CCTF

Traceability to UTC from GNSS measurements

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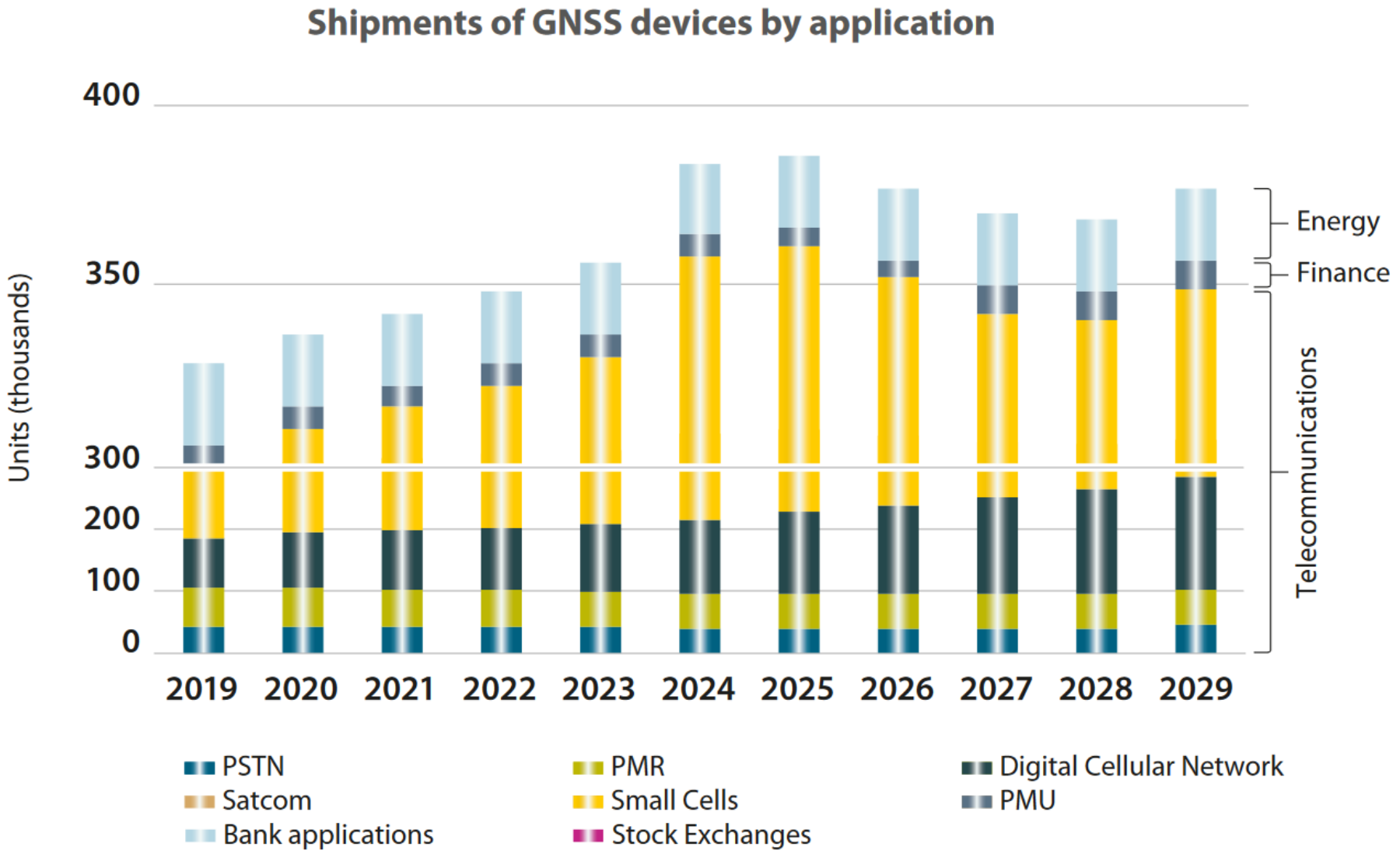
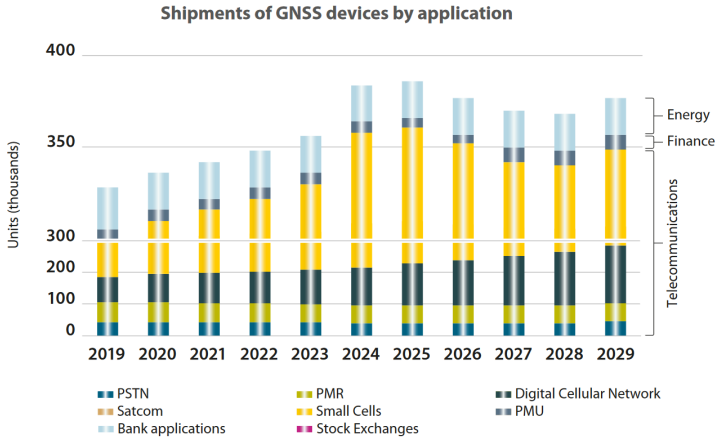
On behalf of the CCTF Task Force on Traceability to UTC from GNSS measurements

