NIST Digital Time Services

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Outline

- UTC, UTC(lab)
- Traceability
- Baseline requirements
- Trade space
- NIST Services
- NPL Services
- Summary

Coordinated Universal Time (UTC)

- Paper time scale computed by the International Bureau of Weights and Measures (BIPM, Paris)
  - No physical clock realizes UTC
  - Not available in real time
- UTC(lab): physical time scale computed by timing laboratory and steered to UTC
  - UTC(NIST), UTC(USNO), UTC(NPL), …
  - UTC – UTC(lab) ~ few ns
    - Documented in BIPM Monthly Circular T

Time Traceability - 1

- An unbroken chain of measurements from the *end-user application* back to the national reference time scale
- Each link in the measurement chain characterized by time delay and uncertainty
- Ensuring adequate traceability is usually the responsibility of the end-user

Time Traceability - 2

- Why?
  - Comparison of events or data referenced to different sources of time
    - Forensic analyses
    - International time coordination
  - Legal requirements

Time Traceability - 3

- Log files and documentation
- Concerns:
  - Uncalibrated and unmonitored client hardware operation and path delay
    - Link between output of GPS receiver and UTC
  - Calibrating and documenting latency in link from time reference to application
  - Traceability if application is in the cloud
  - Log files document only errors and failures or totally absent

Baseline Requirements

- Full traceability documented and validated
  - Consistent with requirements of application
- Log files and indicators reviewed for proper operation
- Correct handling of leap seconds
  - Extra second inserted at correct time
    - following 23:59:59 UTC (not local time)
  - No Google "smear"

Traceability Metrics

- Traceability requires time *accuracy*
  - Stability measures (AVAR, TDEV, …) not sufficient
    - Not sensitive to offsets in time or frequency
- Traceability parameters not always stationary
  - Statistical (RMS) models may be misleading
- MTIE may give better insight
  - Necessary but not sufficient

Trade space

- Independent of navigation satellites
- Monitoring and validating strategy
  - Network requirements
  - External assessment
- Availability/Redundancy
- Holdover performance
  - Network requirements
- Time delay in establishing traceability
  - Important for GPS-based systems
- Recurring and non-recurring costs

