Report on GPS activities 2018

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NIST

Timing Subcommittee of the 58th CGSIC Meeting – Miami, FL

OUTLINE

GPS Time Transfer for Coordinated Universal Time (UTC)

Time Dissemination and Services via GPS

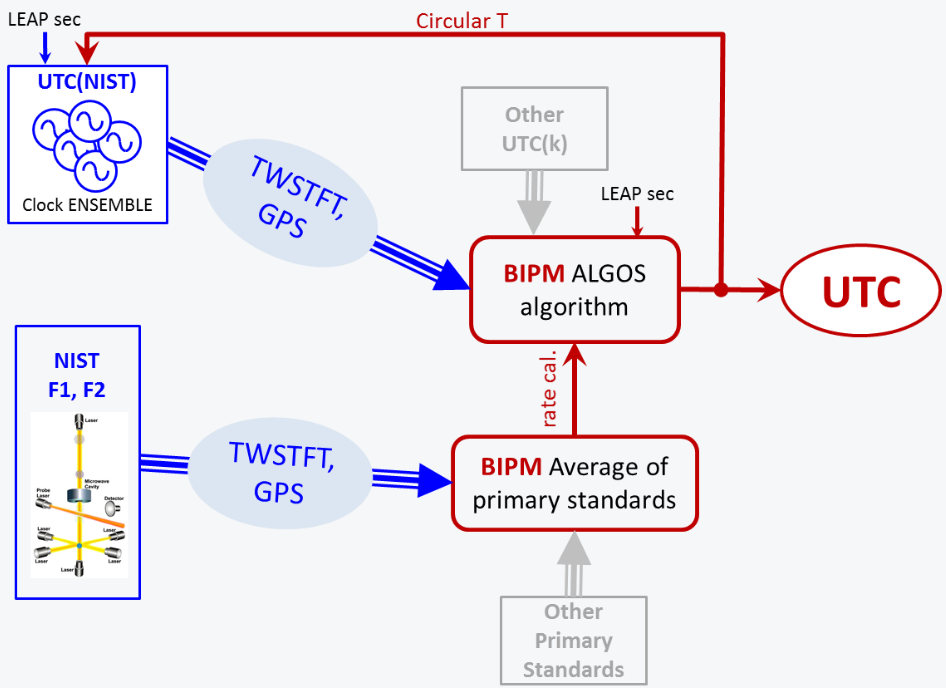
Science: comparing clocks and supporting ACES

A resilient timing infrastructure

UTC

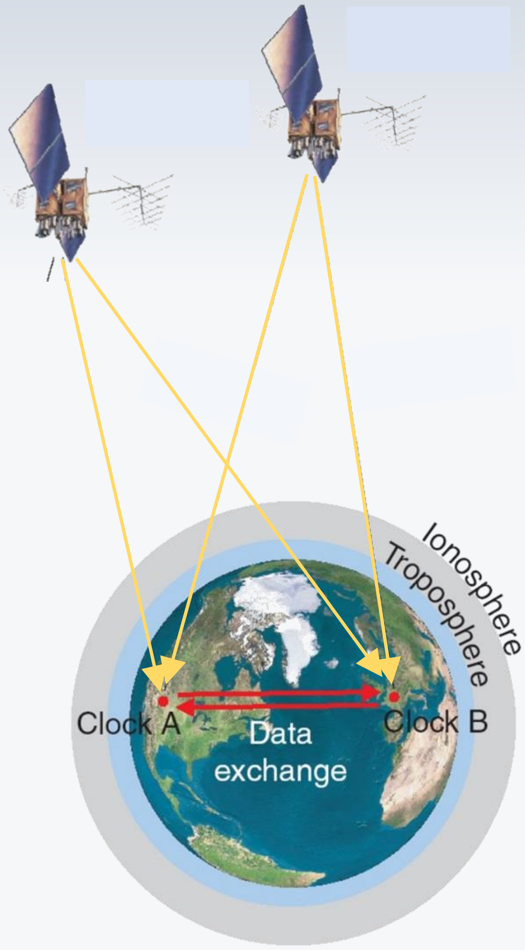
Coordinated Universal Time (**UTC**) is the official world time scale.

UTC is computed by the International Bureau of Weights and Measures (**BIPM**) in France.

