Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Traceability to UTC from GNSS Measurements

Andreas Bauch, PTB,

on behalf of the Task Group

"Traceability to UTC from GNSS measurements",

initiated by BIPM

- **Work Program:**

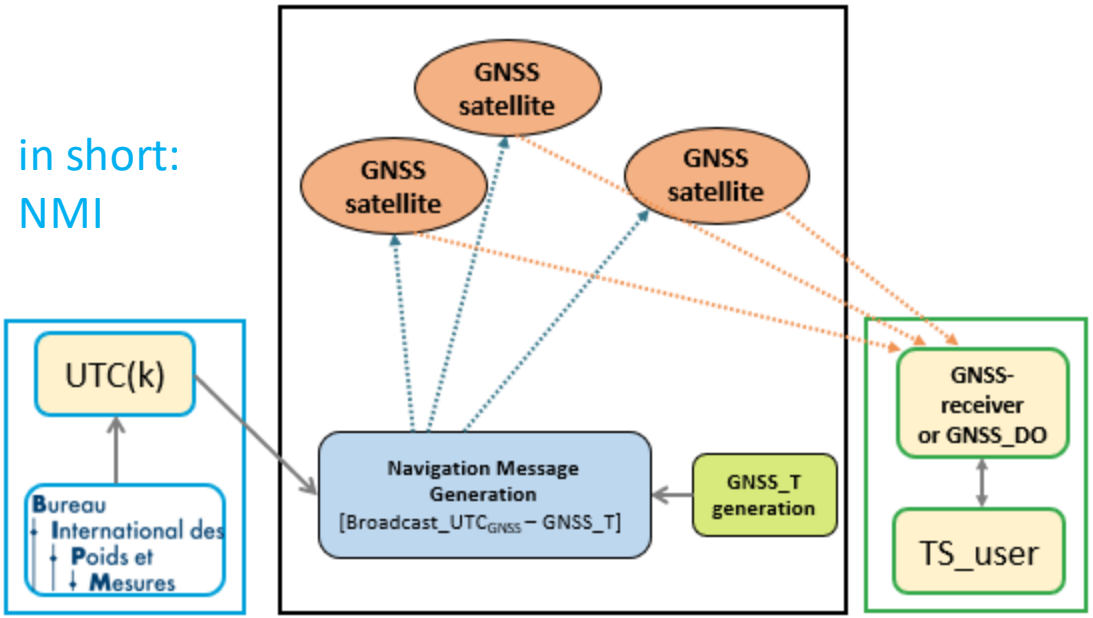
- **Propose guidelines on how to get traceability to a realization of UTC through GNSS measurements**
- **Disseminate the information to the end user, via e. g. Regional Metrology Organisations ICG, GNSS providers, GNSS stakeholders.**

Achieved so far: Release of a White Paper V.2 for approval by CCTF 2022, June

Task Group on "traceability to UTC from GNSS measurements"

Metrology community | GNSS provider | User | Vocabulary

in short:
NMI



GNSS_T:
system time of GNSS

GNSS_DO:
Disciplined oscillator

Broadcast_UTC$_{GNSS}$ – 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”

The required calibrations should be performed by National Metrology Institutes (NMI) or Designated Institutes (DI) participating in the CIPM-MRA and having their CMCs published in the Key Comparison Data Base (KCDB).

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 classes of users / technology:

3) 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.

Distinction of three classes of users / technology:

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

Assessment:
Uncertainty requirement >= 1 ms (properties of NTP and typical applications)

