REALIZATION OF

the Swedish national time scale UTC(SP)

and contribution to the world time UTC

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Solar time

Vera C. Rubin Observatory and Venus at sunset, RubinObs/NSF/AURA, Creative Commons Attribution 4.0 International license.

- The year, month and day provided by observations of the sky.
- Division of the day
  - Egyptians 2000 BCE: 2 times parts of 12 (Seasonal/temporal hours)
  - Babylonians 300 BCE: parts of 60, subparts of 60
  - Ancient greeks: parts of 60 and parts of 24 (equinoctial hours)
- Division of the hour:
  - *Pars minuta prima* (first small part)
  - *Pars minuta secunda* (second small part)

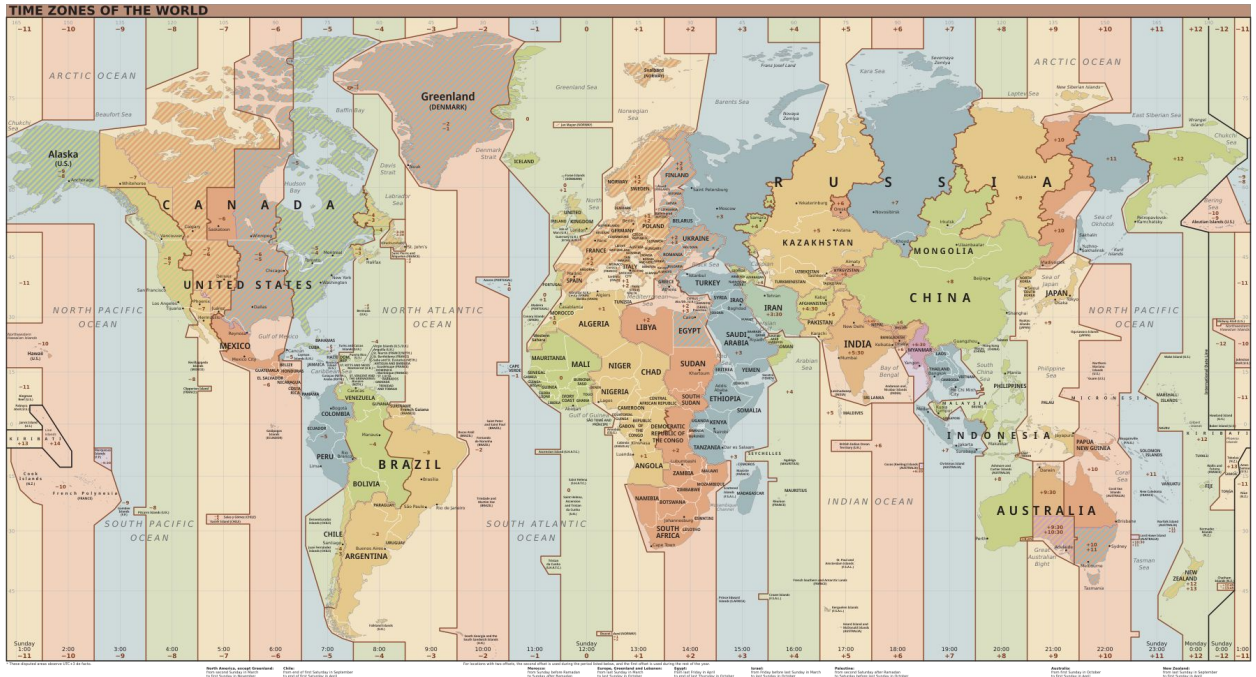
GMT and UT

- The British Association for the Advancement of Science stated in 1862

  “All men of science are agreed to use the second of mean solar time as the unit of time.”

- The International meridian conference in Washington D.C. 1884 established the Greenwich meridian as the prime meridian and thus as origin of time (GMT or UT).

- Bureau International de l’Heure (BIH) formed in 1912 disseminated UT(BIH) by radio time signals. Later employed UT(i) for weighing and averaging of multiple laboratories.