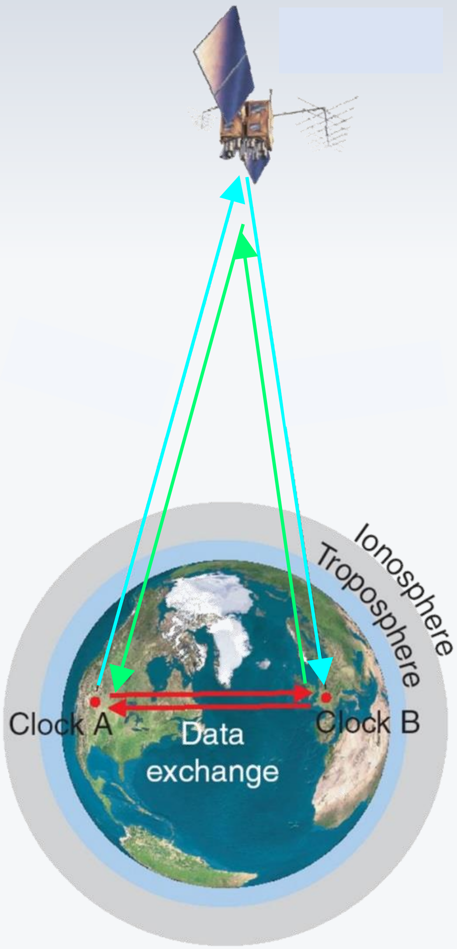


- **UTC(NIST)** is the local realization of UTC. The UTC(NIST) time scale consists of an ensemble of hydrogen masers and cesium clocks.
- NIST maintains and operates **UTC(NIST)** and the U. S. **Primary Frequency Standards**, cesium fountain devices F1 and F2.
- The time transfer links between NIST and BIPM are based on
  - Two-Way Satellite Time and Frequency Transfer (**TWSTFT**) measurements utilizing geostationary satellites.
  - **GPS** common-view measurements.