CONSULTATIVE COMMITTEE
FOR TIME AND FREQUENCY



From EUSPA "Market Report" - Issue 6 (2019)
expected number of units sold for Time and Synchronisation purposes in different sectors.

CCTF Task Force



Increasing use of GNSS for synchronization & increasing demand for traceability

Need for guidelines on
- how the user can get UTC from GNSS (including equipment and calibration)
- and how traceability can be obtained when using GNSS for synchronization to UTC

Task force of the GNSS WG, with the help of the WG on MRA.

- **Provide guidelines**
- **Disseminate the information to the end user, via e. g. RMOs, ICG, GNSS providers, GNSS stakeholders**

(Metrological) Traceability

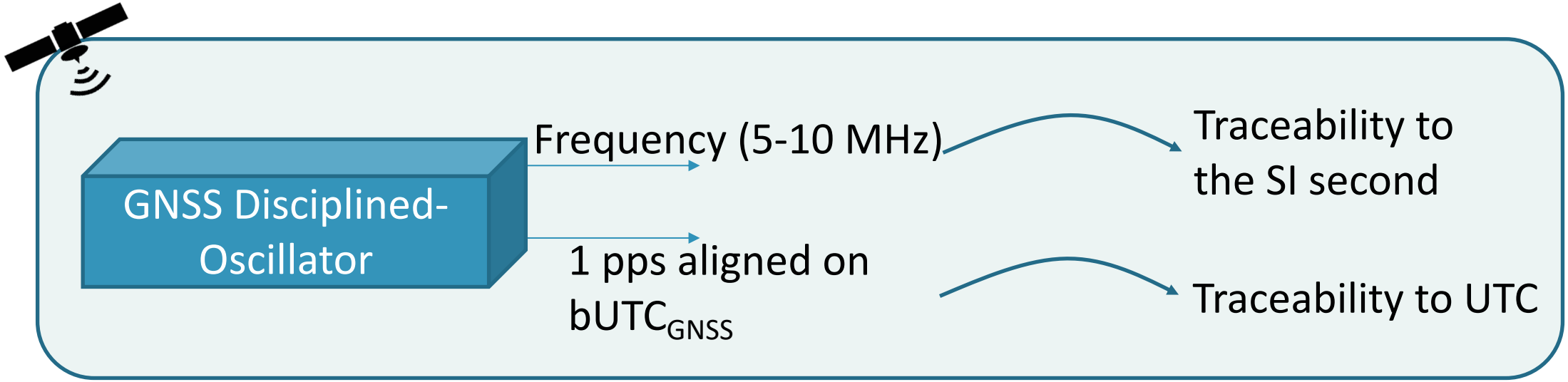
DEFINITION from The International vocabulary of metrology (VIM)

"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:

The required **calibrations** should be performed by **NMIs or DIs** 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** recommended by CIPM.