The Meter Convention and the SI

- Meter Convention Signed 1875
  - Originally for Kilogram and Meter
  - Later included Kelvin, Ampere & Volt
  - Conférence générale des poids et mesures (CGPM)
  - Maintained by the Bureau International des Poids et Mesures (BIPM)
- SI-system
  - Agreed upon in 1960
  - Included the Second defined as 1/86 400 of the mean solar day in 1900

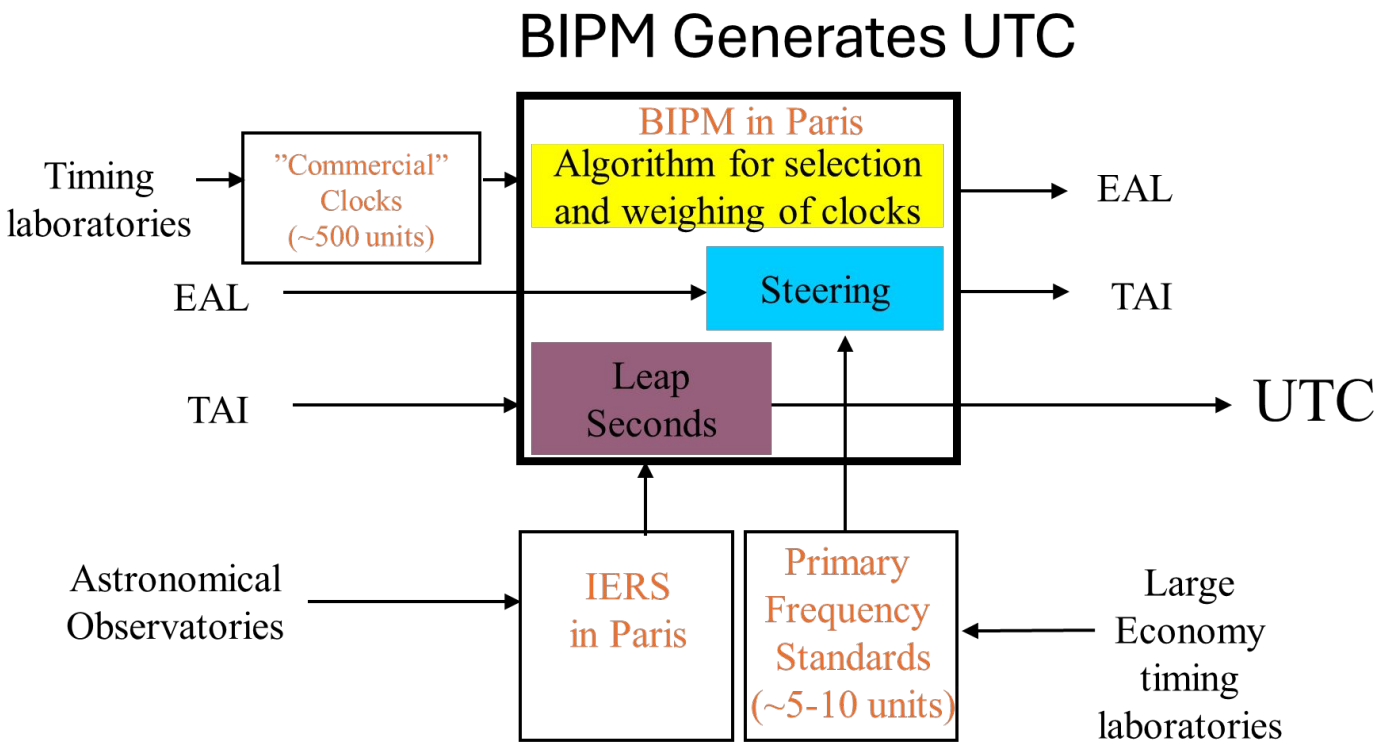
    "The second is the fraction 1/31 556 925.9747 of the tropical year for 1900 January 0 at 12 hours ephemeris time.“

Atomic time

- First demonstration of Cs frequency standard in 1955 by Essen and Perry.
- TA timescales published by BIH from 1960
- Redefinition of SI-Second in 1967

  "The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom"

- UTC (Coordinated Universal Time or Temps universel coordonné) and TAI (Temps Atomique International) endorsed by CGPM in 1975.
- BIH defunct in 1988
  - Atomic time scales maintained by BIPM
  - UT maintained by IERS, International Earth Rotation and Reference Systems Service