UTC



GPS Common-view



Two-Way Satellite Time and Frequency Transfer

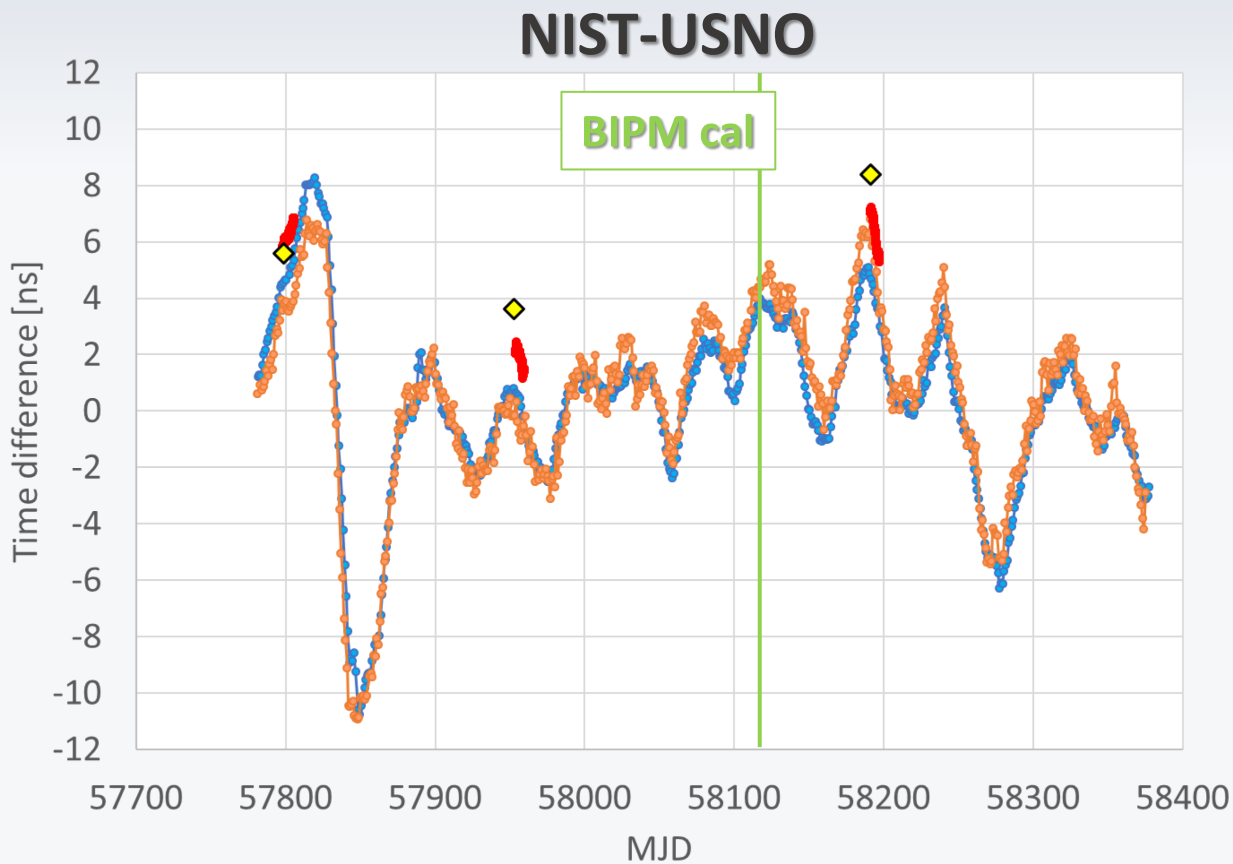
UTC

USNO shares with NIST the responsibility of maintaining accurate realizations of UTC in the US

GPS: common-view

TWSTFT: Indirect satellite link going through PTB

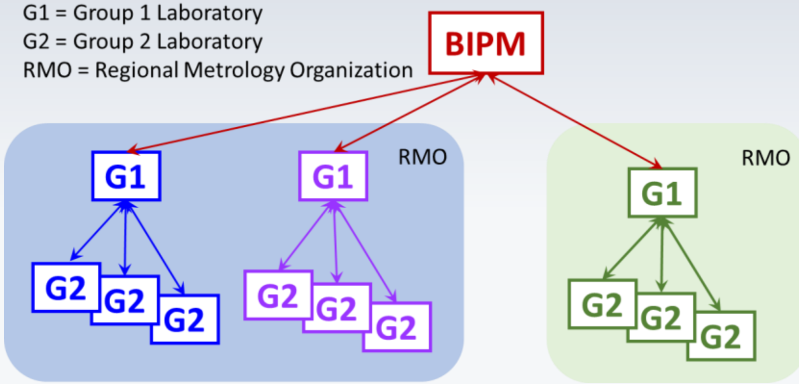
SUV: TWSTFT mobile station owned by USNO, periodically driven to NIST in Boulder, CO



GPS with SUV cal: common-view calibration

UTC

BIPM issued updated Calibration Guidelines for all laboratories contributing to UTC



NIST (Boulder, CO, USA)
CNM (Queretaro, MEXICO)
CNMP (PANAMA)
INTI (Buenos Aires, ARGENTINA)
INXE (Rio de Janeiro, BRAZIL)
NRC (Ottawa, CANADA)
ONRJ (Rio de Janeiro, BRAZIL)
INM (Bogota, COLOMBIA)
INCP (Lima, PERU)

USNO (Washington, DC, USA)
APL (Laurel, MD, USA)
IGNA (Buenos Aires, ARGENTINA)
NRL (Washington, DC, USA)
ONBA (Buenos Aires, ARGENTINA)

DISSEMINATION

TMAS FMAS NISTDO

- NIST provides common-view GPS measurement systems to its remote customers, allowing them to compare their clocks to UTC(NIST) by using the GPS.

- The common-view data is processed in real-time and shows the time or frequency difference between UTC(NIST) and the customer's clock.