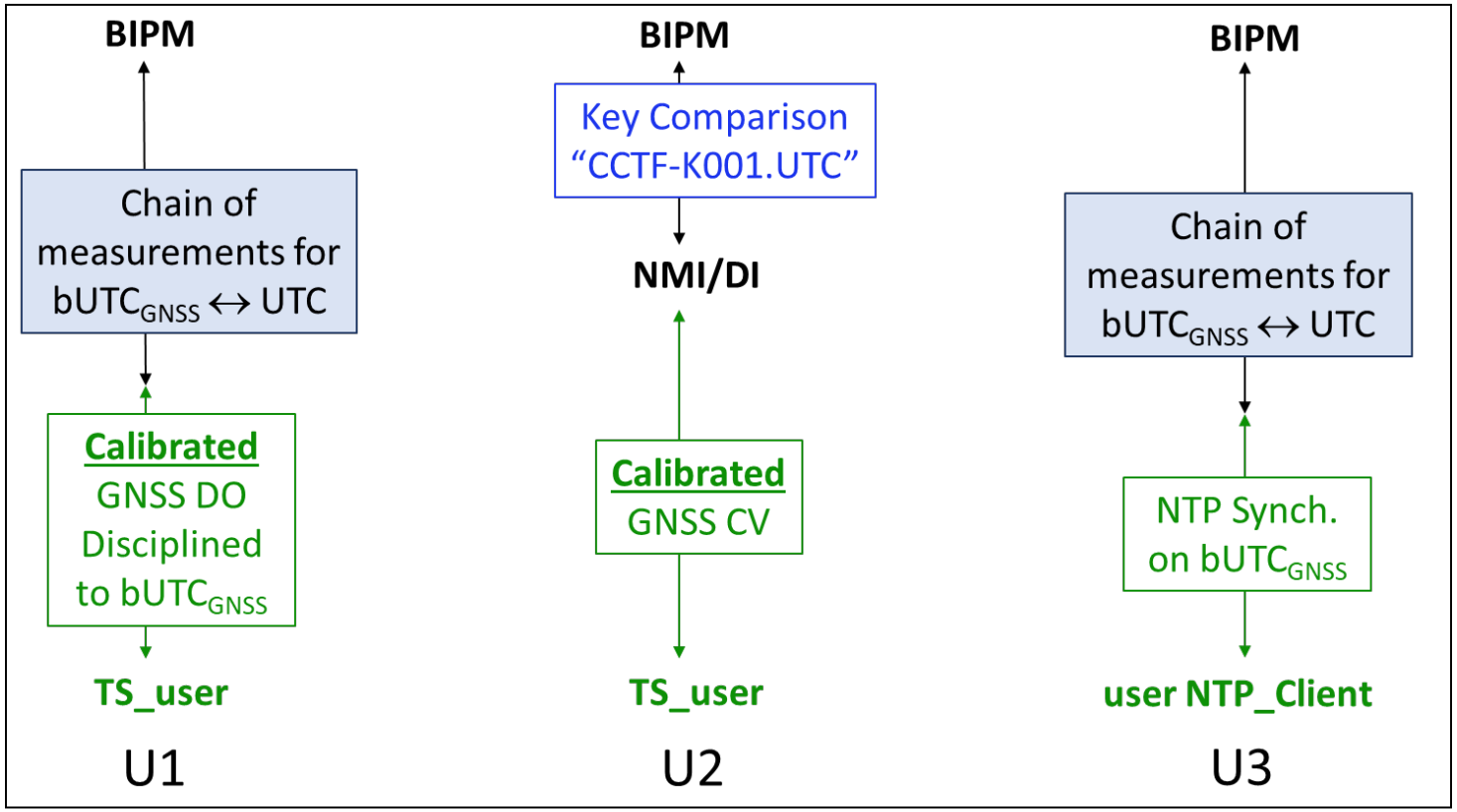
Traceability to SI second / to UTC



In both cases : traceability requires

- Calibration of the user device
- Traceability route to UTC

Different kinds of users



U1:
User operates GNSS-DO for
"all you can get" from GNSS:
time-of-day, PPS, standard frequency