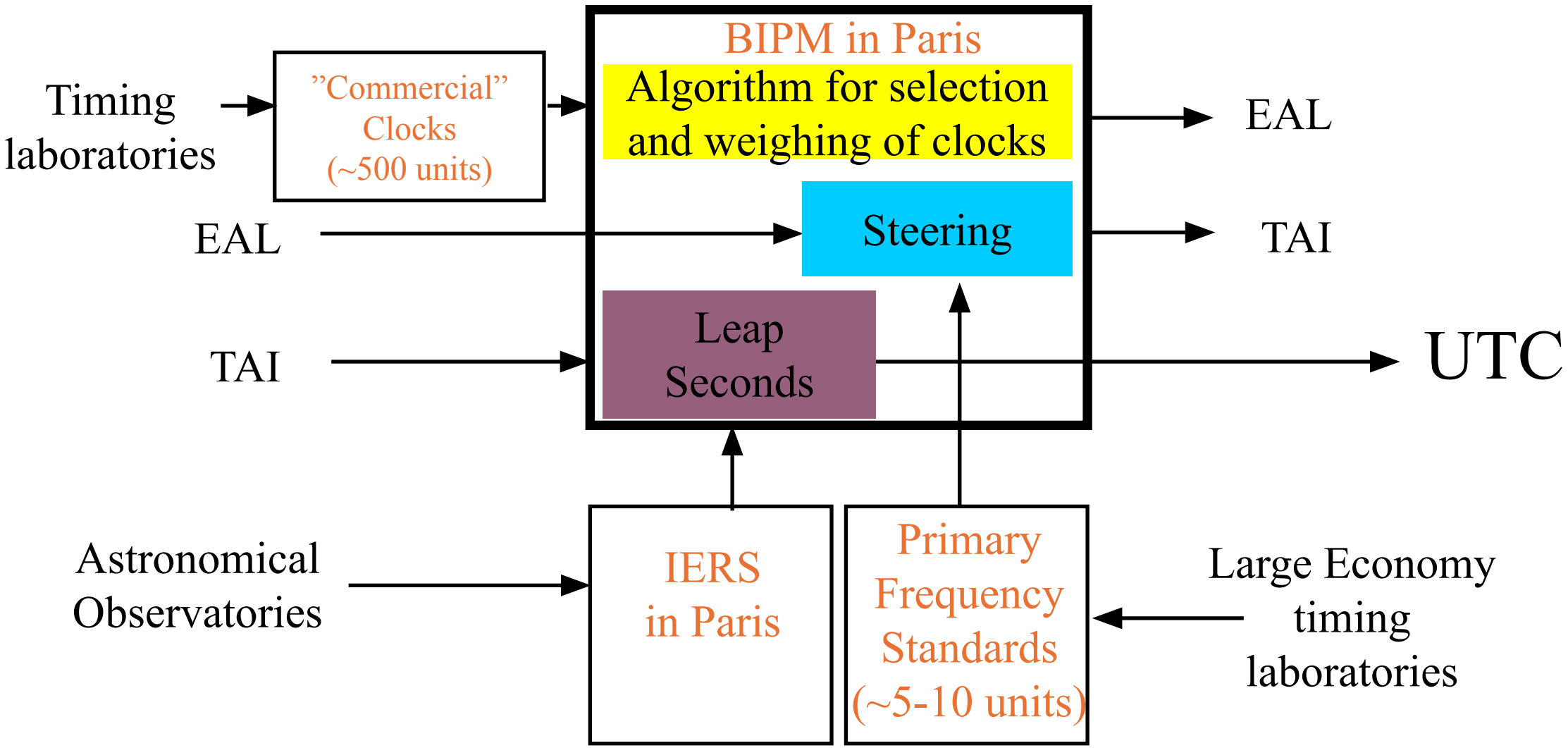
The current status

- Cs-transition still the basis for definition of the SI-second.
  - mise en pratique (SI Brochure – 9th edition (2019) – Appendix 2)
  - SI second defined in *proper time*
- UTC and TAI defined in *coordinate time*. Specifically on the geoid co-rotating with the earth.
- Local real time realizations - UTC(k)
- Results for a month distributed in the middle of the next (Circular-T).