  FMAS: reports frequency uncertainty to the customer

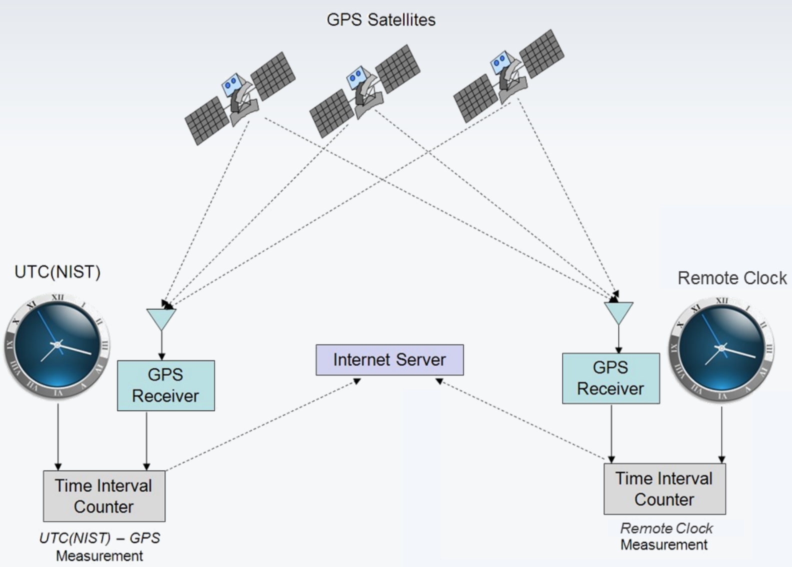
  TMAS: reports time uncertainty to the customer

  NISTDO: locks the customer's clock (rubidium or cesium) to the UTC(NIST)

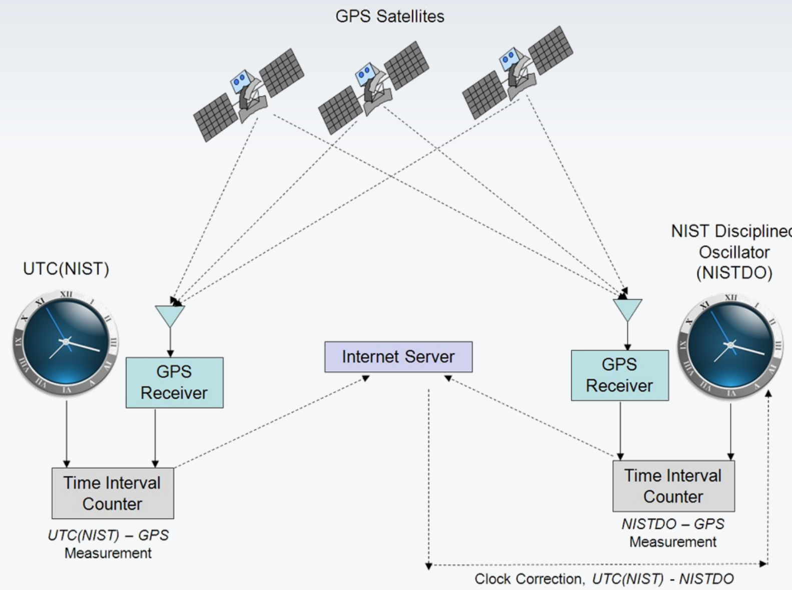
- Customers can then show traceability to the International System (SI) of units through NIST.

DISSEMINATION

GPS Common-view



TMAS and **FMAS**



NISTDO uncertainty
~5 × 10-14 at τ = 1 day for frequency
~10 ns for time,
(k = 2)