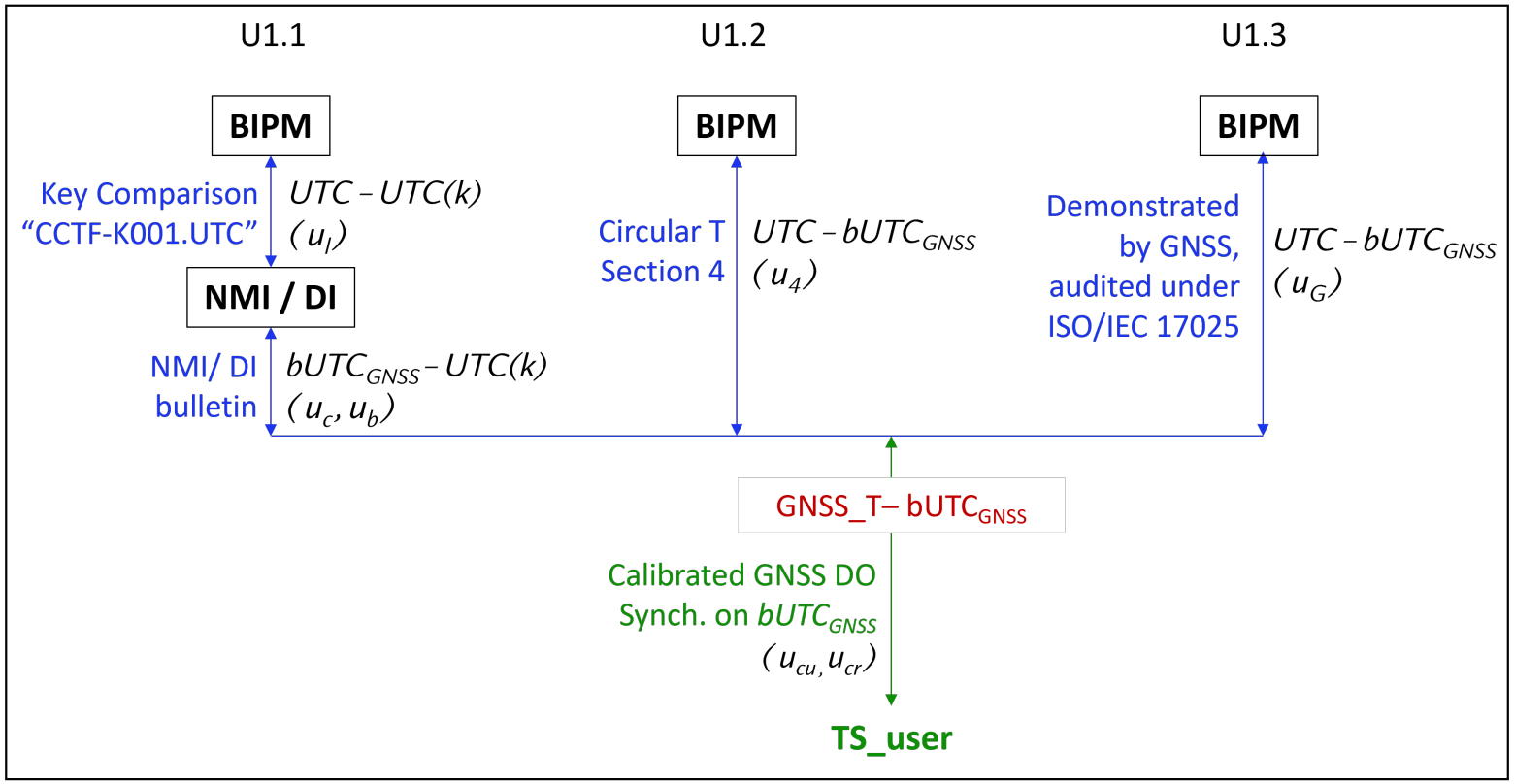
U2:
User – UTC(k)
GNSS Common View

U3:
Distribution of time-of-day via NTP to user NTP_Client

TS_user: local time scale
(1 PPS, 10 MHz)

Traceability route to UTC

U1: GNSS DO



U1.1

NMI Bulletin: reports on UTC(NMI)-Broadcast_UTC_{GNSS}

U1.2

Circular T Section4:

reports on UTC-Broadcast_UTC_{GNSS}
(no info available for Galileo and BeiDou, no uncertainties, "work in progress")

