CCTF

Leap seconds in UTC: building a consensus for a continuous time scale

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CONSULTATIVE COMMITTEE
FOR TIME AND FREQUENCY

Requirements of Applications

- Time, time interval, and frequency should be smoothly varying, monotonic, and single valued
- Parameters should be derived from a single, international time scale
  - Distribution methods should eliminate or minimize ambiguities
- UTC was intended to satisfy these requirements
- Current methods of realizing the leap second do not satisfy these requirements

Typical Requirements

– Wide-area distribution of electrical power
  - Timing accuracy: 1 µs

– Time stamp of financial transactions
  - Accuracy: 100 µs

– Telecommunications frequency
  - Accuracy: 10^{-11}

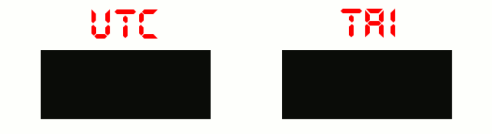
Time Scales

- TAI:
  - Computed by the BIPM
  - Realizes the SI frequency defined by the hyperfine transition in cesium 133
- UT1:
  - Based on astronomical observations of the rotation of the Earth
- UTC:
  - Frequency of TAI will additional integer leap seconds added so that |UTC-UT1| < 0.9 s

Integer Leap seconds

- Added after 23:59:59 when necessary
  - Usually on 30 June or 31 December
  - Only positive leap seconds required since 1972
- Name of leap second is 23:59:60
  - Next second is 00:00:00 of next day
- Most clocks cannot display leap second
  - Most significant for digital systems that measure time internally as elapsed seconds and fractions since some epoch
    - Computer systems, GPS, Galileo, …
    - Conversion to hh:mm:ss representation by application

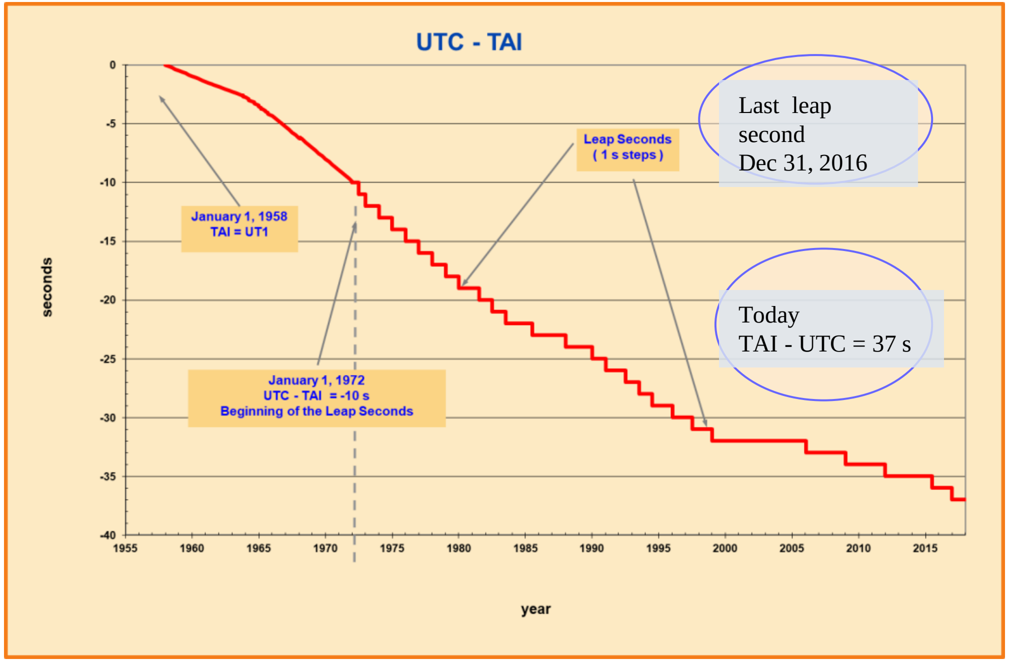
Coordinated Universal Time and leap seconds



When the UT1 time scale, which is related to the rotation of the Earth, reaches a 0.9 second difference with respect to UTC, an integer second is added to UTC to keep it within 1 s of UT1. There is no change to TAI.

|UTC - UT1| < 1 second

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



UTC = TAI + leap seconds

Why this long lasting discussion is **HOT** today?