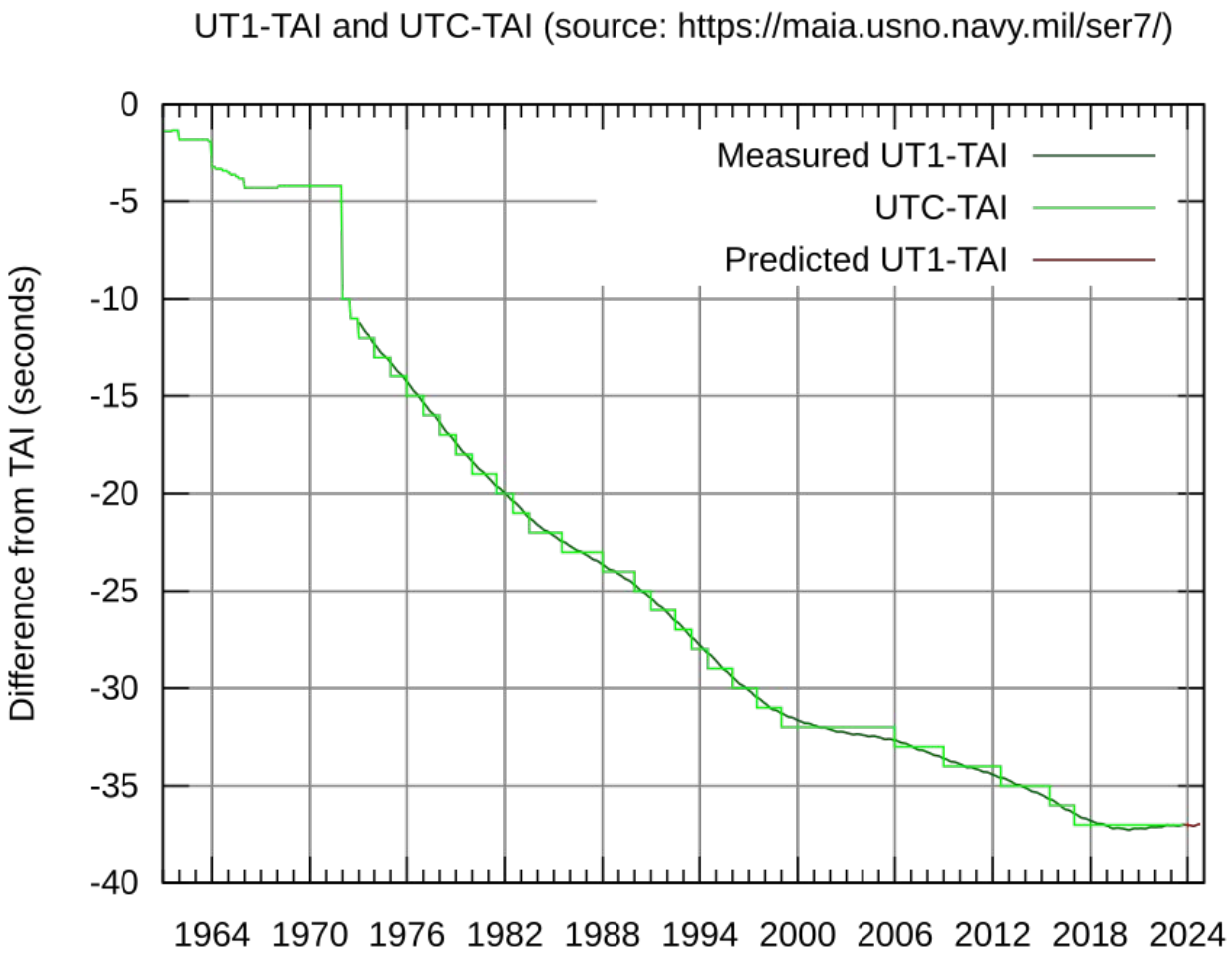
(EAL, *Echelle Atomique Libre,* a.k.a. the fly wheel)

webtai.bipm.org

BIPM Generates UTC



Leap Seconds



- Applied to keep UTC aligned with UT1 (solar time)
- Applied according to Recommendation ITU-R TF.460-6
- CGPM decision in 2022 to increase the tolerence in offset by 2035.
- Goal to have a Continuous UTC for at least a century.
- Risk of negative leap second before that.

Leap Second

Research

Cite this article: Stephenson FR, Morrison LV, Hohenkerk CY. 2016 Measurement of the Earth's rotation: 720 BC to AD 2015. *Proc. R. Soc. A* **472**: 20160404. http://dx.doi.org/10.1098/rspa.2016.0404