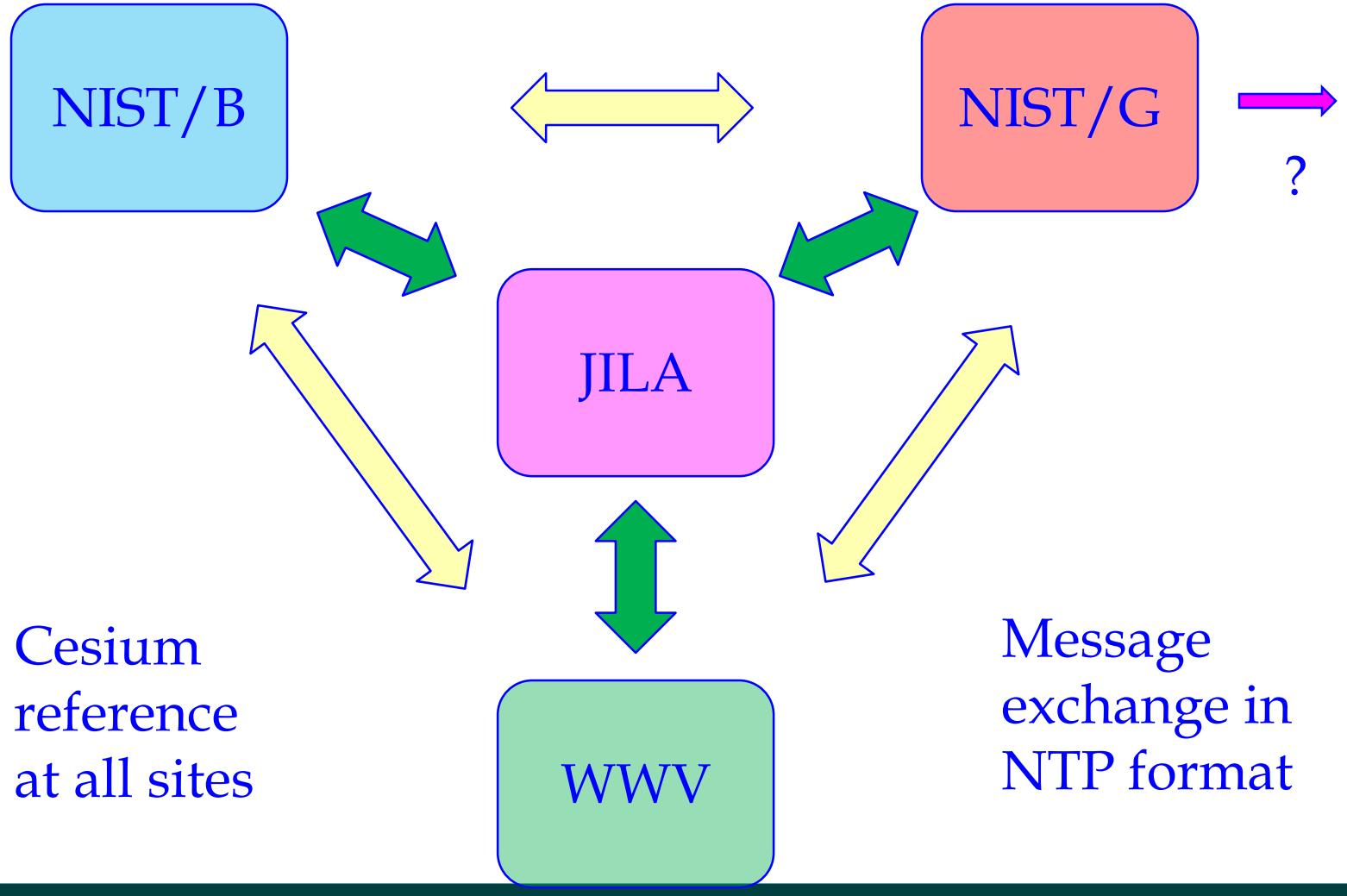
NIST Time Service - 1

- Multiple, independent sites, redundant hardware at every site
  - 4 sites, 19 systems
- Reference clock ensemble at every site
  - Almost completely independent of any external reference
  - *Maximum* time offset: ±50 ns w.r.t. UTC(NIST)
- Internal monitoring every 10 seconds
- External validation of traceability every 35 minutes

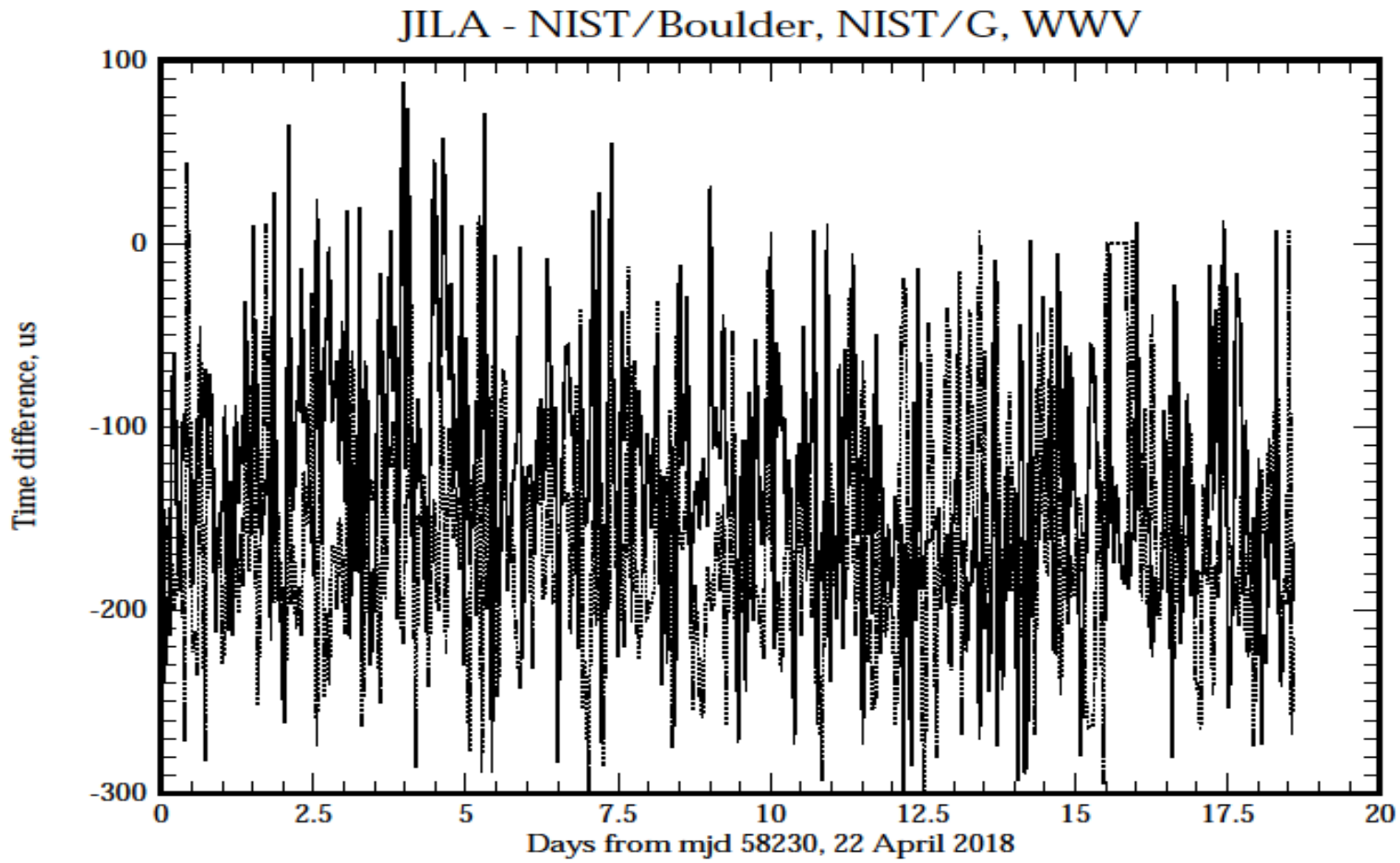
NIST Time service - 2

- 450,000 requests per second (mostly NTP format)
- 1145+ systems registered for authenticated NTP service
- (UT1 time in NTP format)
- Commercial hardware, open software
- Time accuracy at server about 1 μs
- User accuracy limited by symmetry of network delay