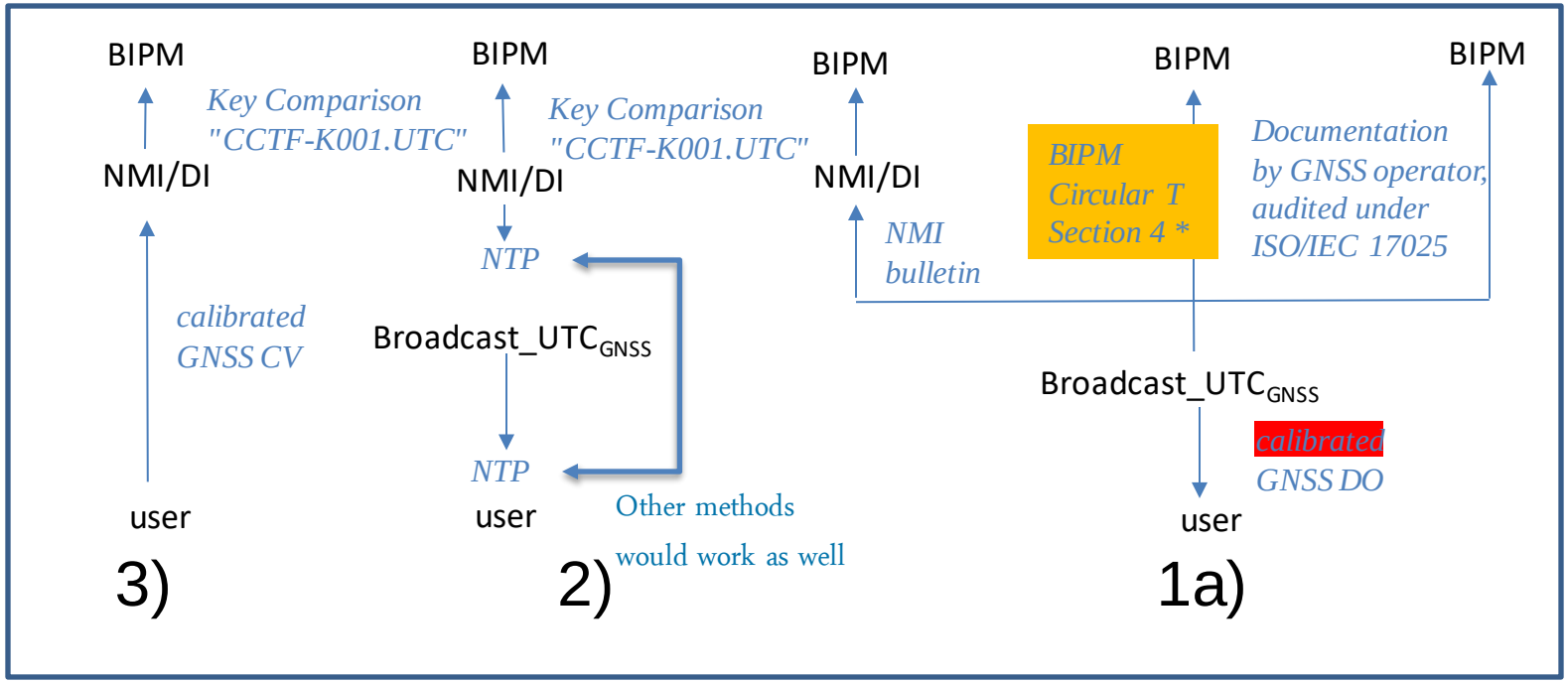
Distinction of three classes of users / technology:

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

Assessment:
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. If **traceability to UTC** is required, user falls under 1a)

Types of use and ways to demonstrate traceability:



Continuation refers to Case 1a) only

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

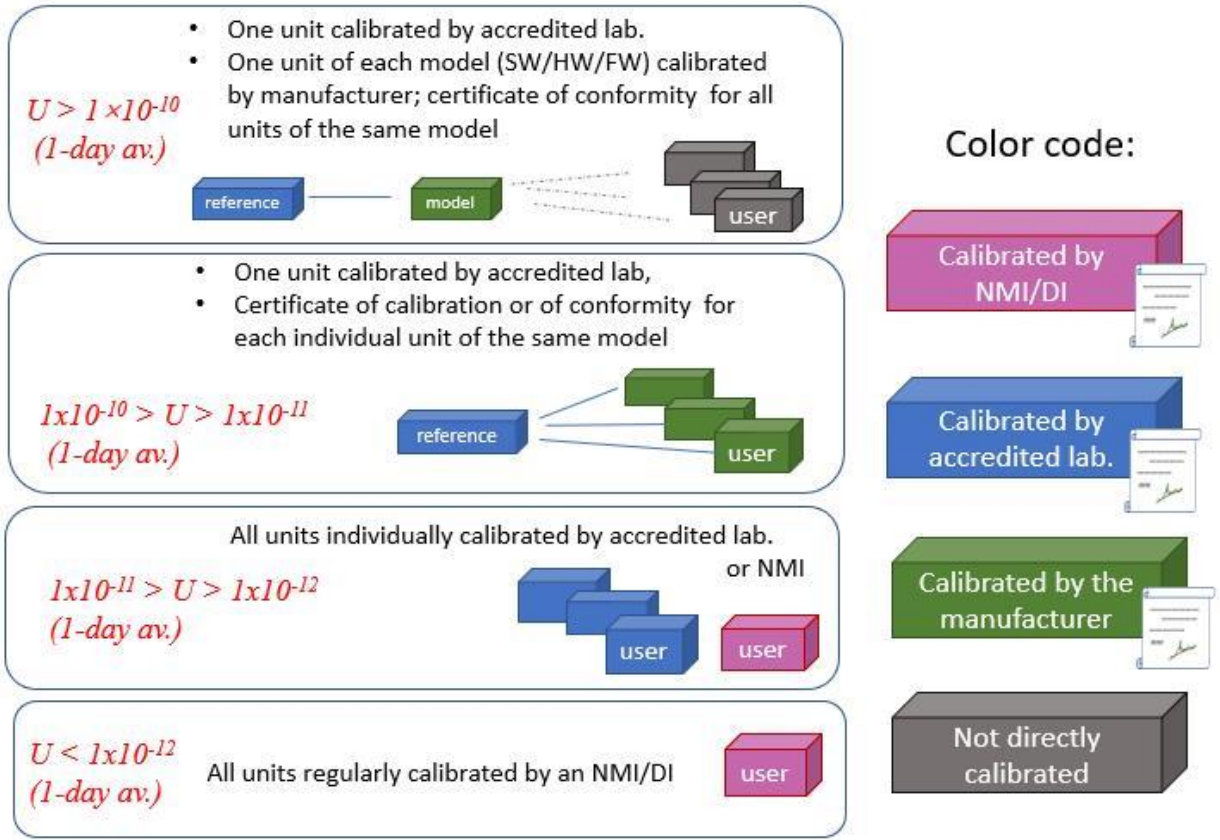
Assumption:
GNSS signals „okay“ and reception conditions „okay“
GNSS_DO lock to external signal „okay“

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.

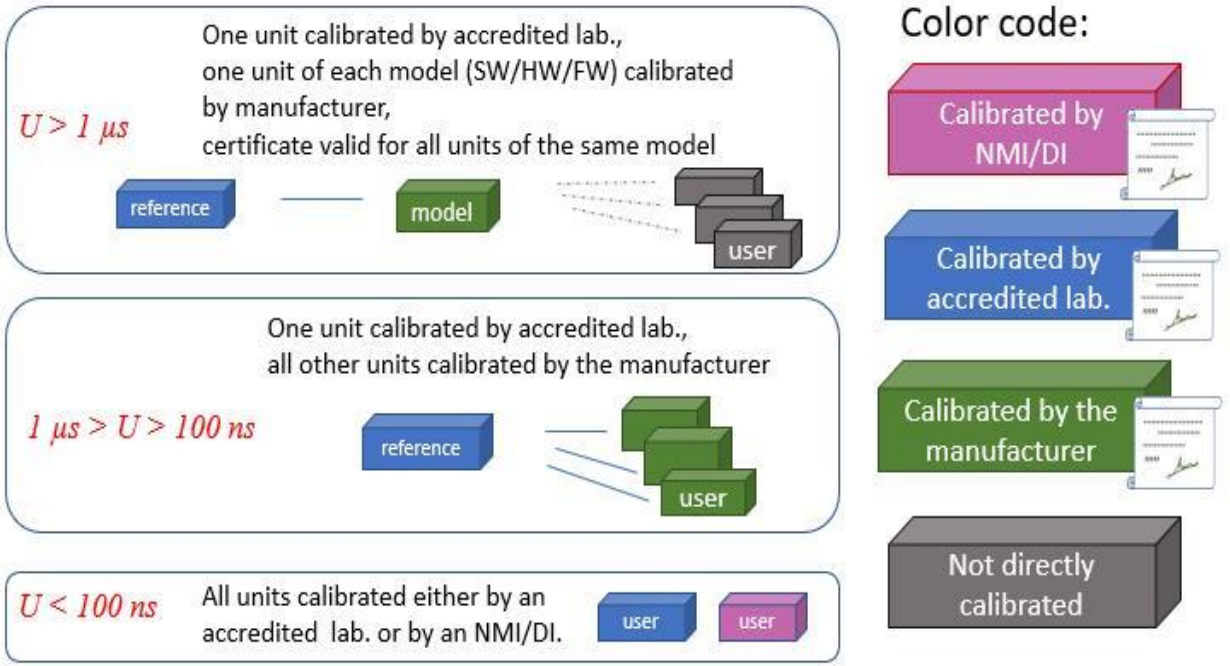
Requirements proposed by the Task Group:

Frequency



Requirements proposed by the Task Group:

PPS



Conclusions:

Recommendations to GNSS_DO equipment manufacturers:

- Technical documentation of products should include
  - time uncertainty wrt UTC
  - frequency instability as function of averaging time according to metrological rules;
- Include functions in products that allow verification of correct operation, such as record of control parameters to oscillator, 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) 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.

Task Group on “traceability to UTC from GNSS measurements”

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- Joseph Achkar (LNE-SYRTE)
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- Paul Koppang (USNO)
- Alexander Kuna (UFE)
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- Peter Whibberley (NPL)
- Michael Wouters, (NMIA)
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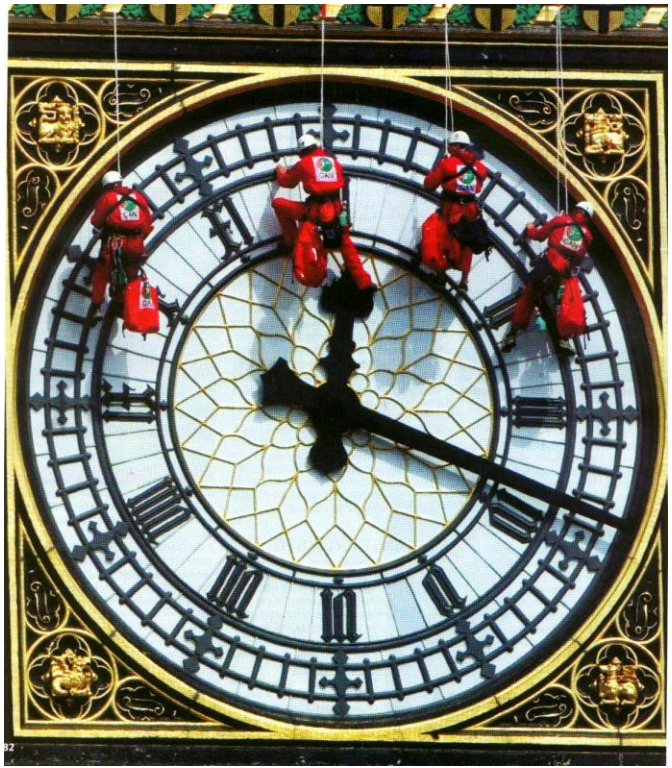

Questions are welcome.

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

Bureau International des Poids et Mesures

(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”

BIPM, International Organization of Legal Metrology (OIML), and accreditation bodies confirmed:

The required calibrations should be performed by NMIs or Designated Institutes (DI) participating in the CIPM-MRA and having their CMCs published in the KCDB.

In addition, measurements traceable to the SI can as well be made by an accredited laboratory whose calibration and testing capabilities were formally approved by an accreditation body, so that they fulfil the rules of ISO/IEC 17025 as recommended by the CIPM.

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$_{GNSS}$ (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 $\text{BroadcastUTC}_{\text{GNSS}}$ – GNSS_T , and therefrom the uncertainty of $\text{BroadcastUTC}_{\text{GNSS}}$ - UTC