

Timing Traceability and GPS

Demetrios Matsakis
US Naval Observatory

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How does the International Vocabulary of Metrology define traceability?

2.41 (6.10)

metrological traceability

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

(Italics and bold font added by speaker for emphasis)

Reference: <http://www.bipm.org/en/publications/guides/vim.html>

Who Wrote the VIM?

International Bureau of Weights and Measures (BIPM)

International Electrotechnical Commission (IEC)

International Federation of Clinical Chemistry and Laboratory Medicine (IFCC)

International Organization for Standardization (ISO)

International Union of Pure and Applied Chemistry (IUPAC)

International Union of Pure and Applied Physics (IUPAP)

International Organization of Legal Metrology (OIML)

International Laboratory Accreditation Cooperation (ILAC)

<http://www.bipm.org/en/publications/guides/vim.html>

Legal Requirements

- In USA
 - Financial Industry Regulatory Authority Rule 4590
 - Applies only to members of FINRA
 - 1 s for manual clocks
 - 50 ms for computer systems
 - SEC Rule 613 (Consolidated Audit Trail)
 - Applies to security exchange or association and its members
 - Accuracy 50 ms
 - Granularity 1 ms
 - Time must be traceable to UTC(NIST)
- In Europe, and for trading with Europe: MiFIR/FiFID (Jan 2018)
 - If “gateway latency” > 1 ms
 - Accuracy 1 ms
 - Granularity 1 ms
 - If “gateway latency” ≤ 1ms and high-frequency algorithmic trading
 - Accuracy 100 μs
 - Granularity 1 μs
 - Gateway latency = time of acknowledgement minus time of reception
 - at the outer gateway of a system
 - <http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32017R0574&from=EN>

Today, only GNSS can do sub-ms

- www.time.gov , WWVB, “telephone time”, etc. have large and sometimes uncomputed uncertainties
- “Alarm-clock time” from Power Lines could soon start to wander by ~ 7 minutes/several months
- Time from NTP depends on internet access
 - It cannot be better than 1 ms RMS
 - I would say 10 ms RMS variations for some internet providers, but I have seen 100 ms
 - <http://tycho.usno.navy.mil/papers/ts-2013/Matsakis-NTPAccuracyAsSeenByTheUsers.IONPTTI-2013.pdf>
 - Calibration issues are non-trivial
- GNSS accuracy limited by receiver calibration
 - Calibration services exist (e.g. NIST)
- Fiber-based systems may surpass GNSS in future

UTC realizations

- UTC = Coordinated Universal Time
- UTC(k) = Lab k 's real-time estimate of UTC
 - Physically, they are time-ticks, or equivalents
 - UTC(k) is usually the legal standard in k 's country
 - America Competes Act shares between USNO and NIST
 - “...as interpreted or modified by the Secretary of Commerce in coordination with the Secretary of the Navy”
 - Traceability to UTC usually means traceability to UTC(k)
 - UTC(k) not traceable to UTC in real time
 - All UTC(k) traceable to UTC every month, through Circular T
 - Ditto UTC(labX)-UTC(labY)

Does GPS broadcast UTC(USNO)?

- GPS Time is *NOT* time from GPS
 - No leap seconds
 - For navigational solutions only
- Time from GPS is computed from GPS Time
 - Use Subframe 4, Page 18 of Navigation Message
 - It is a prediction of UTC(USNO)
 - Linear extrapolation over last 1-2 days
 - It deviates from UTC(USNO) by ~1 ns RMS
 - I will write it as UTC(USNO via GPS)
 - Measurement of current UTC(USNO) to an accuracy of 1 ns
 - Signal-in-space

Can GPS provide real-time traceability to any UTC(k)?

- Yes, if lab k makes common-view data available
 - Super-real-time, if ignore the web pages being a few hours old
- Example: NIST publishes UTC(NIST)-UTC(USNO via GPS)
 - You measure UTC(USNO via GPS) -clock
 - You use web pages to infer UTC(NIST)-clock
 - Ditto for any other lab, including USNO
 - USNO publishes GPS Time – UTC(USNO)
- Yes, for UTC(USNO via GPS) directly from GPS
 - Must add 1 ns RMS uncertainty to allow for error in prediction/measurement of UTC(USNO via GPS)
 - Procedures, etc. documented in ICD200 and ICD202
 - Accuracy of UTC(USNO via GPS) also verified in section 4 of Circular T
- But no lab is responsible for your setup's bias and uncertainties

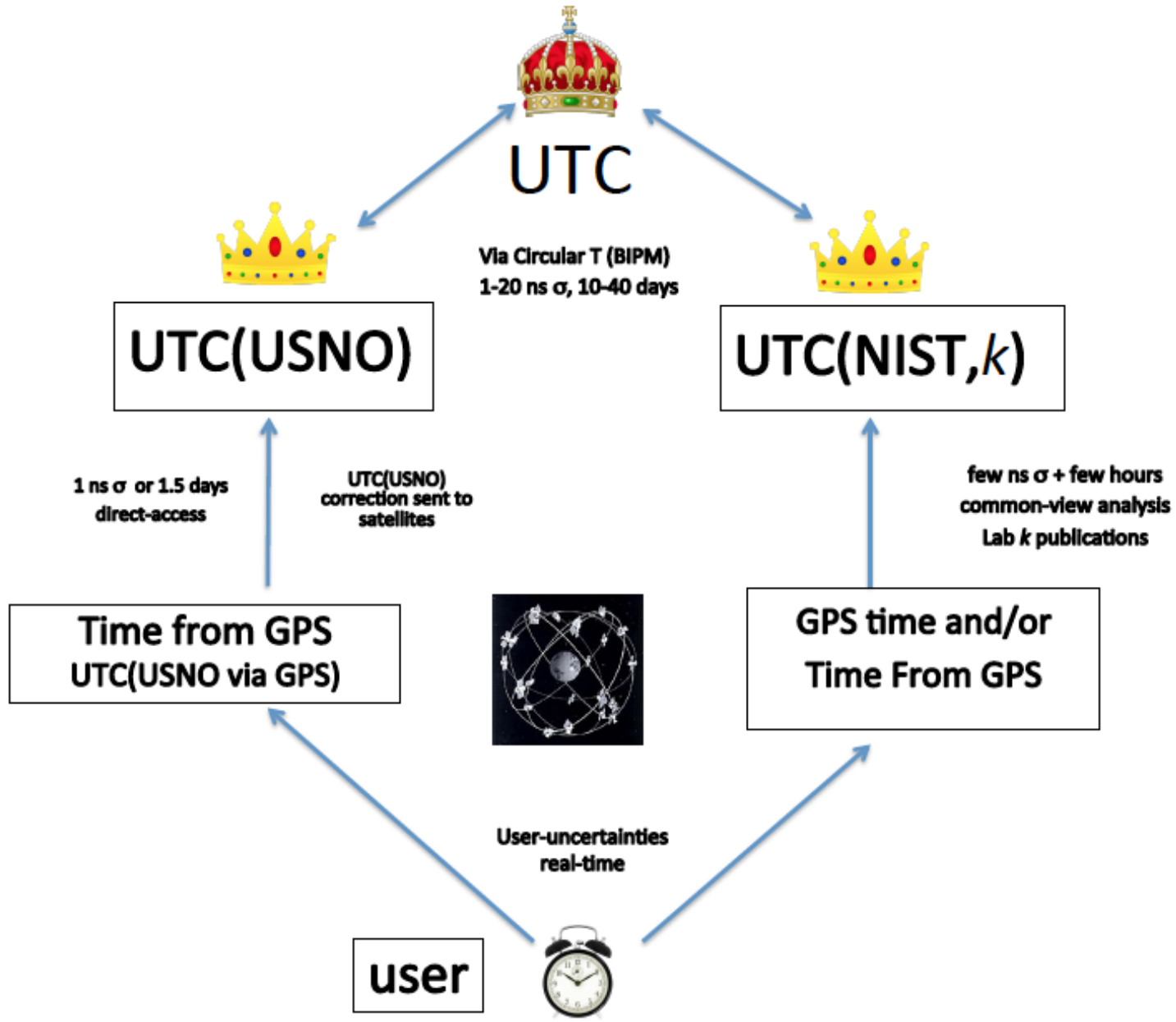
Repeat: User Responsibility

- GPS is responsible for its broadcast signal
- UTC labs responsible only for what they put out
- User is responsible for user equipment
- To stand up in court your lawyer might want:
 - 1. Verification of the accuracy of your GPS receiver
 - External service such as NIST's might show due diligence
 - NTP sanity check, or second GPS system, would help
 - 2. Appropriate log files

Summary

- GPS can be used to provide traceability to UTC(k)
 - Using corrections provided by timing labs
 - And with a very small time-lag
- Time directly from GPS is traceable
 - In post-processed mode
 - In real time, if you account for the uncertainty in the control loops
 - and accept USNO's uncertainty evaluations
- Your biggest problem is to calibrate your equipment

GPS path from user to UTC & UTC (k)



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- Large Crown:
https://en.wikipedia.org/wiki/Diamond_Crown_of_Bulgaria#/media/File:Crown_of_Bulgarian_Queen.svg
- Yellow crowns:
http://www.clipartpanda.com/clipart_images/free-clip-art-
- GPS:
https://en.wikipedia.org/wiki/GPS_satellite_block#/media/File:GPS_satellite_constellation.jpg
- Alarm Clock:
https://en.wikipedia.org/wiki/Alarm_clock#/media/File:2010-07-20_Black_windup_alarm_clock_face.jpg

Backup: ITU definition of traceability

“The property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an *unbroken* chain of comparisons *all having stated uncertainties*”

- ITU=International Telecommunications Union
- Recommendation ITU-R TF.686-3
 - Approved Dec 12, 2013
 - <https://www.itu.int/rec/R-REC-TF.686-3-201312-I/en>

Is post-processed GPS directly traceable to UTC?

- Yes, via Circular T, in two ways
 1. UTC-UTC(k) in section 1
 - Supplement with GPS data $-UTC(k)$ measured by lab k
 2. UTC-UTC(USNO via GPS) in section 4
- Uncertainties estimated in both sections
- Latency is 10 to 40 days