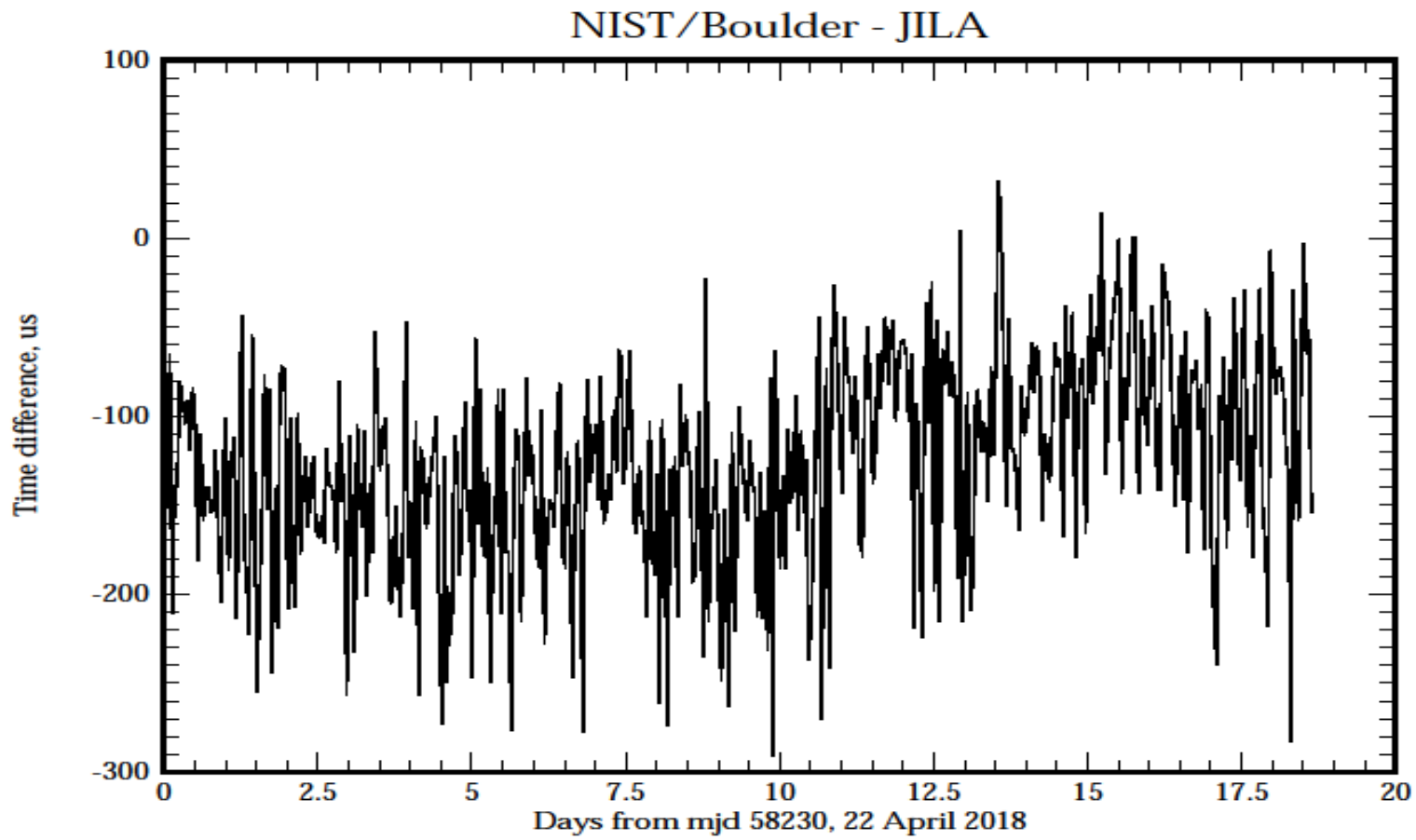
Comparing Sites - 1



Comparing Sites - 2



Comparing Sites -3



Static Time Offset

- Time accuracy about 150 μs
- Same offset in both directions
  - Independent of total path delay
  - Not consistent with network delay asymmetry
- Switching delay at Denver Main Switch?

NPL Time

- www.npl.co.uk
- Dedicated fiber circuit from Teddington to London Financial district
  - Supports legally-mandated traceability of time stamps for financial transactions
- Independent of GPS or other satellites systems
- Reference clocks at London end support holdover if fiber link fails
- Model for possible NIST stratum-1 service

Summary

- Documenting and validating full traceability is important
  - Traceability at user facility often inadequate
- Multiple parameter trade space
  - Cost, availability, holdover, accuracy, …
- NIST services realized with commercial hardware, atomic clock references
  - Accuracy limited by stability and symmetry of circuit delay
- NPL system realized with dedicated circuit with very stable delay