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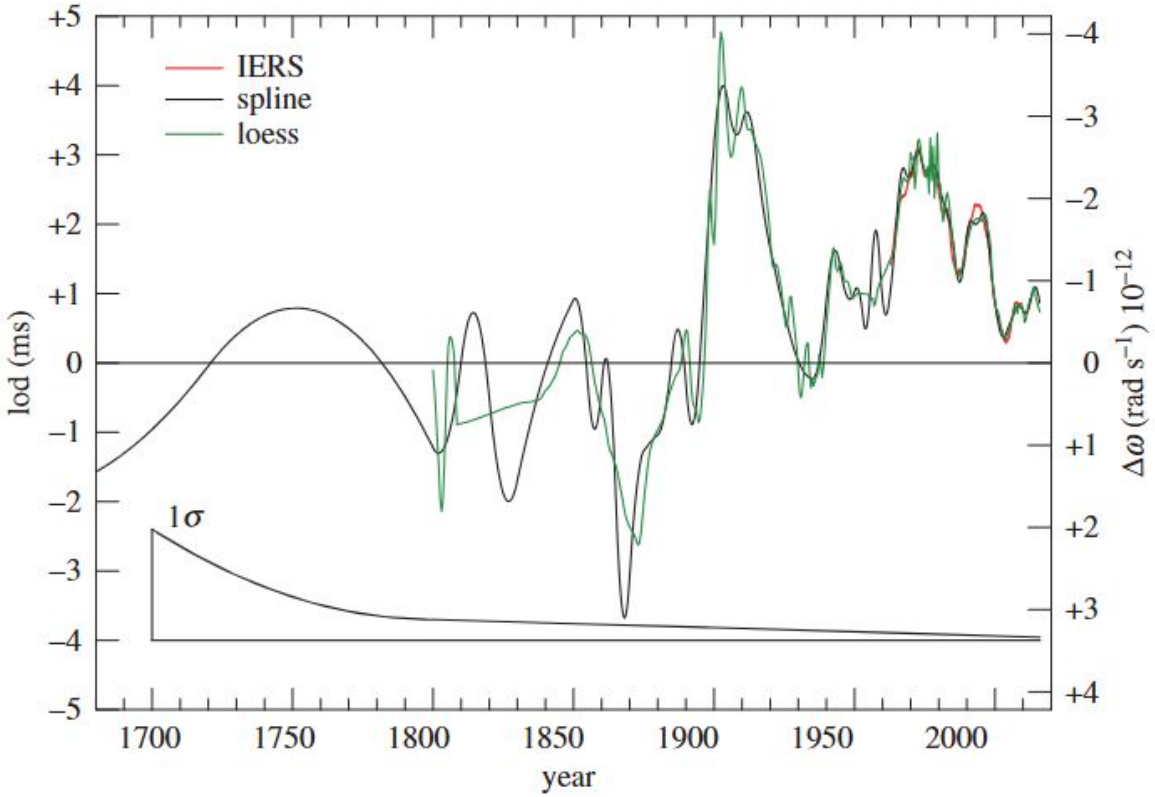

- Applied to keep UTC aligned with UT1 (solar time) +/- 1 s
- Applied according to Recommendation ITU-R TF.460-6
- CGPM decision in 2022 to increase the tolerence in offset by 2035.
- Goal to have a Continuous UTC for at least a century.
- Risk of negative leap second before that.

Time in Sweden

RI.
SE

Regulations

Förordning (1979:988) om svensk normaltid

Regeringen föreskriver att den för tidsangivning inom landet gällande tiden (svensk normaltid) skall vara den av Bureau International de l'Heure fastställda normaltiden Temps Universel Coordonnue (UTC) ökad med en timme.

Regulations and standards

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Lag (2011:791) om ackreditering och teknisk kontroll

Riksmätplatser och laboratorier för mätning

11 § Med riksmätplats avses ett organ som har utsetts att för en viss storhet officiellt svara för sådan mätning som i förhållande till nationella mätnormaler eller vetenskapligt definierade måttenheter säkerställer riktigheten av mätningar som utförs inom landet och se till att dessa mätnormaler och måttenheter är anknutna till internationellt antagna enheter.

12 § En riksmätplats utses av regeringen för en eller flera storheter.

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Förordning (2019:16) om riksmätplatser

1 § Riksmätplatser enligt lagen (2011:791) om ackreditering och teknisk kontroll är de organ som anges i tabellen. Där anges också storheterna för varje riksmätplats.