DISSEMINATION

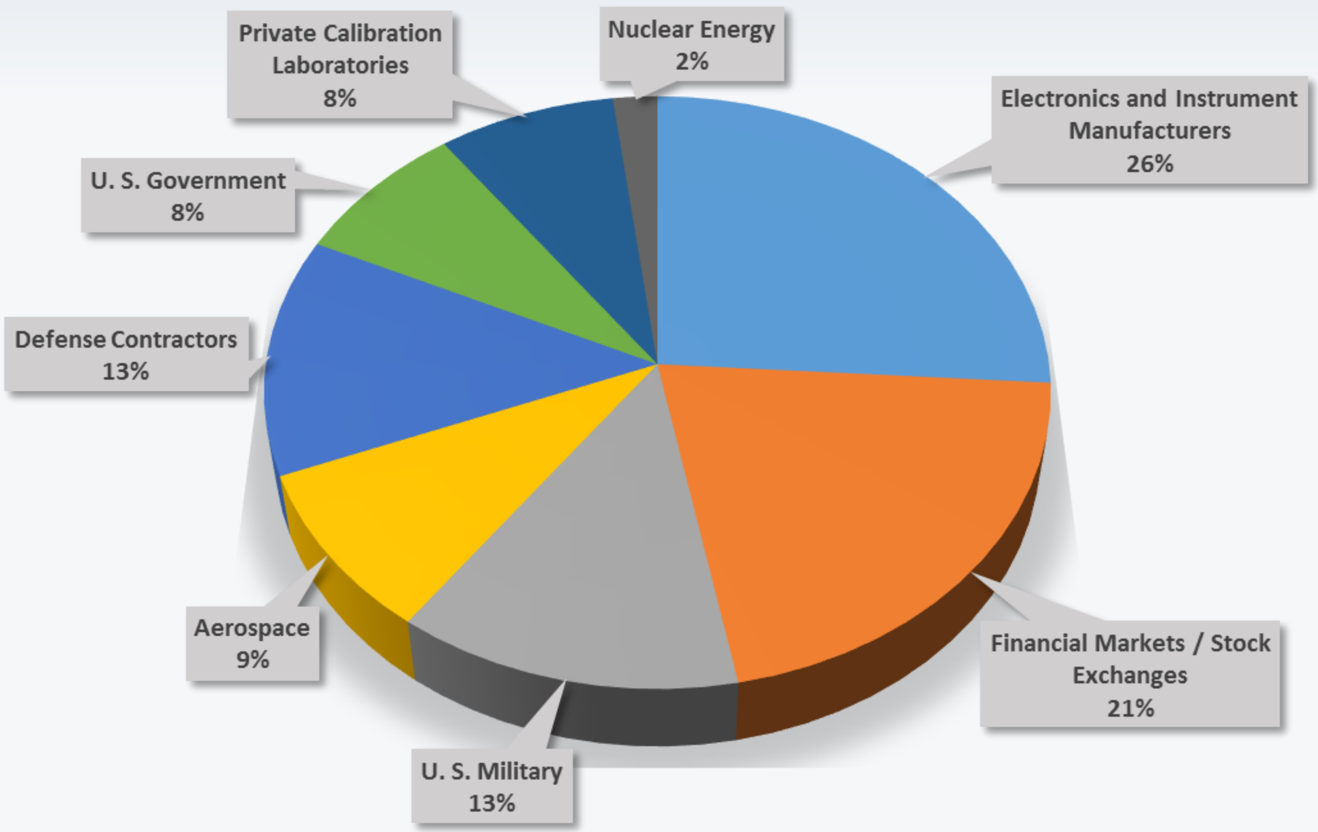
Map of Common-View GPS Systems Maintained by NIST

(78 total systems deployed, 53 at customer sites and 25 in SIM Time Network)

DISSEMINATION

NIST remote time and frequency dissemination

Customers by sector



DISSEMINATION

- International GNSS Service (IGS) Tracking Network

  Receiver NIST is an active station https://igscb.jpl.nasa.gov/network/site/nist.html

- NIST data archives:
  - One-way GPS data vs UTC(NIST)
    http://www.nist.gov/pml/div688/grp40/gpsarchive.cfm
  - Common-view UTC(USNO)-UTC(NIST)
    http://www.nist.gov/pml/div688/grp50/nistusno.cfm
  - Monthly Bulletins http://www.nist.gov/pml/div688/grp50/TimeScales.cfm
  - SIM Time and Frequency Metrology Working Group http://tf.nist.gov/sim

TIMING INFRASTRUCTURE

The acknowledgment of vulnerabilities in the GPS signals has spurred a lot of activities on both the user side (power grid, telecom and finance) and the provider side (GPS receivers manufacturers and timing providers).

April 17th, 2018

Booze|Allen|Hamilton
Washington, D.C.