The digital networks cannot cope with the leap second

WIRED — BUSINESS | CULTURE | GEAR | IDEAS | SCIENCE

ROBERT MCMILLAN AND CADE METZ

The Inside Story of the Extra Second That Crashed the Web

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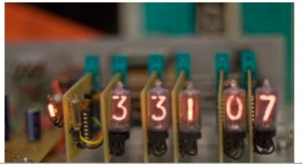

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How and why the leap second affected Cloudflare DNS

John Graham-Cumming

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

NETWORKWORLD FROM IDG

'Leap second' snafu affects Oracle clusterware

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

DIGITAL MAGAZINE | EVENTS & AWARDS PROGRAMS | VIDEO | NEWSLETTERS | RESOURCE LIBRARY

Time Waits for No One: 'leap Seconds' May Be Cut | Security Implications of the Humble Computer Clock | The Big Promise of Big Data

NEWS

Leap Second Bedevils Web Systems Over Weekend

Reddit, LinkedIn and other sites were knocked offline by an extra second added to the official time

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

Leap second problems more common

- UTC as TAI with additional leap seconds based on UT1 is not consistent with requirements of applications at a leap second
- Digital systems cannot assign a unique UTC time stamp during a leap second
- Steps in UTC Time interval and frequency across a leap second
- Clocks do not "remember" previous leap seconds
  - Ambiguity in elapsed time between historical events that cross a leap second
- Global navigation satellites widely used for determining position and for navigation replaces celestial navigation
  - Use of UTC as real-time proxy for UT1 no longer important
  - Step in time interval not consistent with real-time navigation

Problems in other time zones

in the east Asia region, the stock markets are opened at UTC 0 (Japan, Korea), and UTC 1 (Taiwan, China, Hong Kong…).
There is a risk that some Securities Firm or Stock Exchanges will make mistakes in adding the leap second.
The systems are manually re-synchronized after the leap second, which is a very significant effort

Dec 31st at 23:59:59 UTC, when we apply a leap second, is
Jan 1st 07:59:59 in China
Jan 1st 08:59:59 in Japan
Jan 1st 10:59:59 in Sydney Australia
Dec 31st 15:59:59 in Los Angeles, California

Jan 1st not a universal bank holiday. June 30th is a more serious problem because it is not a bank holiday and the stock exchanges are open

How did Alibaba spend the 27th leap second on January 1, 2017?

2017年01月01日第27次闰秒,阿里巴巴是如何度过的?

https://mp.weixin.qq.com/s/bBecGJrTn5HCx7_92a9uWQ

To face Alibaba's complex business, we split 1s into 86400 copies.

•The synchronization rate is adjusted from 0.5ms/s to 0.011574ms/s

•Synchronization start 12 hours before the leap second time and ends 12 hours after the leap second time

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

POSIX Time

https://en.wikipedia.org/wiki/Unix_time

Posix time is used by many computers. It is the number of seconds that have elapsed since the Unix epoch, which is 00:00:00 UTC on 1 January 1970. Every day is treated as if it contains exactly 86400 seconds.

UTC (31 December 1998 to 1 January 1999)	Posix time
1998-12-31T23:59:58.00	915148798.00
1998-12-31T23:59:59.00	915148799.00
1998-12-31T23:59:60.00	915148800.00
1998-12-31T23:59:60.25	915148800.25
1998-12-31T23:59:60.50	915148800.50
1998-12-31T23:59:60.75	915148800.75
1999-01-01T00:00:00.00	**915148800.00**
1999-01-01T00:00:00.25	**915148800.25**

1999-01-01 00:00:00

1999-01-01 00:00:00

Different "solutions"

- 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
  - NIST Network Time Services
  - NPLtime service in the UK
  - 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 solutions are not in agreement with UTC on the leap second day, and many disagree with each other