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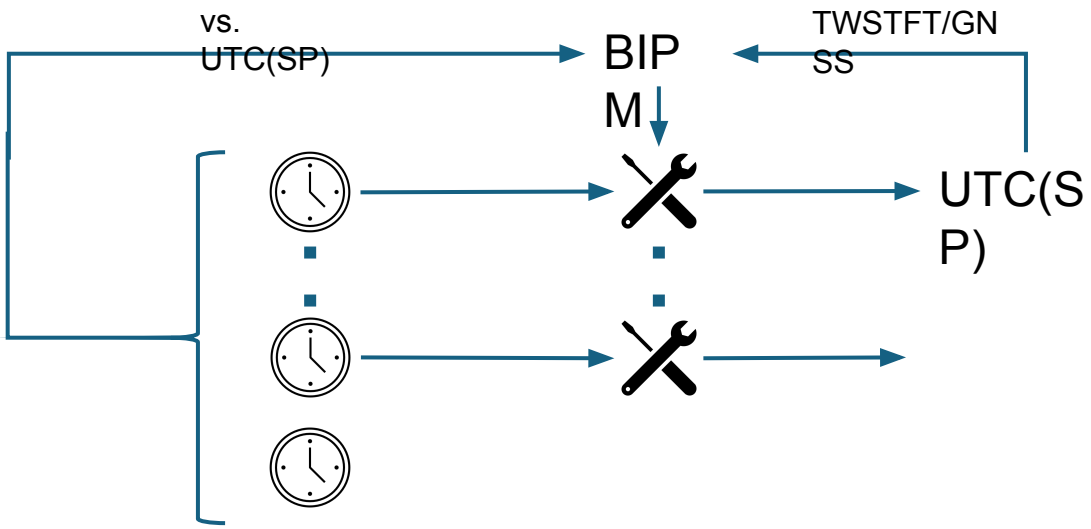
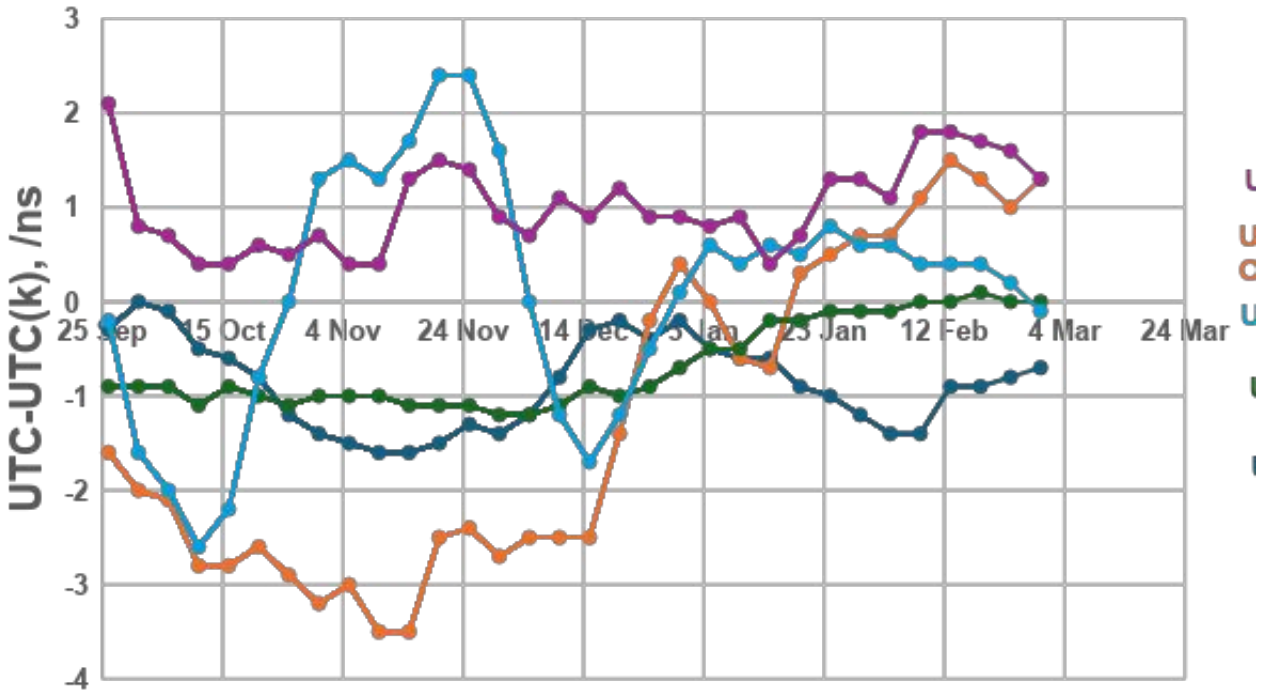
Tid och frekvens

RISE Research Institutes of Sweden AB (1-3)

1. tidsintervall
2. tidpunkt
3. Frekvens





RISE and UTC(SP)