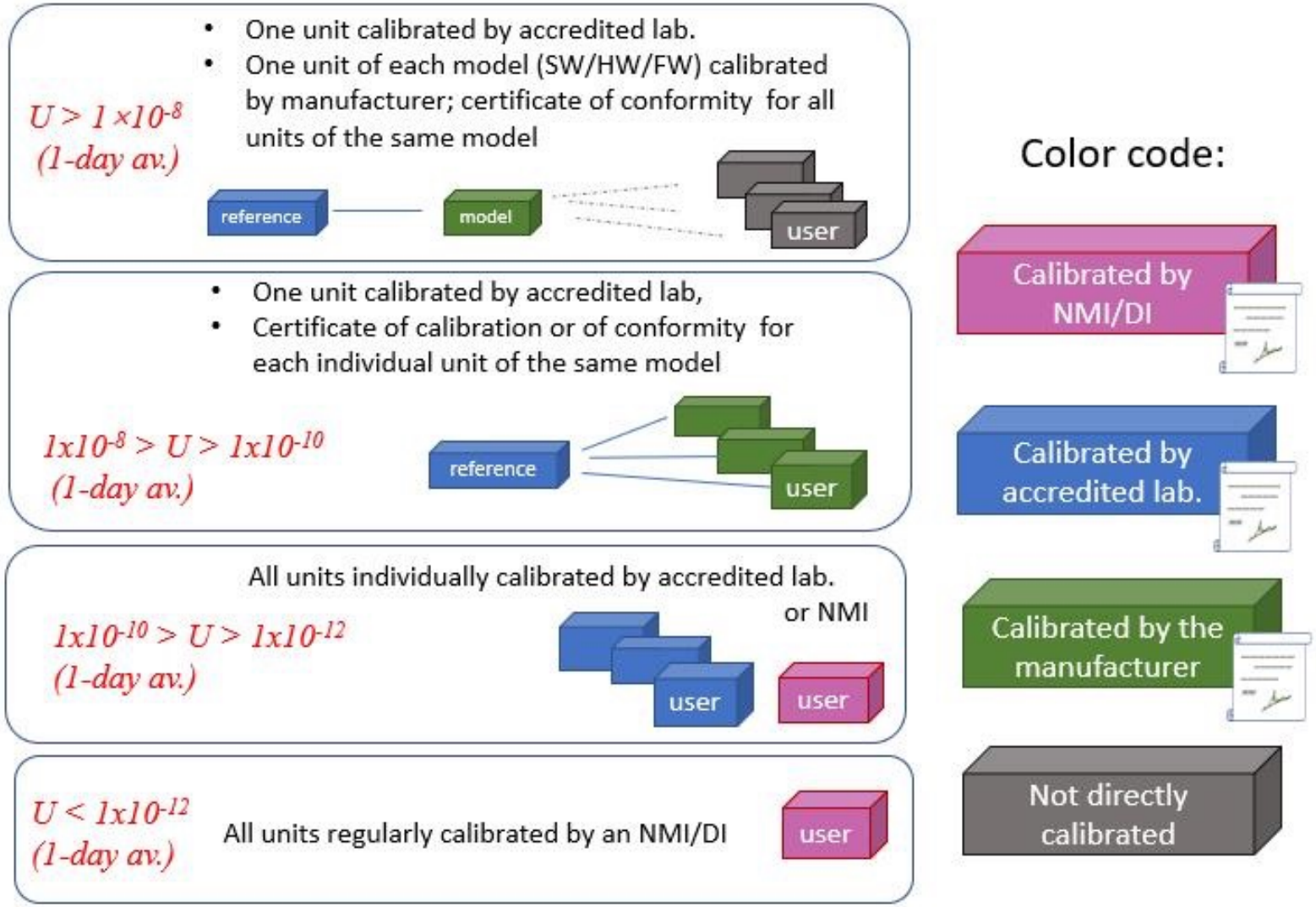
**Agreed under some conditions*
e.g. ISO/IEC under 17025

U1.3

Documentation by GNSS operator, audited under ISO/IEC 17025:

not yet available

U1: calibration - Frequency



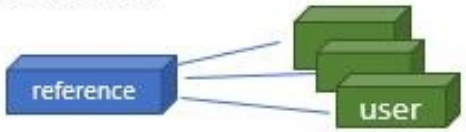
U1: calibration - Time

- One unit calibrated by accredited lab.
- One unit of each model (SW/HW/FW) calibrated by manufacturer; certificate of conformity for all units of the same model

$U > 1\ \mu s$

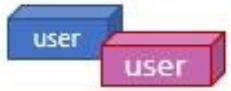
- One unit calibrated by accredited lab.
- All other units individually calibrated by the manufacturer, certificate of conformity for each unit of the same model