June 22nd, 2018

Co-located with WSTS
San Jose, CA

TIMING INFRASTRUCTURE

GNSS Stationary Timing Receiver Resilience Workshop

RECOMMENDATIONS

To the US Government:

1. Establish Assured PNT Program for America's CI
2. Monitor spectrum (see EU Strike3), publish reports and recommendations
3. Promote development & use of PNT maturity model by industries/sectors
4. Enforce against violations of the spectrum: jamming and spoofing

To Standards Organizations:

1. Define resilience (metrics and language) and how to test for it
2. Define standard way of detecting threats, validating receivers resilience
3. Promote the development of a procurement language relating to resilience

To User Industries:

1. Adopt an Organizational Maturity Model: identify system's dependence on GNSS and create case studies to illustrate needs.
2. Adopt a common procurement language
3. Monitor for problems and impacts and report, leveraging user base in collaboration with Government to support spectrum protection
4. Use alternative timing sources

TIMING INFRASTRUCTURE

Assured Access to Accurate Time Workshop

- Provide a common venue for US Government, users and time providers
  - Define attributes and metrics for assured and accurate time

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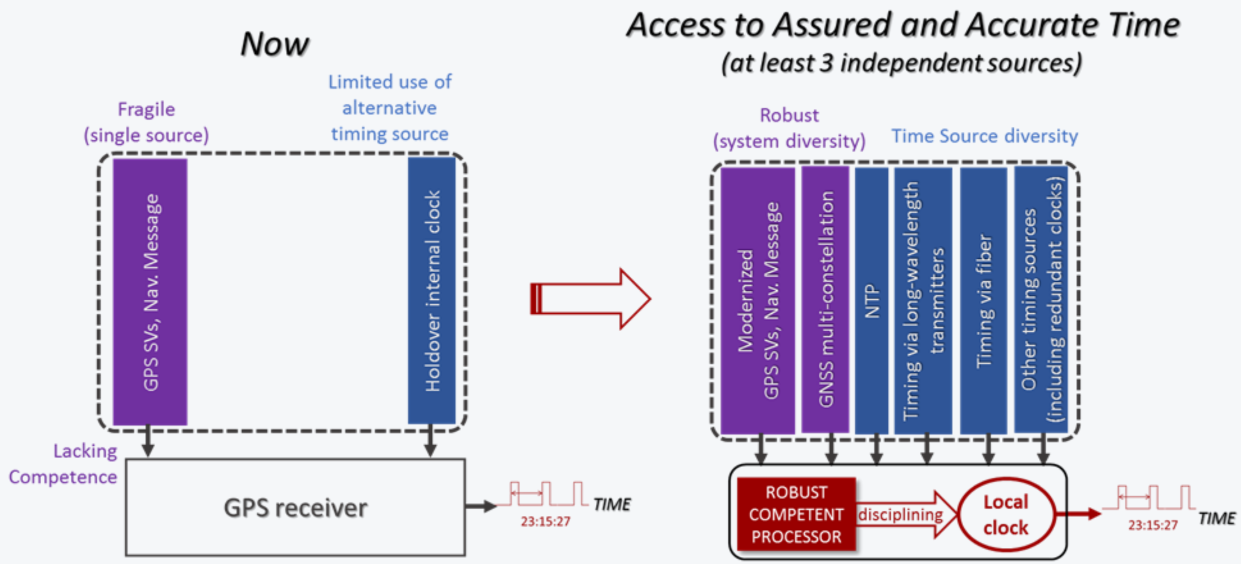
FRAMING THE PROBLEM



NIST
The MITRE Corporation

TIMING INFRASTRUCTURE

Assured Access to Accurate Time Workshop

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  - Define attributes and metrics for assured and accurate time