RISE reported in January 2025

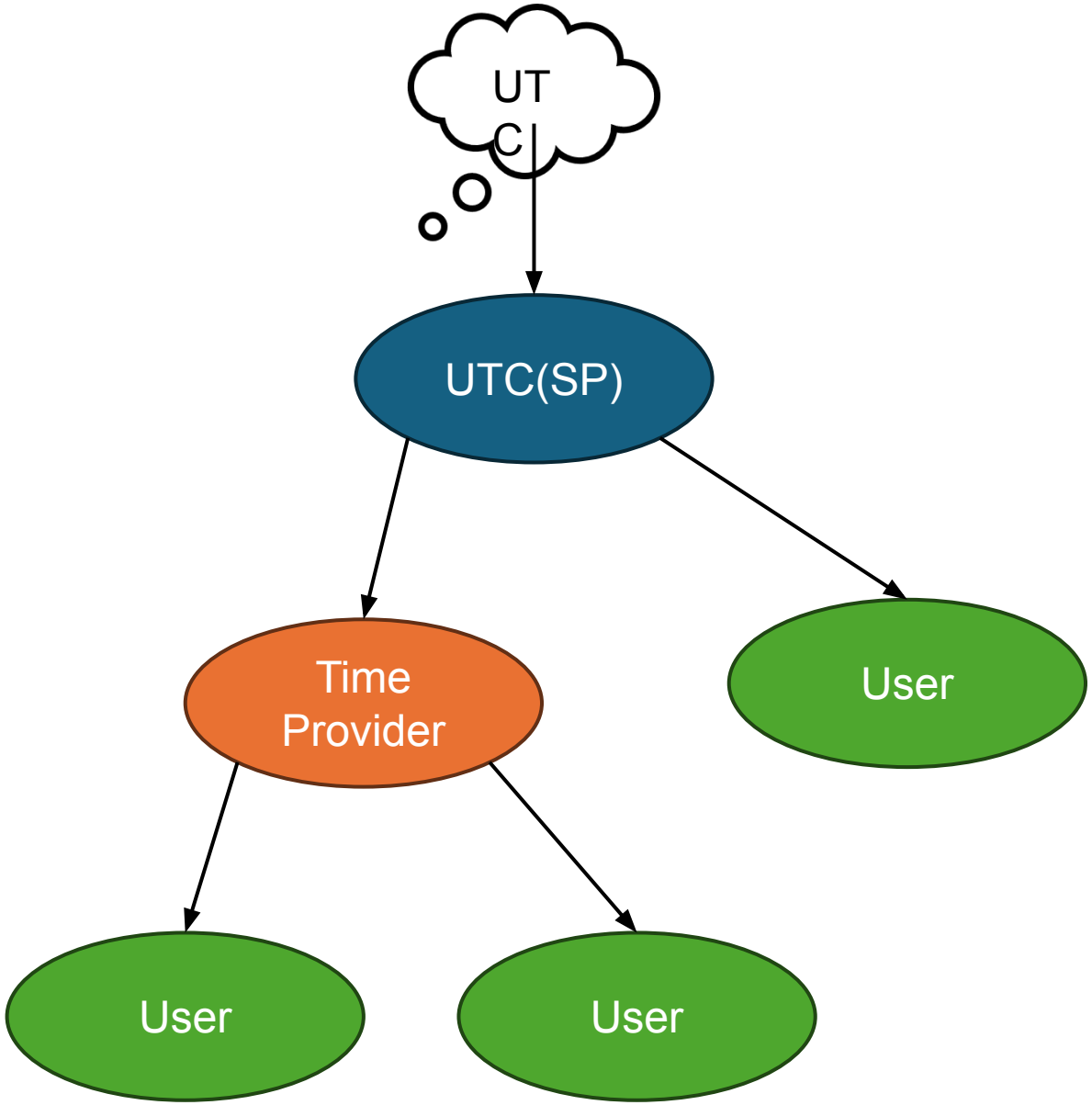
- 5 Active Hydrogen Masers
- 6 Cs Beam Standards

→ ~4.5% of EAL

Linkage by

- TWSTFT
- GNSS

→ 1 ns combined standard uncertainty (68% coverage pobability)



Distribution of UTC(SP)

- Network Time Protocol (NTP/NTS)
- Precision Time Protocol (PTP)
- White Rabbit (WR)
- GNSS Common View (CV)
- Speaking Clock (”Fröken UR”)

- Remote clock vs. UTC +/- 10 ns 95% confidence interval
- Remote clock vs. UTC(SP) +/- 7 ns 95% confidence interval

More regulations

MIFID2 &
(EU) 2017/574

HFT < 100 µs from UTC

Clearly demonstrated traceability

MSB FS 2020:7
4.Kap
13§:

Government agencies shall use correct and robust time traceable to UTC(SP)

Förordning (2022:511) om elektronisk kommunikation
9.Kap
7-8§§:

Traceable time in event logs

Metrological Traceability

"*Metrological traceability is … one of the elements that establishes international confidence in the world-wide equivalence of measurements.*"

"The BIPM, OIML, ILAC, and ISO endorse the following recommendations:
in order to be able to rely on their international acceptability, calibrations should be performed

- *in National Metrology Institutes who should normally be signatories to the CIPM MRA and have CMCs published in the relevant areas of the KCDB*

or

- *in laboratories accredited by accreditation bodies which are signatories to the ILAC Arrangement"*