$1\ \mu s > U > 100\ ns$

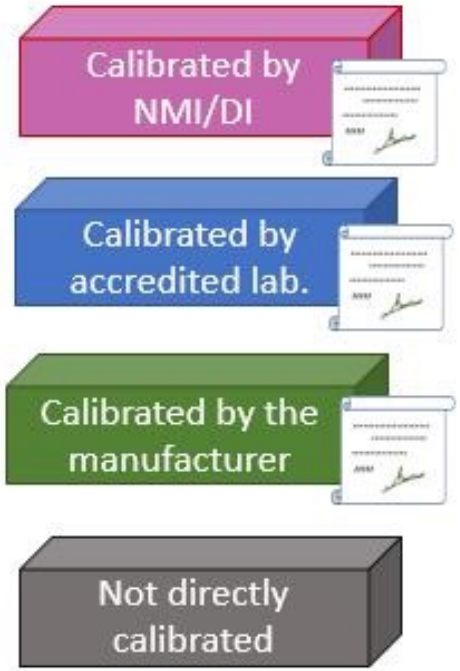


$U < 100\ ns$

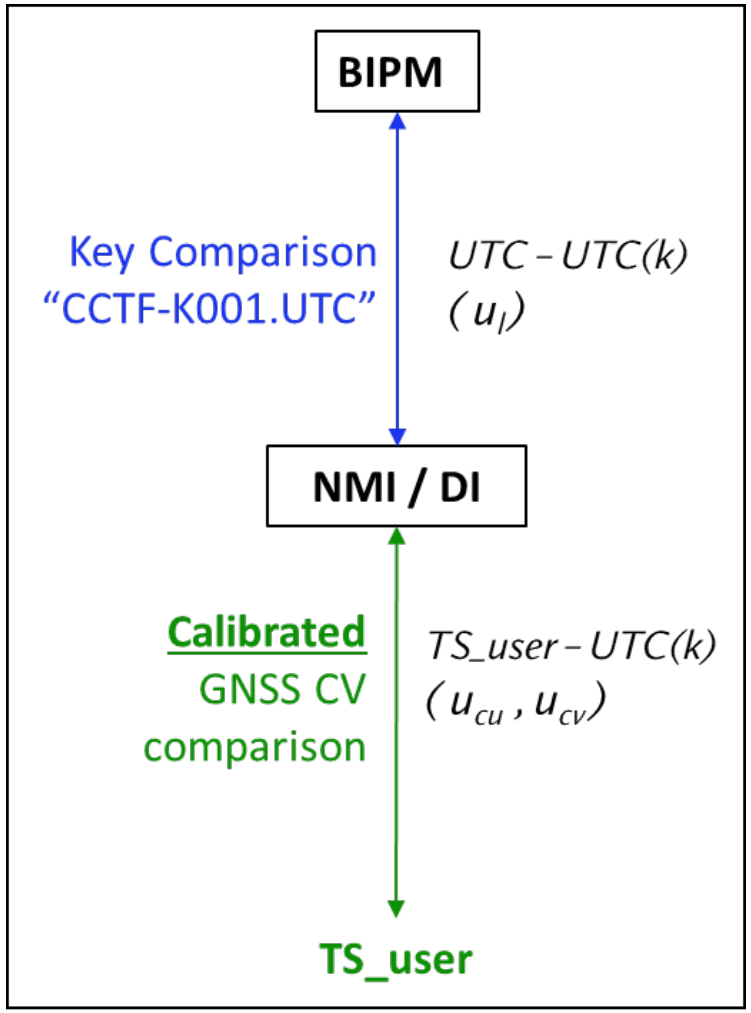
- All units regularly calibrated by accredited lab. or an NMI/DI.
- Optionally comparison via GNSS CV



Color code:



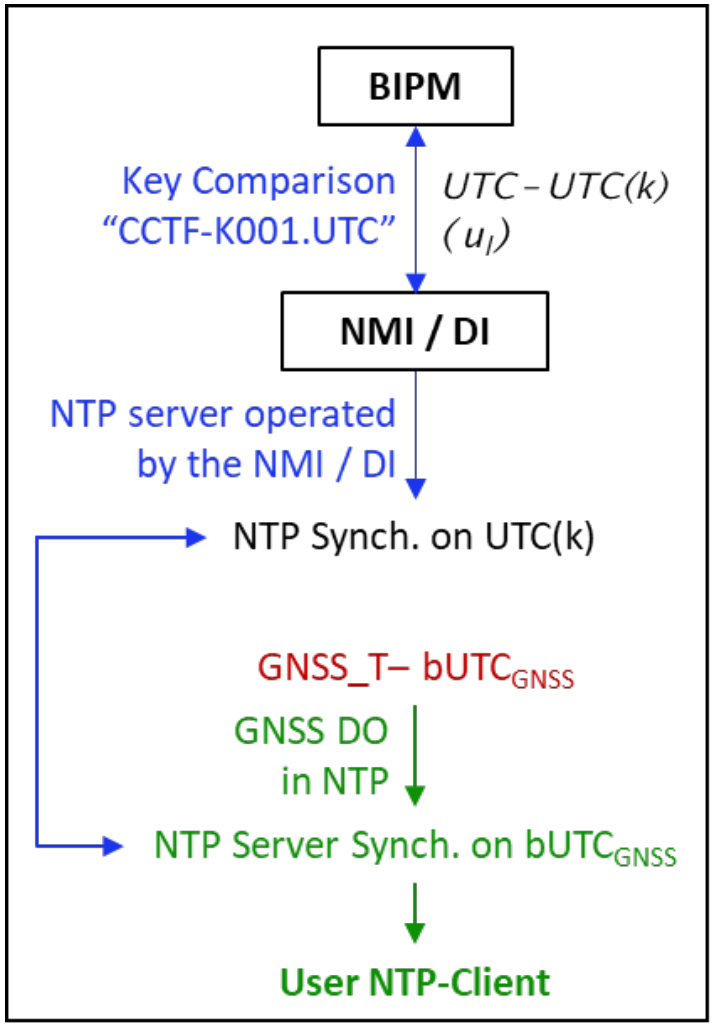
Traceability route to UTC



U2: GNSS CV with NMI / DI

- Services offered by NIST, NPL, other NMIs (?) (commercially)
- Calibration of user terminal only needed for time, must be done by the NMI / DI
- technically complex, but ideal from metrological standpoint
- Very low uncertainties possible on user-UTC(k) (< 10^{-12} @ 1 day and a few ns)

Traceability route to UTC



or routes as for U1

U3: Dissemination via NTP

➤ Concerns User that operates NTP-servers for distributing time-of-day in a LAN.

➤ User establish link to NTP server operated by NMI, and monitor the locally distributed time.
This is technically feasible even if access from LAN to the public Internet is blocked (IT security).

➤ only valid for uncertainty requirement >= 1 ms (properties of NTP and typical applications)

➤ No calibration required

Remark on calibration

Calibration is done at a given epoch

→ Requires **continuous monitoring that the device is operating correctly between calibrations**

Different options exist

- monitor DO parameters : → lock onto the GNSS signals,
  → oscillator control voltage variations.
- Compare GNSS DO outputs with another local time reference / frequency standard (can be another GNSS DO from another manufacturer)

Services by NMIs*

- 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) - $bUTC_{GNSS}$
  (a new service to create under the "Time scale difference" branch)

PROPOSED NEW

*or UTC(k) labs with QMS and accredited for this service

Recommendations to GNSS DO manufacturers

- to seek **calibration** of their GNSS DO models as proposed by the Task Group;

- to provide **technical documentation** of their devices including specifications on the parameters of time accuracy to UTC and frequency instability as function of averaging time etc. **according to metrological rules** and adapted to the users' needs;

- to include **functions** in their devices that allow the user **to verify correct operation**, for example, by monitoring and keeping records of its internal control parameters.

Recommendations to users

- to carefully **analyze** their respective **needs** and **improve the wording** and communication on "**traceability**" in view of the established meaning of this term in metrology;

- to **analyze** their **needs** regarding the **uncertainty** for the time and /or frequency offset of their internal clocks from UTC or its national realizations UTC(k);

- to follow the advice regarding **calibration** of their GNSS disciplined oscillators
  The tighter the uncertainty requirements for time and frequency signals used within their realms, the more care in calibration and monitoring is required.

Recommendations to GNSS providers

- to seek the **collaboration with NMIs/DIs** regarding GNSS system time realization and monitoring

- to **describe** the realization of **GNSS system times** as well as the data contents in the **navigation messages** following **metrological practice and vocabulary.**

Thank You

CCTF

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