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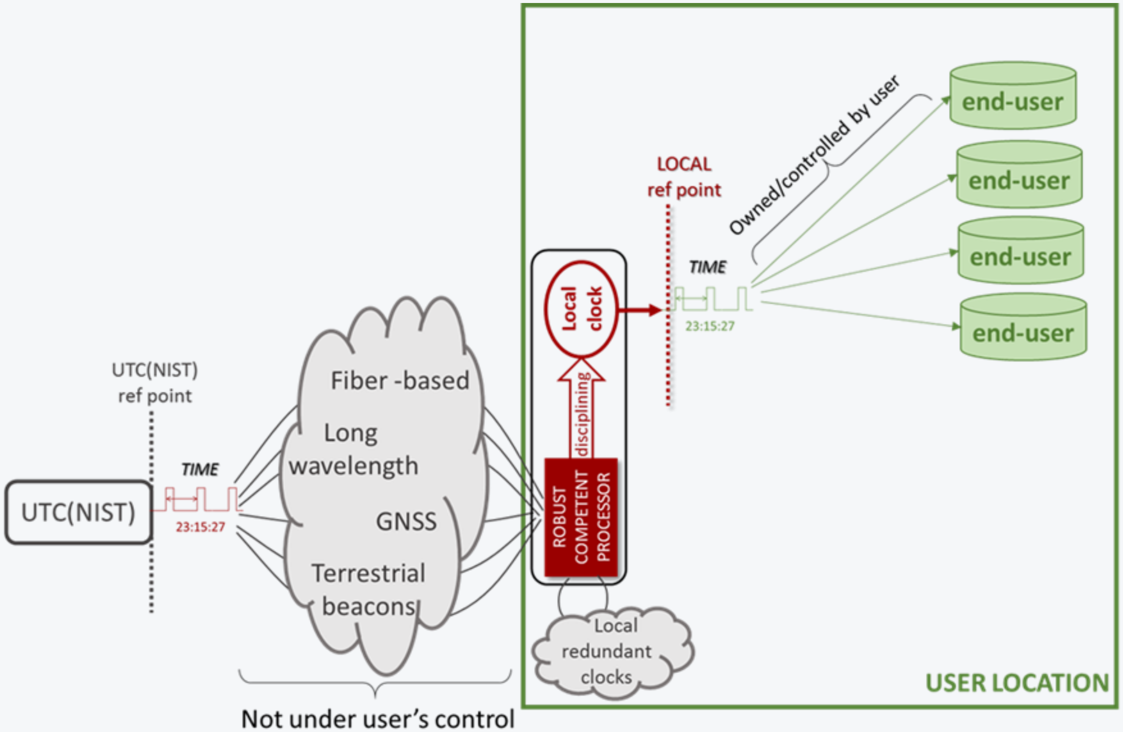

TIMING INFRASTRUCTURE

Assured Access to Accurate Time Workshop

TIME AT USER'S LOCATION

Accuracy
- determined by calibration to a known standard
- traditional statistical estimator may not be appropriate

Stability
- Statistical noise
- Long-term drifts (how often to calibrate)

Traceability

Assuredness
- Reliability
- Signal integrity
- Confidence (flag or statistical)

Availability
- “No signal is better than wrong signal”
- Geographical
- For both time delivered to user and to competent processor

Continuity
- Temporal availability (probability of delivery of assured signal over time)
- Holdover

COMPETENT PROCESSOR

Processor’s health
- Exceeds RAIM

Number of timing inputs
- >3 for diagnostic

Degrees of diversity of inputs
- All UTC, different deliveries

Use of corollary information
- Well-surveyed antenna
- Frequent checks on frames
- Doppler information
- Etc.

Graceful degradation
- Quantify the degradation as one or more inputs are compromised

Time to first time/recovery

TIMING INFRASTRUCTURE

Next steps:

- Continue as working group
- Quantify the attributes to derive metrics and performance bands
- Define reference architectures to be characterized
- Develop testing procedures and protocols

Assured Access to Accurate Time Workshop II

January 28th, 2019

Co-located with PTTI

Reston, VA

SCIENCE

Atomic Clock Ensemble in Space (ACES) mission support

Accurate position of the International Space Station (ISS) to allow for the best frequency transfer between ground stations and ISS.

Test of Local Position Invariance principle

Using long-term (14 years) comparison of remote clocks (H masers and Cs fountains), via UTC.

x5 better than previous effort in 2007.

ARTICLES

https://doi.org/10.1038/s41567-018-0156-2

nature physics

A null test of general relativity based on a long-term comparison of atomic transition frequencies

Neil Ashby[1,2], Thomas E. Parker[1] and Bijunath R. Patla[1*]

The next improvement will use optical clocks

PEOPLE

Atomic Standards
S. Römisch – Leader
T. Parker
B. Patla
V. Zhang

Time and Frequency Services
J. Lowe – Leader
M. Deutch, WWV/WWVB
M. Lombardi
A. Novick
D. Okayama, WWVH

Primary Frequency Standards
S. Jefferts – Leader
A. Banducci
A. Radnaev
N. Ashby
J. Shirley

Network Synchronization
J. Levine – Leader
J. Yao

THANK YOU!