

# *Traceability to UTC from GNSS Measurements*

Andreas Bauch, PTB,

on behalf of the CCTF Task Group

“Traceability to UTC from GNSS measurements”,

initiated by BIPM



- **Initiated by the BIPM in 2020**
- **Work Program:**
  - **Propose guidelines on how to get traceability to a realization of UTC through GNSS measurements**
  - **Disseminate the information to the end user, via e. g. Regional Metrology Organisations, GNSS providers, GNSS stakeholders, and user fora.**

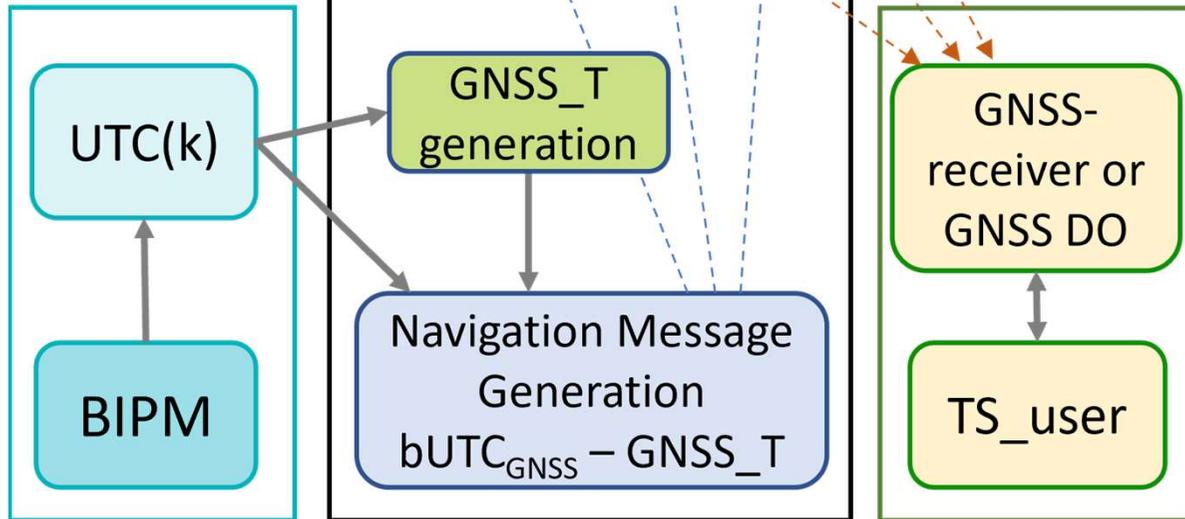
- **Here I am....**



**Achieved so far: Accepted publication in Metrologia:** <https://doi.org/10.1088/1681-7575/ac98cb>.

Metrology  
community

in short:  
NMI



Vocabulary

**GNSS\_T:**  
system time of GNSS

**GNSS DO:**  
Disciplined oscillator

**Prediction  $GNSS\_T \leftrightarrow UTC$**   
 **$bUTC_{GNSS} - GNSS\_T$ :**  
Data content in the  
GNSS navigation message

## (Metrological) traceability

The International vocabulary of metrology (VIM) defines “metrological traceability” to a given reference [3.1, Section 2.41]:

It is the

“property of a **measurement result** whereby the result can be related to a reference through a **documented unbroken chain** of calibrations, each contributing to the **measurement uncertainty**”

## Survey of stakeholder needs undertaken, covering documents issued for / obeyed in

- **Electricity sector**
- **Financial sector**
- **Telecommunications (spec. ITU-T SG15)**

### *Observations:*

The term „traceability“ is used quite frequently, but often not in the meaning of „metrological traceability“ as defined before,

