Civil GPS Service Interface Committee

Timing Subcommittee

Chair: Dr. Stefania Römisch – NIST Time and Frequency Division
Co-Chair: Dr. Lin Yi – JPL - NASA

Timing Subcommittee

A forum for users of GPS timing applications.

- Time Generation: Coordinated Universal Time
- Time Dissemination: Telecommunications, financial markets and power grid among others
- As a research and comparison tool: remote comparison of clocks for Earth observations, fundamental physics, support for space missions, etc.

Highlights of this year's session

From timing laboratories:

USNO

- Continues to compute:
  - UTC(USNO)-GPS Time and delivers it to USAF 2nd Space Operation Squadron to steer GPS Time;
  - Time and frequency offsets from GPS Time to predicted UTC(USNO) [LNAV and CNAV]
- Will include GGTO (GPS to GNSS Time Offset) to CNAV message type 35 with OCX to increase interoperability;
- Will work with USAF to determine inter-frequency and inter-signal biases;
- Absolute calibration of GNSS receivers for all systems is being validated.

Naval Research Laboratory

- Precise Clock evaluations Facility (PCEF)
  - for extended life testing, including GPS III RAFS;
  - Supporting DARPA ACES next gen CSACs
- Performance analysis and estimation of all operational GPS clocks informing OCX Kalman filter tuning by 2SOP
- Developed algorithms for next gen GPS Time [OCX]
- Supports NTS-3: first experimental PNT spacecraft in 40 years
- Operates multiple Time Transfer links NRL-USNO (11km)

Highlights of this year's session

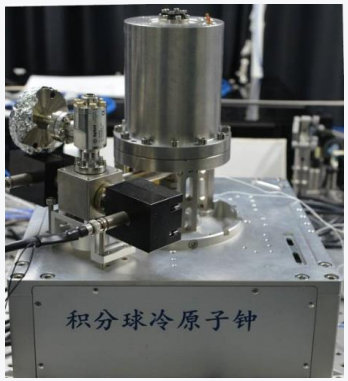
About clocks:

Masterclock:

- The goal is steering a clock to a reference (i.e. GPS Time) compromising between frequency offset, time offset, steer and response to non-stochastic disturbances
- Different techniques are available:
  - Linear Quadratic Gaussian
  - Critical Gains
  - PID controllers

Chinese Academy of Sciences

- Cold Atom Clock Experiment in Space (CACES)
- Integrating Sphere Cold Atom Clock (ISCAC)
  - Diffused light cooling (spherical optical cavity)
  - POP interrogation scheme
  - Stability $\sigma_y(\tau) = 5 \cdot 10^{-13}/\sqrt{\tau}$

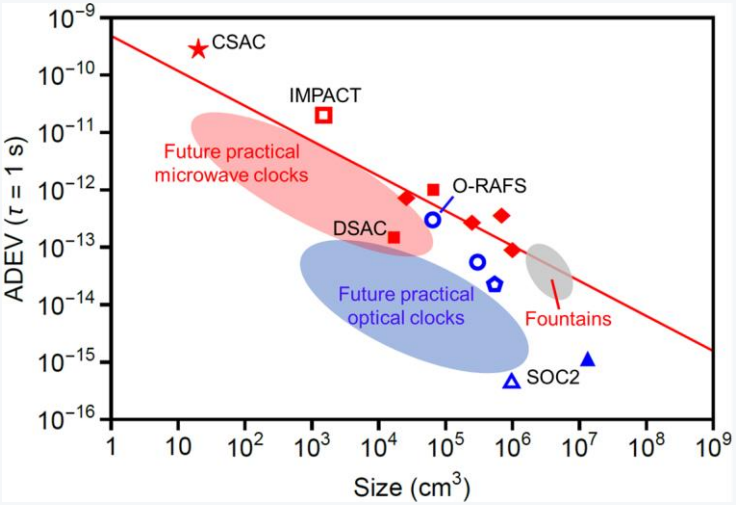


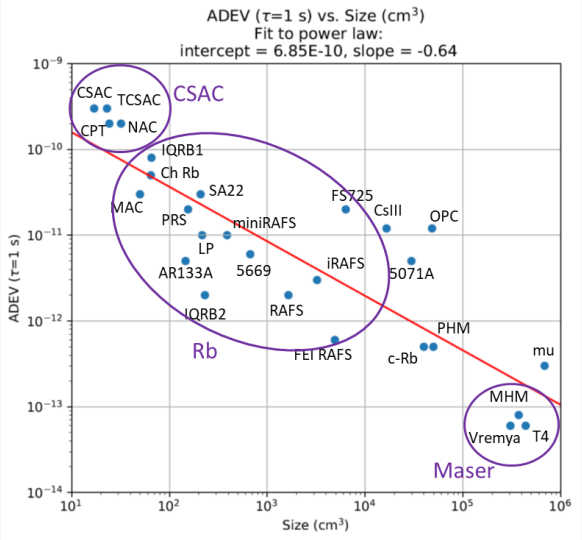
Highlights of this year's session

About clocks:

MITRE

- clock architecture is similar: a local oscillator is locked onto an atomic transition
  - Microwave clock uses quartz
  - Optical clock uses laser -> comb
- Emerging laser-cooled microwave atomic clocks
- Future optical clocks as products will have lower environmental sensitivities





Highlights of this year's session

DLR (German Aerospace Center)

- Kepler GNSS: satellites in MEO and LEO, only one ground monitoring station
- Optical interlinks between LEO/MEO satellites achieve synchronization to Kepler Time without ground segment
- L-band broadcast to Earth
- Onboard clocks only on LEO, cavity stabilized lasers on all satellites;
- LEO launch 2023, MEO launch 2025

Royal Observatory of Belgium

- ICG proposed unifying xyTO dissemination by using a common reference
  - prediction of UTC or average of GNSS times?
  - Broadcast or computed?
- High-precision receivers (<5ns) need to estimate xyTO even with only 5 satellites in view
- Mass-market receivers (i.e. smartphones) (<20ns) broadcast value is ok, no need for a reference different from predicted UTC

MITRE

- Transition of resilient PNT from DoD to Civilian users
- Resilient behavior: Prevent, Detect, Report, Mitigate, Recover
- Detection and mitigation apply to design and user practices
- Resilient PNT Conformance Framework allows users and manufacturers to quantify performance

THANK YOU!