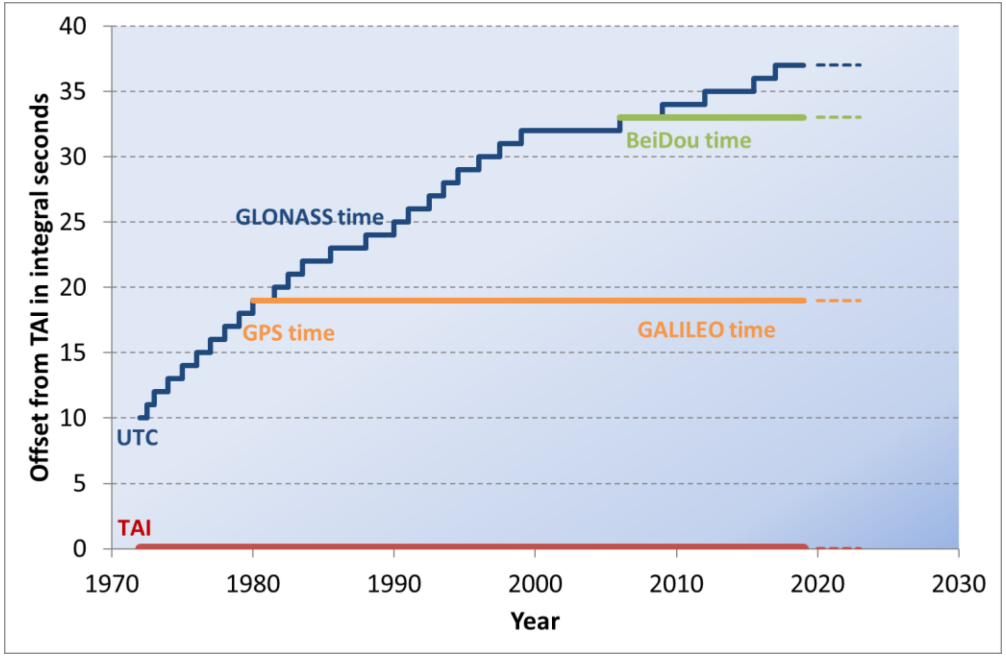
Users cannot tell which method is used by a time source

Details can be found for example here:

https://en.wikipedia.org/wiki/Unix_time
https://developers.redhat.com/blog/2015/06/01/five-different-ways-handle-leap-seconds-ntp/
https://googleblog.blogspot.com/2011/09/time-technology-and-leaping-seconds.html
https://www.theregister.co.uk/2016/12/02/google_public_ntp_servers/
https://spectrum.ieee.org/tech-talk/telecom/internet/facebook-new-time-keeping-service
https://engineering.fb.com/production-engineering/ntp-service/
https://en.wikipedia.org/wiki/Precision_Time_Protocol
https://blog.meinbergglobal.com/2019/04/15/ptp-timescale-and-what-the-heck-is-arb-time/
https://mp.weixin.qq.com/s/bBecGJrTn5HCx7_92a9uWQ

Different solutions: 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



The outcome

- UTC with leap seconds does not satisfy requirements of many applications
- Several different solutions have been implemented
- Solutions are not universal and different methods are not compatible with UTC or with each other
- UTC is becoming less relevant and less useful
  - The trend is likely to continue

The value of UTC

UTC is universal and international; it is computed by the BIPM with contributions from the timing laboratories of many countries and hundreds of physicists and metrologists. It is widely recognized as the legal and practical source of time and frequency.

The computation of UTC by the BIPM is under the authority of the CGPM as defined by the Treaty of the Meter, which has been adopted by member states and associates

The computation of UTC is not controlled by a single country, a single State Department, any commercial entity. In contrast, Google is proposing that its « smear » method be adopted as an international standard.

UTC is disseminated in each country by the NMI/DI by a real-time local approximation UTC(k).

UTC is a worldwide time and frequency reference and has to meet the needs of current and future users

If UTC is not modernized it will become marginal and less universal
A GNSS system time, which is continuous and easily accessible, could become the *de facto* source of time frequency signals, or others

Leap seconds and the ITU - 1

- In 1972 the practice of inserting leap second was introduced in the CCIR Recommendation (now ITU-R)
- ITU-R TF.460-6 (2002): *Standard-frequency and time-signal emissions*

recommends

- that all standard-frequency and time-signal emissions conform as closely as possible to coordinated universal time (UTC)
- that standard-frequency and time-signal emissions… contain information on DUT1 = UT1 – UTC whose magnitude < 0.8 s.
- the UTC scale is adjusted by the insertion or deletion of seconds (positive or negative leap seconds) to ensure approximate agreement with UT1.
- a code for the transmission of DUT1 is established. The values of DUT1 are given by the IERS

- In 2000, ITU-R adopted question 236-2/7
  - To study the future of the UTC time scale
  - Question referred to Study Group 7 and Working Party 7A
- Studies conducted in 2002-2003-2007, 2007-2012 and 2012-2015
  - Several conferences and questionnaires
  - Proposals to revise TF.460-6 to eliminate leap seconds