### *instead expressing*

„Source of time information globally available, source well-defined (like UTC).“

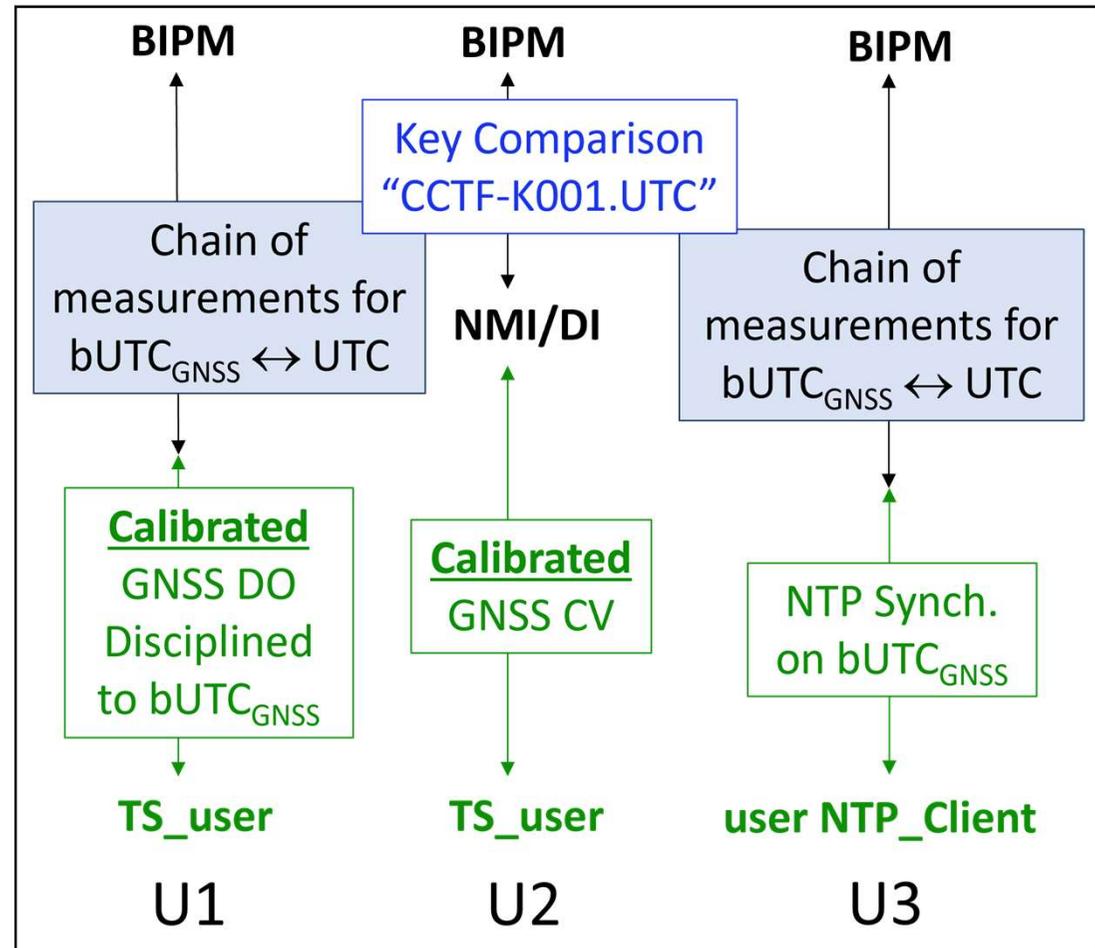
Occasionally „GPS“ is mentioned as an equivalent to UTC.



Distinction of three use cases that should reflect the variety of applications

Two measures to claim traceability:

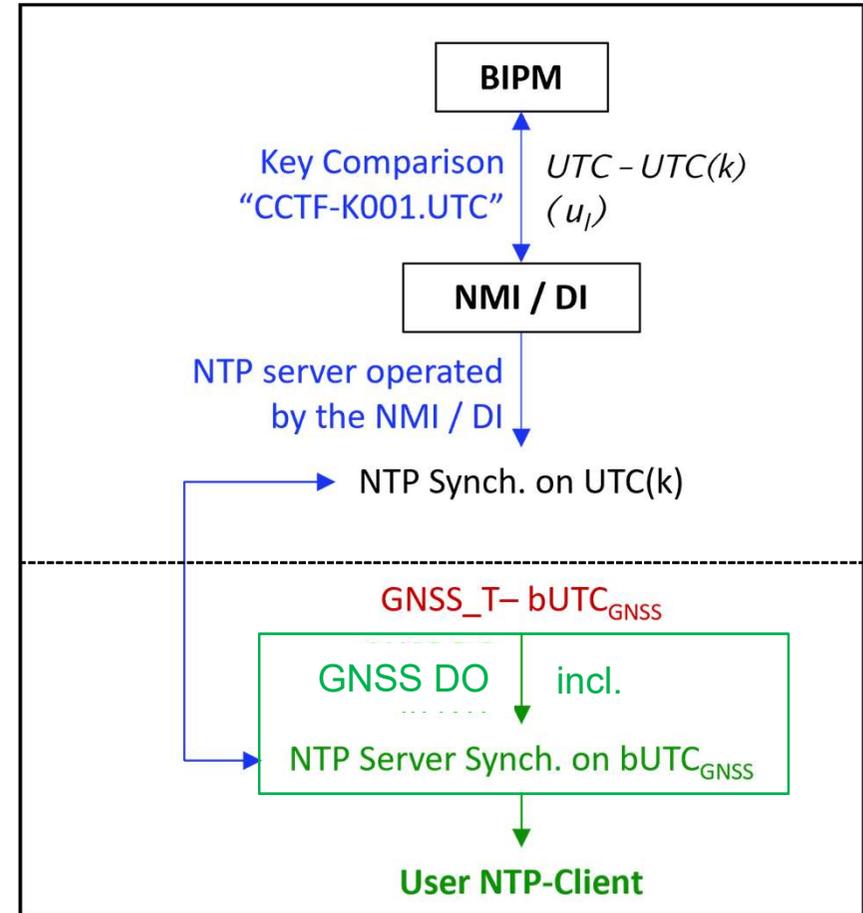
- Link to UTC or UTC(k)
- Calibration



### Use case U3:

User operates NTP-server that uses GNSS signals as input for time-of-day and distributes it in a LAN.

Assessment:  
 Uncertainty requirement  $\geq 1$  ms  
 (properties of NTP and typical applications)



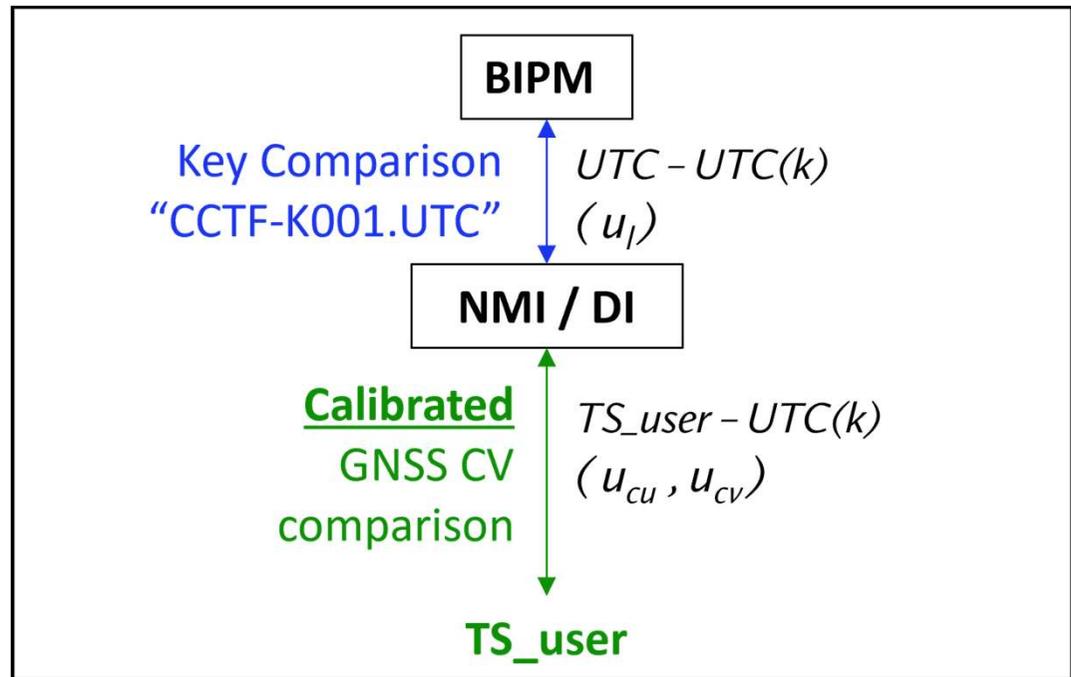
## Use case U2:

UTC(NMI) and **TS\_user** are compared using GNSS CV or equivalent technique:

Services offered by NIST, NPL, other NMIs (commercially), case by case by many NMIs.

### Assessment:

under full control of NMI – calibration of receiving equipment assumed – technically complex, but ideal from metrological standpoint.



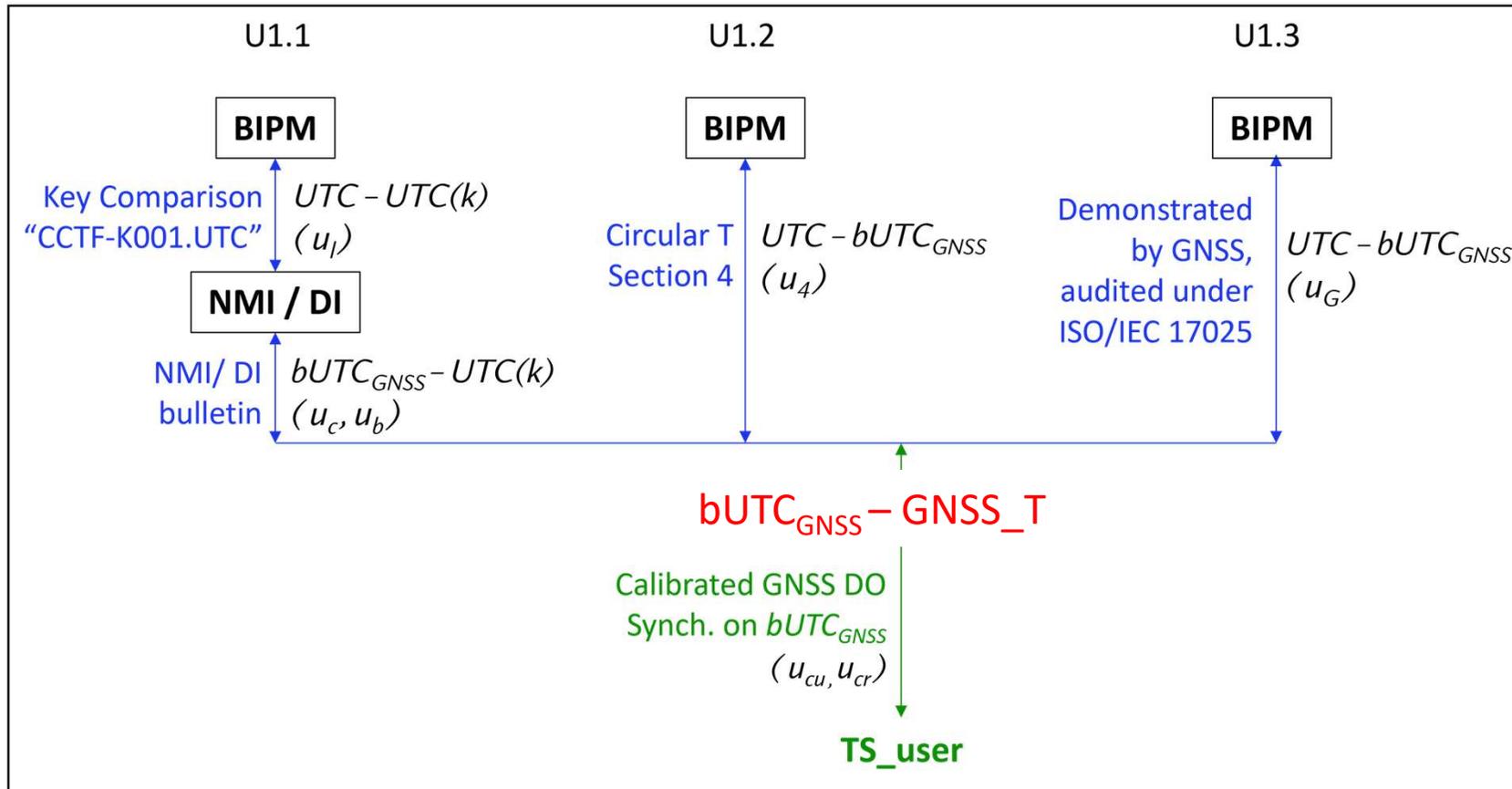
## Use case U1:

User operates GNSS DO for „all you can get“ from GNSS:  
time-of-day, PPS, standard frequency.

Second distinction needed:

- a) User offers calibration and measurement services to third parties, external customers > **ISO/IEC 17025 applies.**
- b) User distributes signals under sector-internal regulations for internal use only. > **No regulations apply**  
If **traceability to UTC** is required, clause a) applies.

# Use case U1: How to relate $bUTC_{GNSS}$ to UTC?



Continuation refers to Case U1a) only

Distinction needed between quantity „time“ (PPS epoch) and frequency

Assumption:

GNSS signals „okay“ and reception conditions „okay“

GNSS DO lock to external signal „okay“

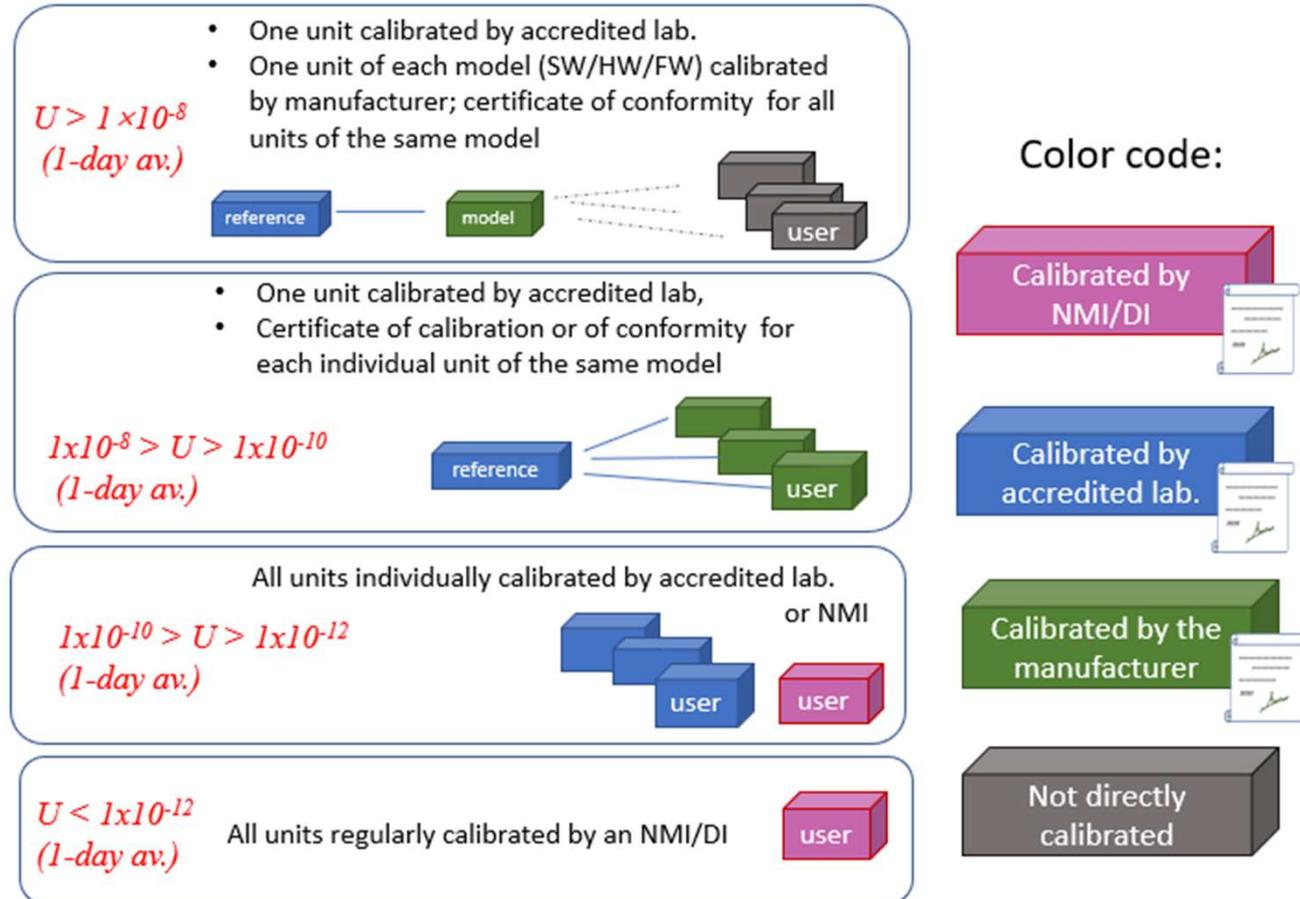
Assessment:

GNSS DO **frequency output** has „nominal offset zero“ on average, properties dictated by the stability of the internal oscillator and sophistication of the receiver > **calibration** recommended.

GNSS DO **PPS output** on average offset due to signal delays (antenna, antenna cable, internal processing) > **calibration** required.

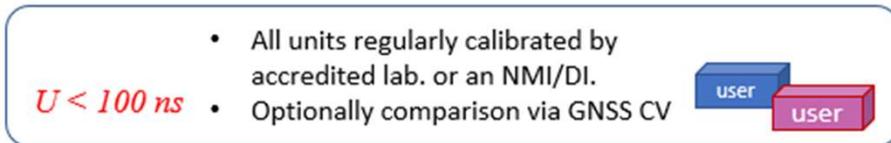
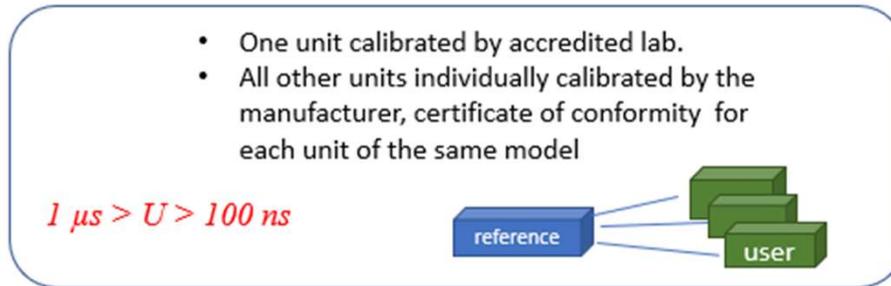
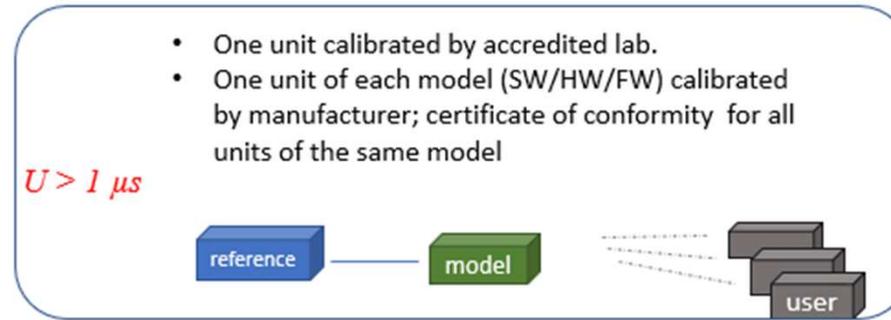
# Requirements proposed by the Task Group:

## Frequency

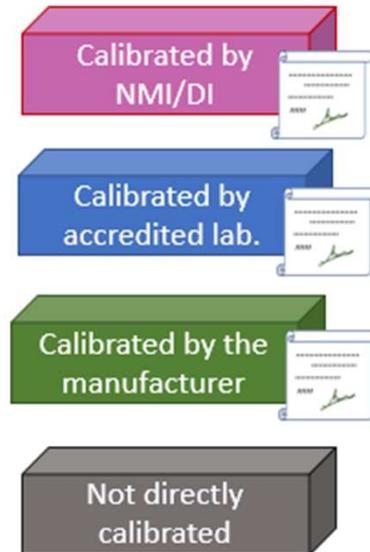


# Requirements proposed by the Task Group:

PPS



Color code:



## Conclusions:

### Recommendations to GNSS DO equipment manufacturers:

- Technical documentation of products should include
  - time uncertainty wrt UTC, incl. constraints due to GNSS properties etc.
  - frequency instability (output) as function of averaging time
- Include functions in products that allow verification of correct operation, such as record of oscillator control parameters, lock status etc.
- Seek calibration of GNSS DO models as proposed by the Task Group.

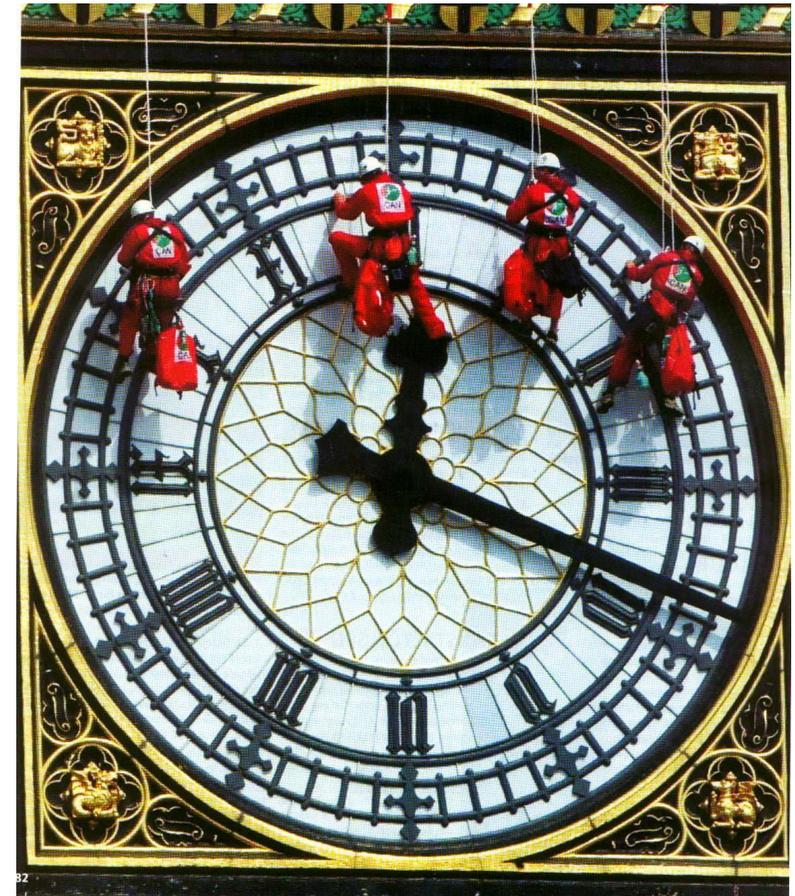
## Conclusions:

### Recommendations to users:

- Make a trade-off between requirements (uncertainty for the time and /or frequency offset from UTC or UTC(k) ) and efforts needed;
- Confirm the usage of “traceability to UTC” in documentation and communication in view of the established meaning of this term in metrology;
- Follow the advice regarding calibration of GNSS DO and the need for demonstrating the link between UTC and received GNSS signals.

- Andreas Bauch (chair, PTB)
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- Pascale Defraigne (ORB)
- Jerome Delporte (CNES)
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- Hector Esteban (ROA)
- Marina Gertsvolf (NRC)
- Ryuichi Ichikawa (NICT)
- Artyom Karaush (VNIIFTRI)
- Paul Koppang (USNO)
- Alexander Kuna (UFE)
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- Calvin Lin (TL)
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- Pierre Waller (ESA)
- Yuzhuo Wang (NIM)
- Peter Whibberley (NPL)
- Michael Wouters, (NMIA)
- Wenjun Wu (NTSC)

## Task Group on “Traceability to UTC from GNSS Measurements”



Questions are welcome.

Suggestions from  
practioneers are very welcome.

Thanks.

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# *Extra Slides*



# Task Group on “traceability to UTC from GNSS measurements”



In total 25 participants at Kick-Off and on the mailing list

Distribution of background (duplicate mentioning possible)

Chair:  
Andreas Bauch, PTB

Background	Number	Comments
Metrology „Time and Frequency“	15	Representing their National Metrology Institutes
Time and Frequency experts	6	Non NMI representatives (IGS, NRL, USNO)
Fundamental metrology	4	
BIPM	2	Gianna Panfilo, Secretary
GNSS	6	From institutes collaborating with BeiDou, Galileo, GLONASS and GPS



## Conclusions:

### Services to be offered by NMIs: (covered by CMCs and their internal QS)

- → Frequency calibration by direct comparisons (“Local frequency standard” service under the “Frequency” branch)¶
- → Frequency calibration via GNSS CV (“Remote frequency standard” service under the “Frequency” branch)¶
- → Time comparison via GNSS CV (“Remote clock vs. UTC(NMI)” service under the “Time scale difference” branch)¶
- → Calibration of GNSS equipment delays (“Delay meter” service under the “Time interval” branch)¶
- → Regular publication of UTC(k) - Broadcast\_UTC<sub>GNSS</sub> (a new service to create under the “Time scale difference” branch)¶

*new*

## Conclusions:

### Recommendations to GNSS providers:

- to seek the collaboration with NMIs regarding GNSS\_T realization and monitoring;
- to describe the realization of GNSS\_T as well as the data contents\* in the navigation messages following metrological practice and vocabulary.

\* e.g. the quantity  $bUTC_{GNSS} - GNSS\_T$ , and therefrom the uncertainty of  $bUTC_{GNSS} - UTC$

## On the use and future development of UTC

The General Conference on Weights and Measures (CGPM), at its 27th meeting, **noting** that

- the accepted maximum absolute value of the difference (UT1-UTC) has been under discussion for many years because the consequent introduction of leap seconds creates discontinuities that risk causing serious malfunctions in critical digital infrastructure,
- operators of digital networks and GNSSs have developed and applied different methods to introduce the leap second, which do not follow any agreed standards,
- the implementation of these different uncoordinated methods threatens the resilience of the synchronization capabilities that underpin critical national infrastructures,

**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,

**decides** that the maximum absolute value for the difference (UT1-UTC) will be increased in, or before, 2035, available at <https://www.bipm.org/en/cgpm-2022>.