BUREAU INTERNATIONAL DES POIDS ET MESURES

ORGANISATION INTERNATIONALE DE METROLOGIE LEGALE

INTERNATIONAL LABORATORY ACCREDITATION COOPERATION

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

JOINT

BIPM, OIML, ILAC AND ISO

DECLARATION ON

METROLOGICAL TRACEABILITY

9th November 2011

Michael Kühne
Director of the BIPM

Stephen Patoray
BIML Director

Peter Unger
ILAC Chair

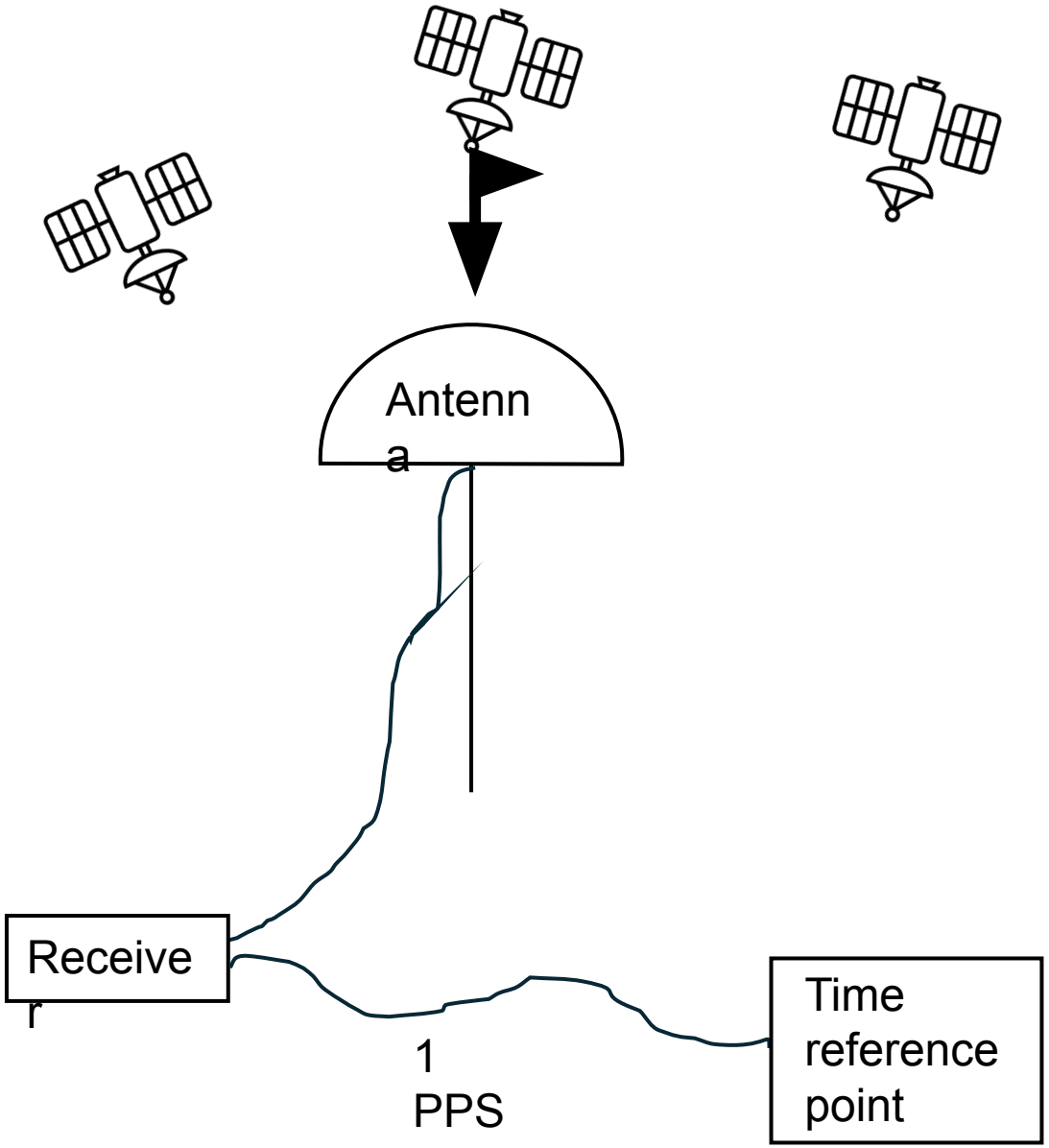
Robert Steele
ISO Secretary General

Example:
delay in GNSS system

- GNSS system time NOT metrologically traceable per se
  -> Must be pinned to a UTC(k)

- Unknown offset between antenna and time reference point
  -> Must be calibrated

P Defraigne et al 2022 Metrologia 59 064001



Future time

The time to come

- Optical Clocks
  - Operating at higher frequencies ($^{27}Al^{+}$ 1127 THz, ^{88}Sr 429 THz, …)
- Nuclear Clocks
  - Even higher frequencies at ionizing energies (Th 2020 THz)
  - Thorium clock (Tiedau et. al., 2024)
- Redefinition of second
- Lunar time scale

Meterkonventionen 150 år

20 maj 2025
Borås

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Anmäl dig: