NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

Improvements Made to NIST-Traceable GNSS Time Transfer Systems

Ben Pera

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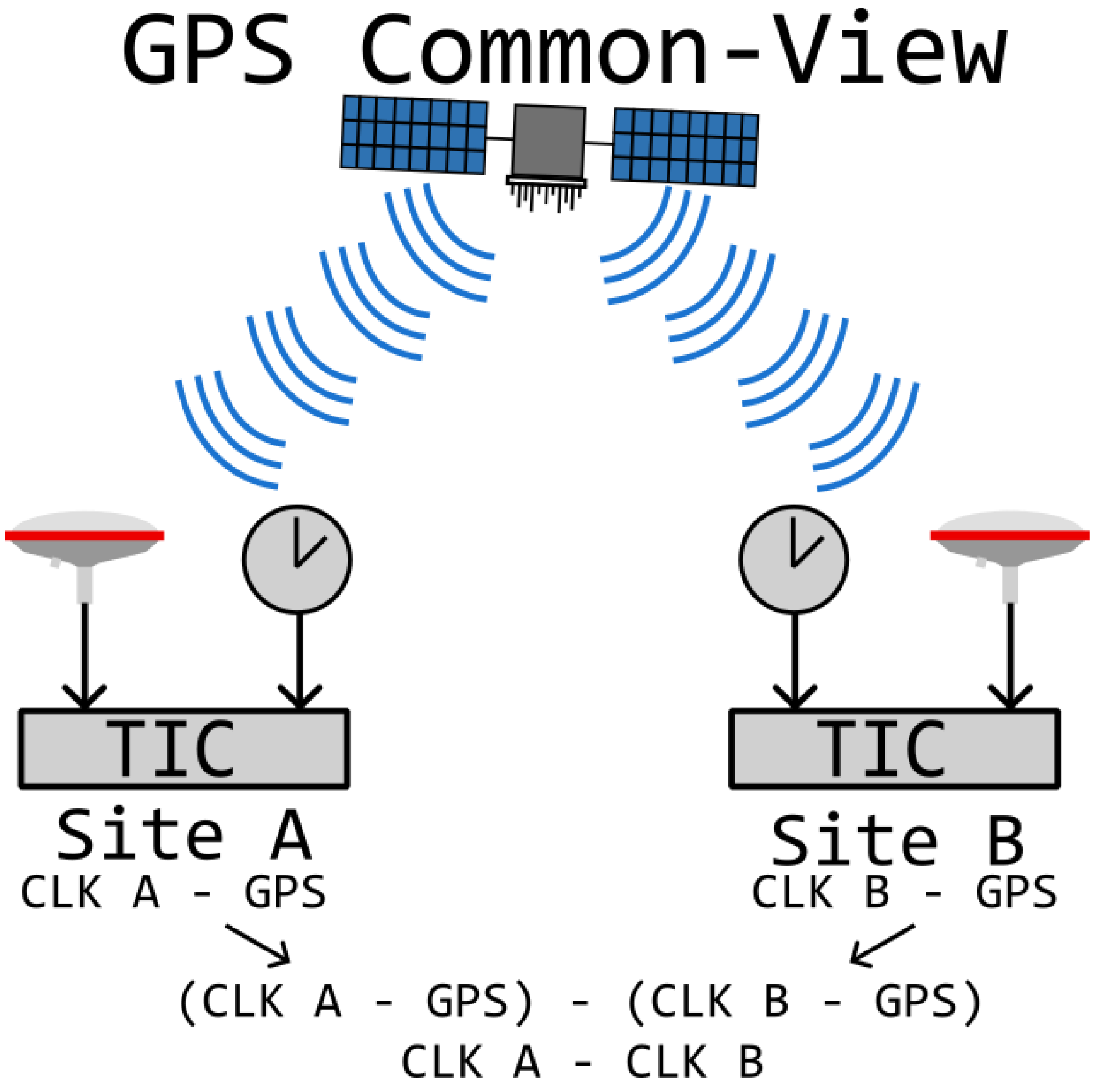
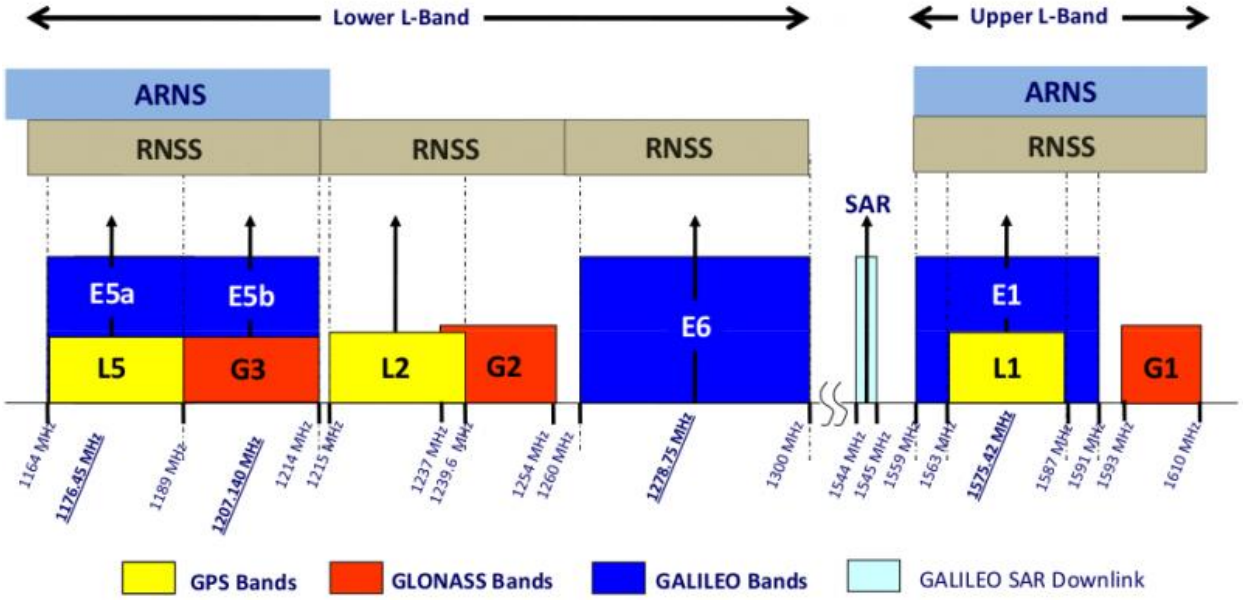
Overview of common-view time transfer

- NIST site observes GPS satellite to limit dependency on accuracy of satellite clock
- Provides traceable time transfer from UTC(NIST) to user



Multitudes of signals besides GPS L1

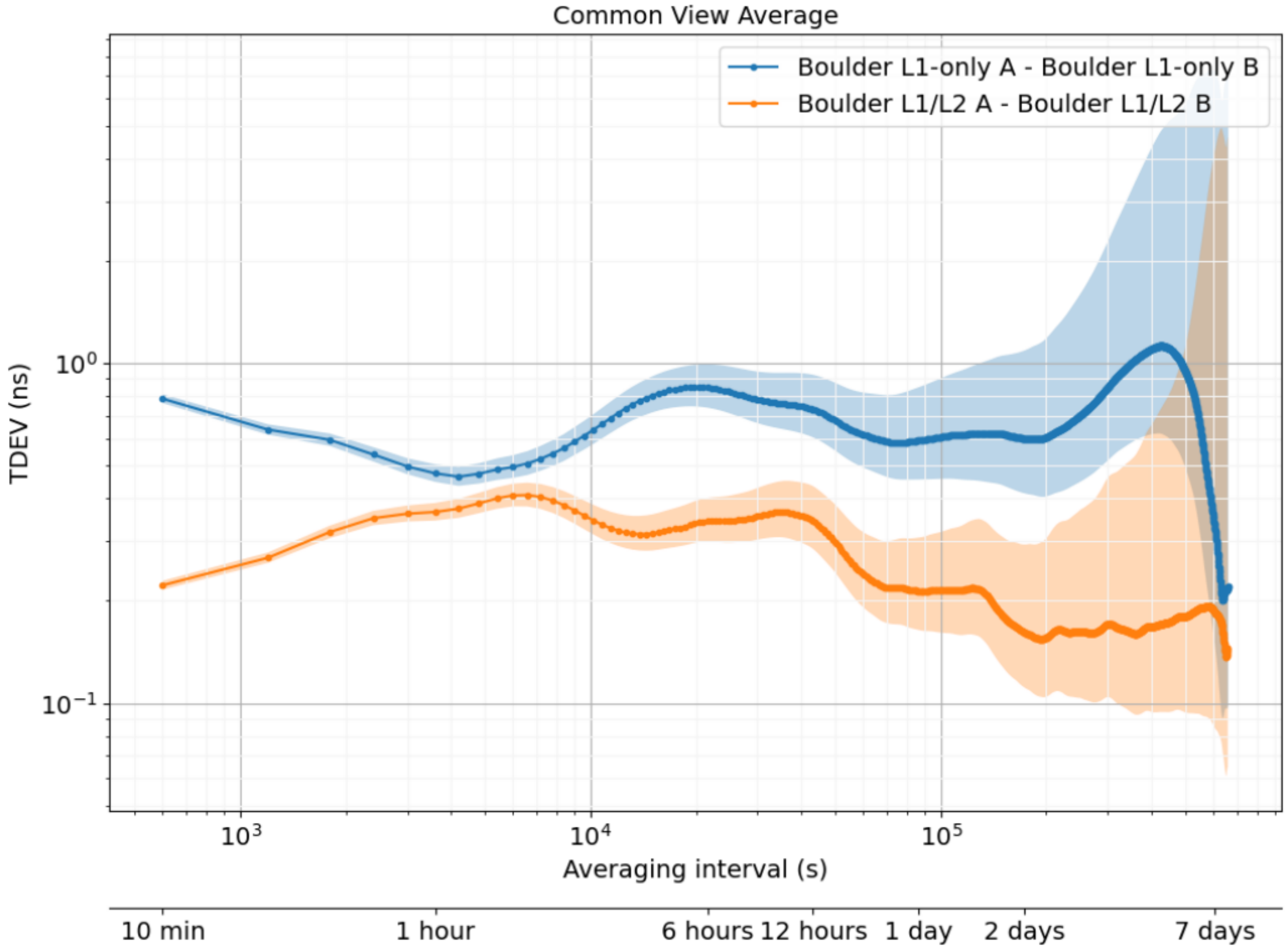
- Single frequency GPS historically used
- Three distinct bands available L1, L2, L5
  - Equivalent in Galileo: E1,E5,E6   Other constellations have similar bands
- Multiple constellations make a much larger dataset for common-view comparison



from ESA navipedia

Why use L2 in a GNSS time transfer solution?

- Combining L1/L2 allows for ionospheric delay mitigation
- Diurnal variations are nearly completely mitigated
- Modern receivers using multi-band often offer other enhanced features as well



Why use L5 in a GNSS time transfer solution?

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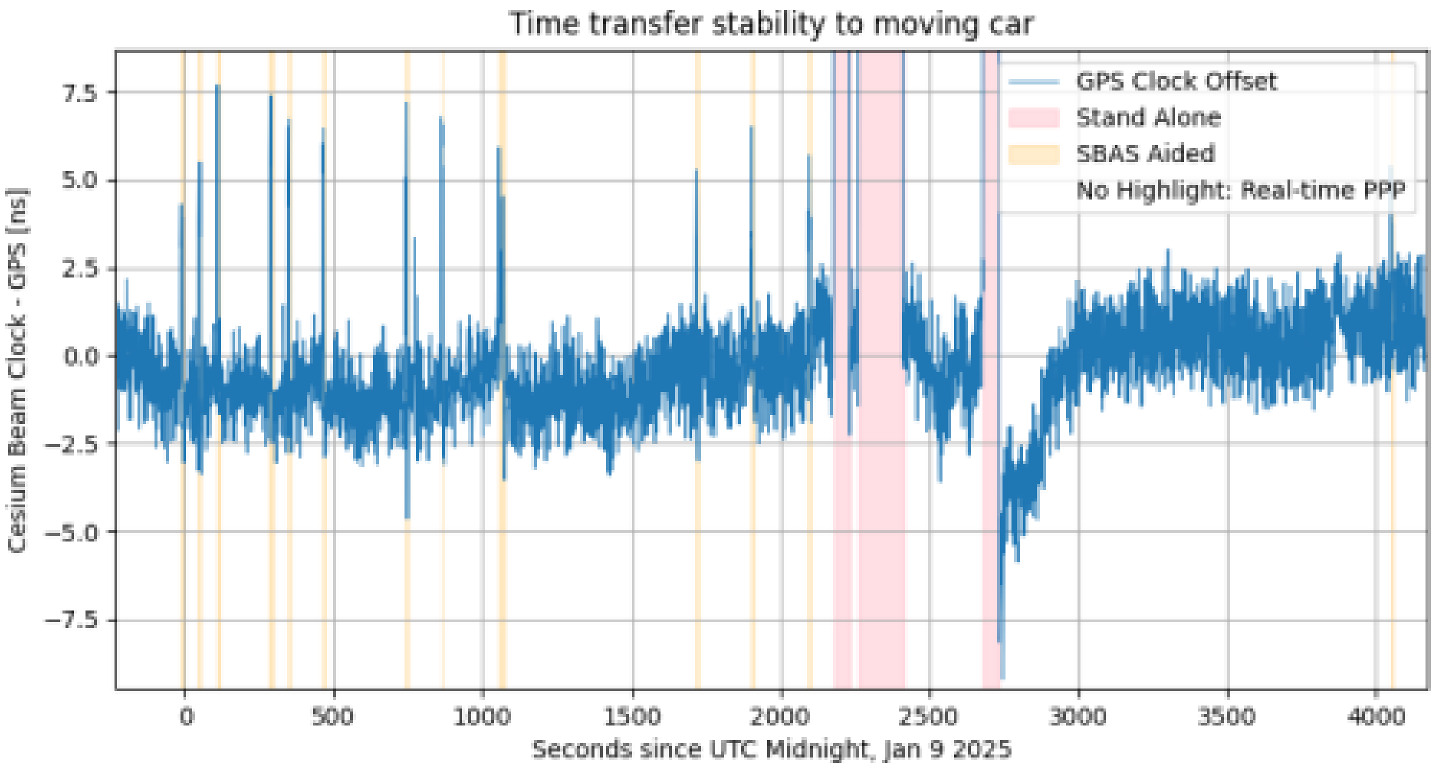
- L5 is pre-operational in the GPS constellation, and operational in Galileo
- 10x higher code rate, interference mitigation, better signal penetration



Even in high interference environments, L5 capable receivers hold robust solutions

Common-view results depend on receiver

- Each receiver has its own proprietary formulas for ionosphere, troposphere, etc. to improve position solutions
- This prevents a common observation of satellites in a strict sense, but is often good enough
- Comparing multiple receiver types leads to biases
- Using BIPM format called “CGGTTS” allows for receiver independent common view time transfer without the high data rates of RINEX

Generating receiver independent data

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- Same calculation for time offsets must be done at every receiver, essentially offloading PVT solution to computer
- All constellations have a standard implementation outlined in their interface control documents
- Including each delay calculation result in the file allows a better result to be post-processed later

Receiver independent timing solutions allow 3rd party collaboration for traceable time

Using a highly accurate time source

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Possibilities:

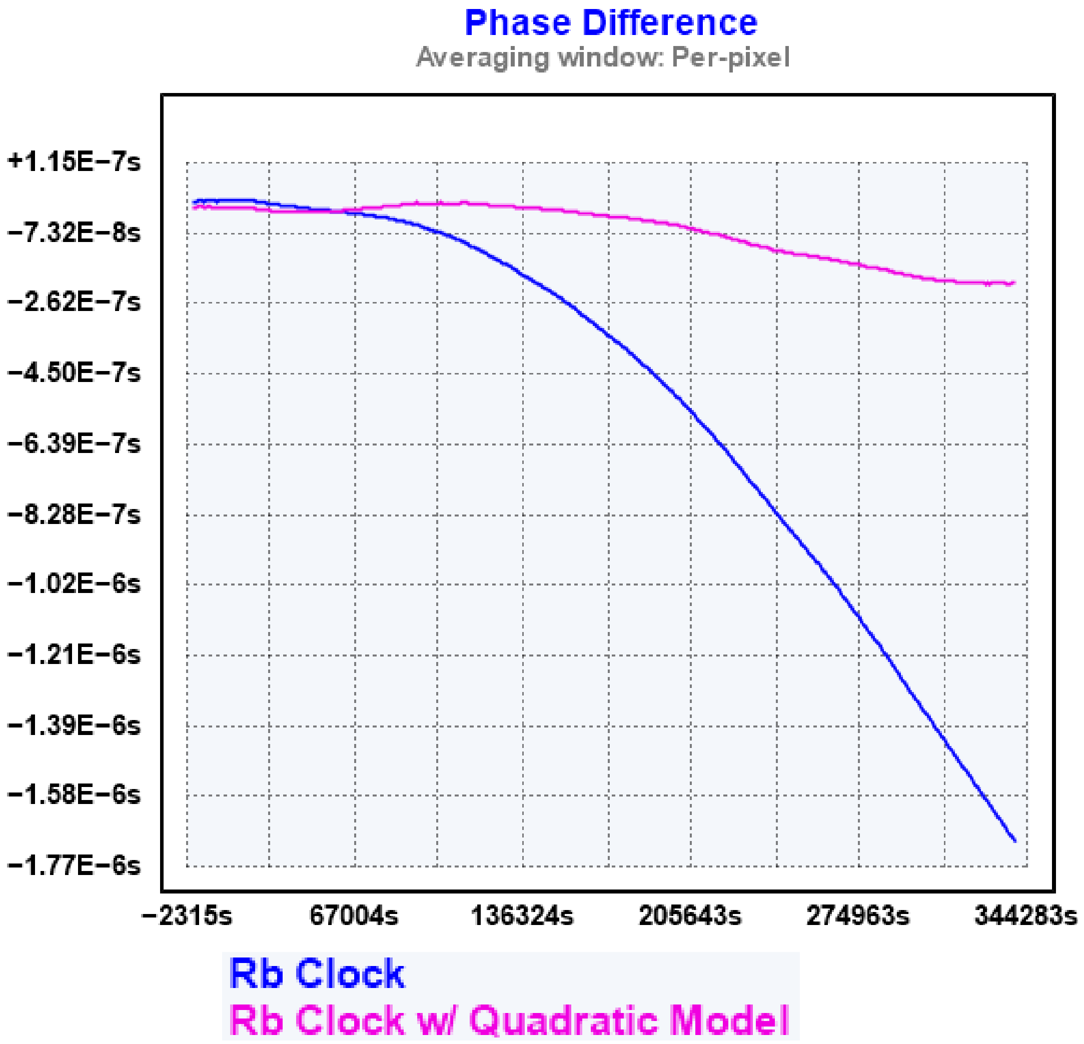
- Disciplined oscillator (DO)
  - Typically built from either a stable quartz or a rubidium oscillator
- Timestamp measurement
  - Using a time interval counter or time tagger allows measurement of user-side events traceably
- Frequency measurement
  - Time interval counters can also measure frequencies besides 10 MHz
- Time distribution
  - Networked time such as NTP, PTP, or White Rabbit

Disciplined oscillator

- To get the most performance out of the system, a hybrid oscillator can be used
- Many rubidium oscillators feature excellent long-term stability, while having poor short-term stability to a comparably priced or cheaper quartz
- By steering a quartz oscillator with knowledge of the GNSS CV in typical conditions, and the atomic clock in holdover, the best resilient system can be built for the cost

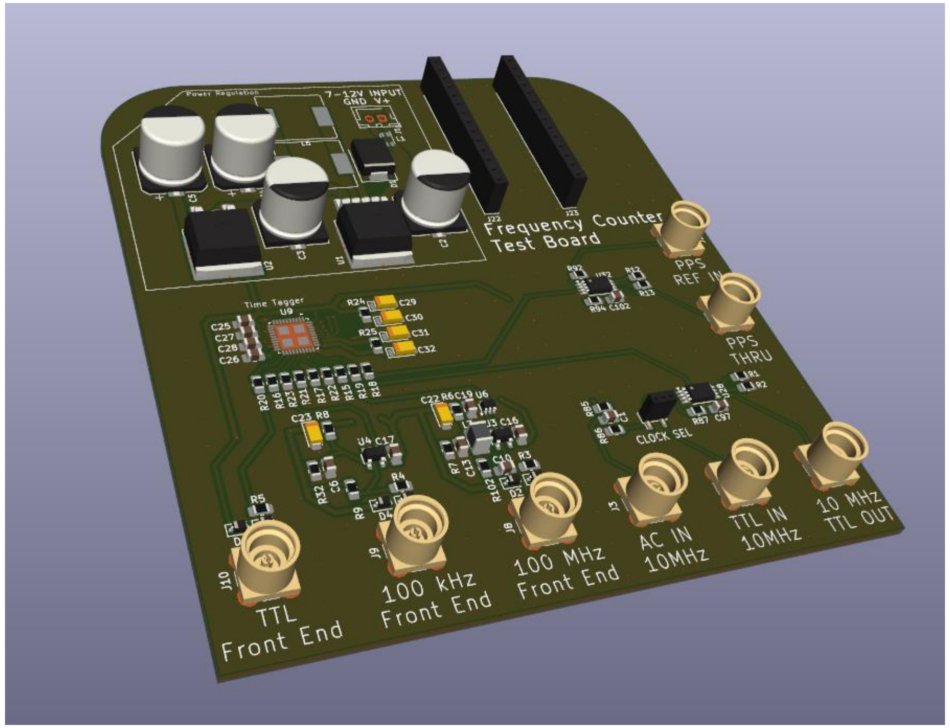
Steering algorithm design

- Simple formulas can be used for a basic control loop design
- Added control can be used to emulate bang-bang type steering for fast startup or failure recovery
- Awareness of clock noise performance allows enhanced tuning of control loop



Low-cost time and frequency measurement

- Digital time taggers with resolution exceeding GNSS time transfer performance are very cheap and common now
- Lidar sensors can be abused to be adequate accuracy for pennies
- Using frequency divider front end, even a low-cost device can accurately measure high frequencies, traceable to a GNSS PPS



Portable Calibrations

- Small, light, low power, low-cost, perfect for a portable system
- Multi-band multi-GNSS allows good performance in poor environments

NIST Timing Services

NIST offers services with these performance enhancements for the best time transfer from UTC(NIST)

Traceable time and frequency

- UTC(NIST) signal sources
- Public NTP server
- Network time monitoring

T&F calibration

- GNSS receivers
- Clock Instability
- On-site calibrations

COMING SOON TO A LAB NEAR YOU!

Questions?

UTC(NIST) Accuracy