can maintain control on the applicability and acceptability of the value implemented,
- draft a resolution including these proposals for agreement at the 28th meeting of the CGPM (2026),

encourages the BIPM to work with relevant organizations to identify the need for updates in the different services that disseminate the value of the difference (UT1-UTC) and to ensure the correct understanding and use of the new maximum value.

Thanks for your attention

patrizia.tavella@bipm.org

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