BIPM and some NMI time experts take part to the ITU-R WP 7A
ITU delegations are composed by telecom experts

Leap seconds and the ITU - 2

- Radiocommunication Assembly 2012
  - Recommendation returned for further study
- World Radiocommunication Conference 2015: *Resolution 655*
- http://search.itu.int/history/HistoryDigitalCollectionDocLibrary/4.297.43.en.100.pdf
  - Further study in cooperation with other interested organizations
  - Report at next conference in **2023**
  - No changes until discussion in 2023

Resolution 655 – 2015:

•To strengthen the cooperation between ITU-R and BIPM, the International Committee for Weights and Measures (CIPM), CGPM, as well as other relevant organizations, and to carry out a dialogue concerning the expertise of each organization;

•To further and more widely study in cooperation with the relevant international organizations, concerned industries and user groups, through the participation of membership, the various aspects of current and potential future reference time scales, introducing their impacts and applications;

•To provide advice on the content and structure of time signals to be disseminated by radiocommunication systems, using the combined expertise of the relevant organizations;

•To prepare one or more reports containing the results of studies that should include one or more proposals to determine the reference time scale and address other issues mentioned in 1,2 and 3 above

We shall support the preparation of World Radio Conference 2023

What did we do?

- 2009 CIPM *Recommendation 4* "On the weakness of the present definition of UTC"

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

- 2018 26th CGPM *Resolution 2* « On the definition of time scales"

recommends that

- all relevant unions and organizations consider these definitions and work together to develop a common understanding on reference time scales, their realization and dissemination with a view to consider the present limitation on the maximum magnitude of UT1 - UTC so as to meet the needs of the current and future user communities,
- all relevant unions and organizations work together to improve further the accuracy of the prediction of UT1 - UTC and the method for its dissemination to satisfy the future requirements of users.

- 2019 CIPM decision 108/40

The CIPM asked the CCTF President and the Director of the BIPM Time Department to establish a CIPM task group to support the preparation of the CIPM for the World Radiocommunication Conference in 2023

- 2020 MoU BIPM-ITU

Mutual intent to collaborate

Assistance to the ITU-R in its role to set standards concerning time signals and frequency standard emissions, protocols, and dissemination procedure

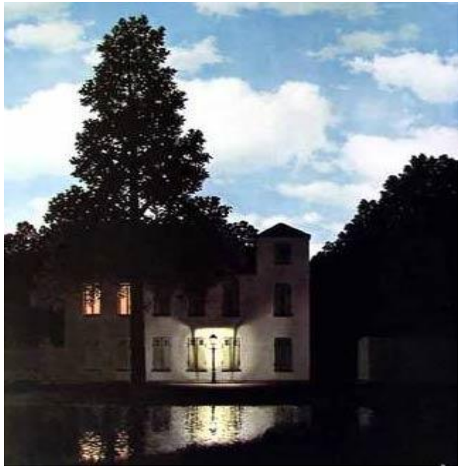
Assistance to the BIPM in its role of defining and realizing measurement standards and reference time-scales

What can we propose to the CGPM 2022?

A Possible Solution

Increase tolerance of |UT1 - UTC|

- If limit of DUT1= |UT1 - UTC| < 100 or XXX 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



Users of UT1 need to find DUT1 information

- IERS and NASA web sites with microsecond uncertainty
- Radio stations, such as WWV operated by NIST, will have problems when magnitude of DUT1 > 0.9 s
- GNSSs, with some update, could still disseminate DUT1

On February 26th 2020 representatives of BIPM met "*State Service for Time and Frequency and Earth rotating parameters determination"* at VNIIFTRI to discuss the implementation of the 26th CGPM *Resolution 2*, 2018

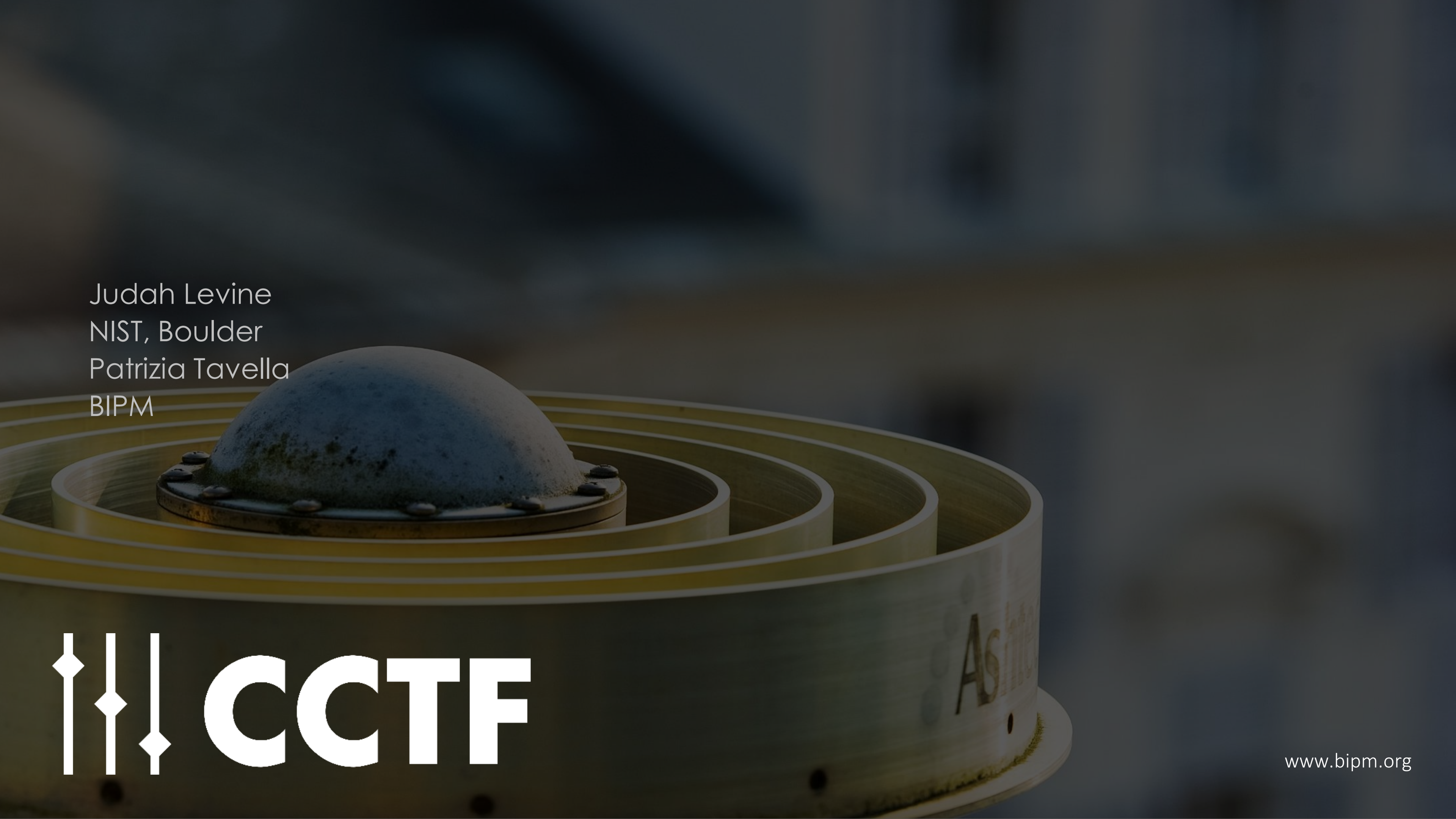
With representatives from: Rosstandart, VNIIFTRI, ITU delegation, GLONASS, Satellite Systems Reshetnev, Russian Institute of Radio Navigation and Time.

1. State Service for Time and Frequency (SSTF) is in favor to establish tolerance for DUT not less than 1000 s and not more than 1 hour
2. State Service for Time and Frequency is in favor to establish a transient period of at least 10-15 years
3. Keeping in mind forthcoming modernization of GLONASS, including adoption of CDMA and expected considerable chan-ges in structure of navigational message, SSTF welcomes to adopt and implement continuous UTC despite considerable investment to space and on land navigation systems

Questions

Assuming that adequate advance notice of the change was provided

- Are there applications in your country that could not adapt to increasing the tolerance of UT1 - UTC?
- Is the representative to the ITU from your country aware of this discussion? Do you work together?
- Is dissemination of DUT1 = UT1 - UTC on the IERS web or by similar means (e.g. GNSS) adequate for your national applications?



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