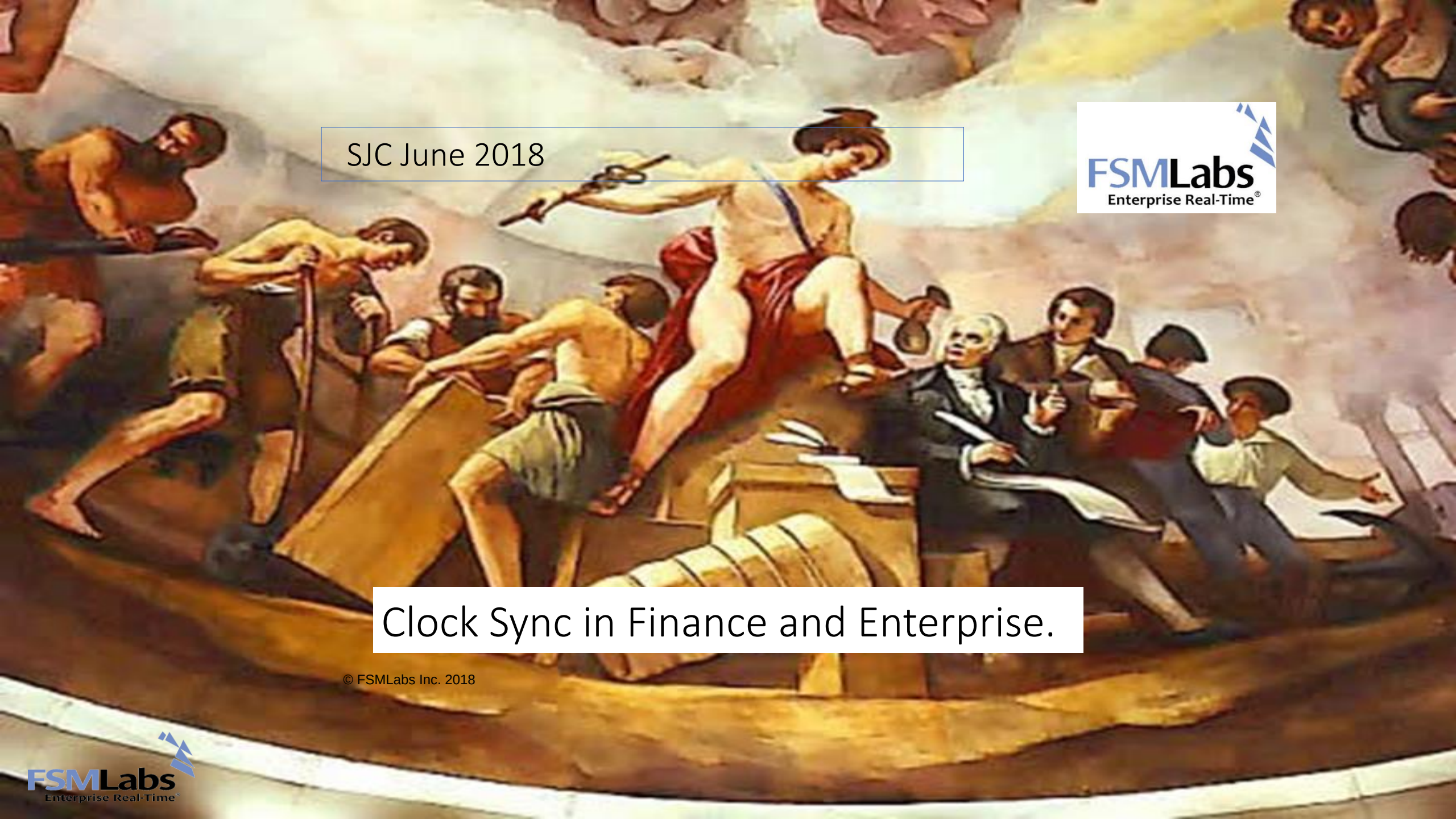

SJC June 2018

Clock Sync in Finance and Enterprise.

Outline of Talk

- Why is clock sync important in finance?
- What's the technology base.
- Challenges.
- Finance to wider enterprise.

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In finance, motivation is generally obvious

- So question becomes: how do you make money by synchronizing clocks?

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Basic fact: enormous volumes of electronic trading of financial assets

- NYSE is over 1 billion trades per day. Over a 12 hour day that' s, 50/microseconds per trade
- There are 19 exchanges world wide that have over $1 trillion in market cap
- There is an expanding universe of private trading venues

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Clock Sync is needed for finding patterns and correlations

- Market intelligence – if you cannot measure when trades take place and when information becomes available, you cannot successfully trade in electronic markets.

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To prevent fraud and SLA violations

- Front running
- Delayed trade information
- Delayed trade execution
- Inconsistent patterns
- Unexpected coincidences

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To avoid fines and worse

- Since 2008 financial crisis Regulators have been demanding more precise “business clocks” and proof of clock accuracy
- 100microseconds
- Pressure for more

esma European Securities and Markets Authority

FINRA Financial Industry Regulatory Authority

U.S. SECURITIES AND EXCHANGE COMMISSION

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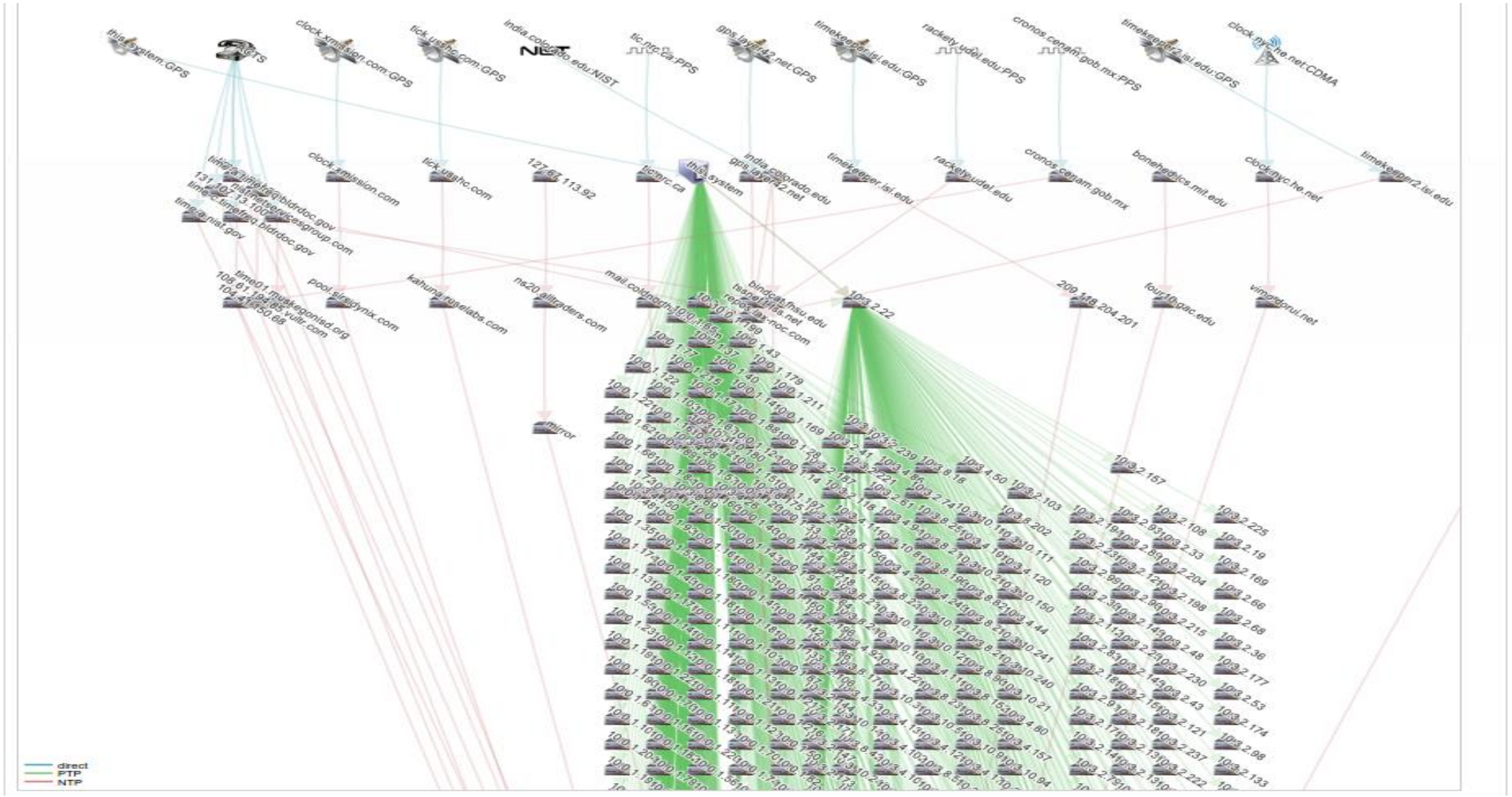
Technology landscape



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Technology landscape

Trading takes place mostly on commodity x86 Server Computers running Linux/Windows/Solaris.

- High processing power and lots of memory
- High speed networking – 10G, 40G, 25G, 100G, ….
- Less than stellar oscillators
- Very limited digital I/O
- Complex and changing configurations
- **Rapidly expanding number of Virtual Machines.**

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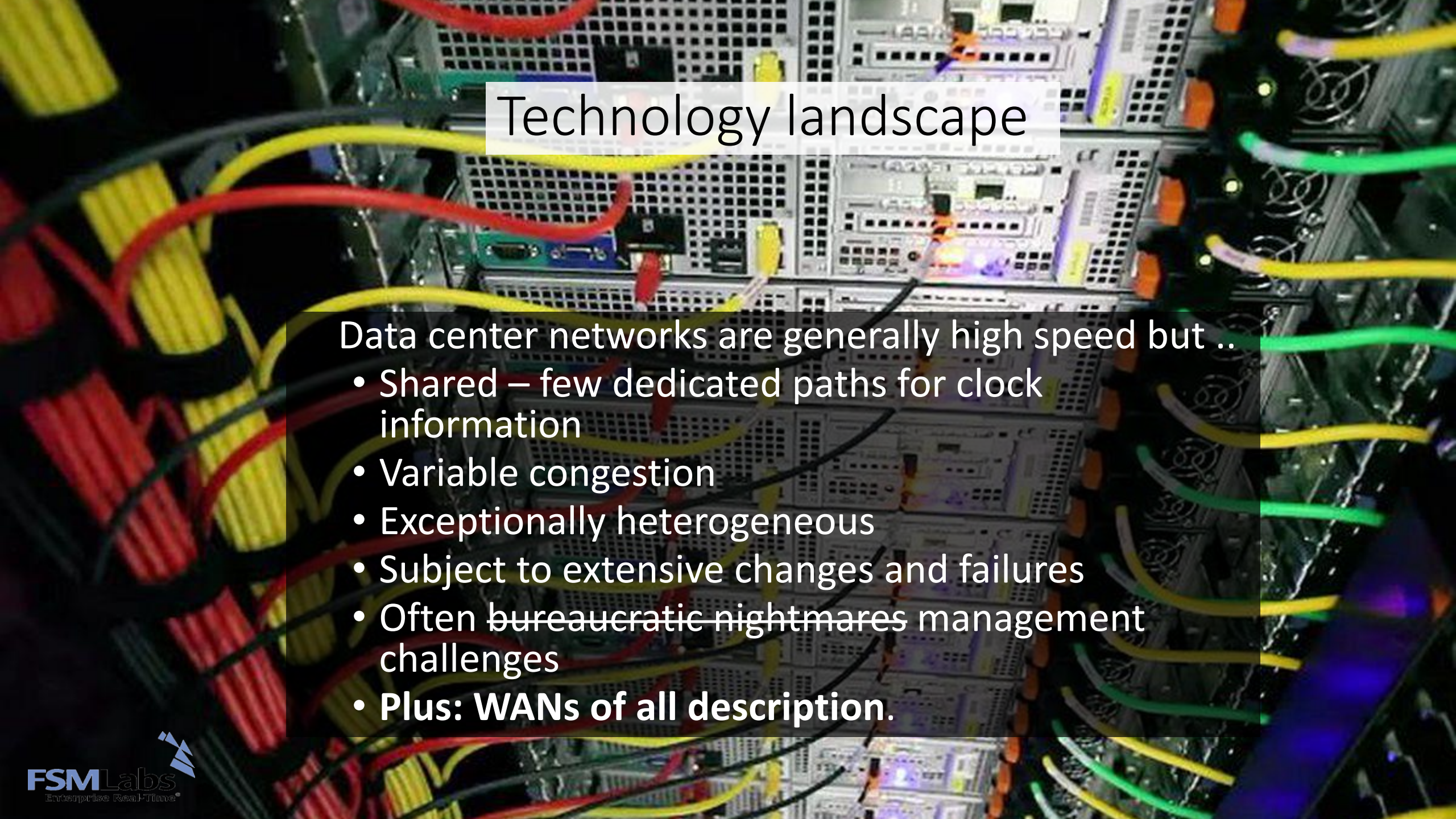

Technology landscape

Data center networks are generally high speed but ..

- Shared – few dedicated paths for clock information
- Variable congestion
- Exceptionally heterogeneous
- Subject to extensive changes and failures
- Often ~~bureaucratic nightmares~~ management challenges
- **Plus: WANs of all description**.

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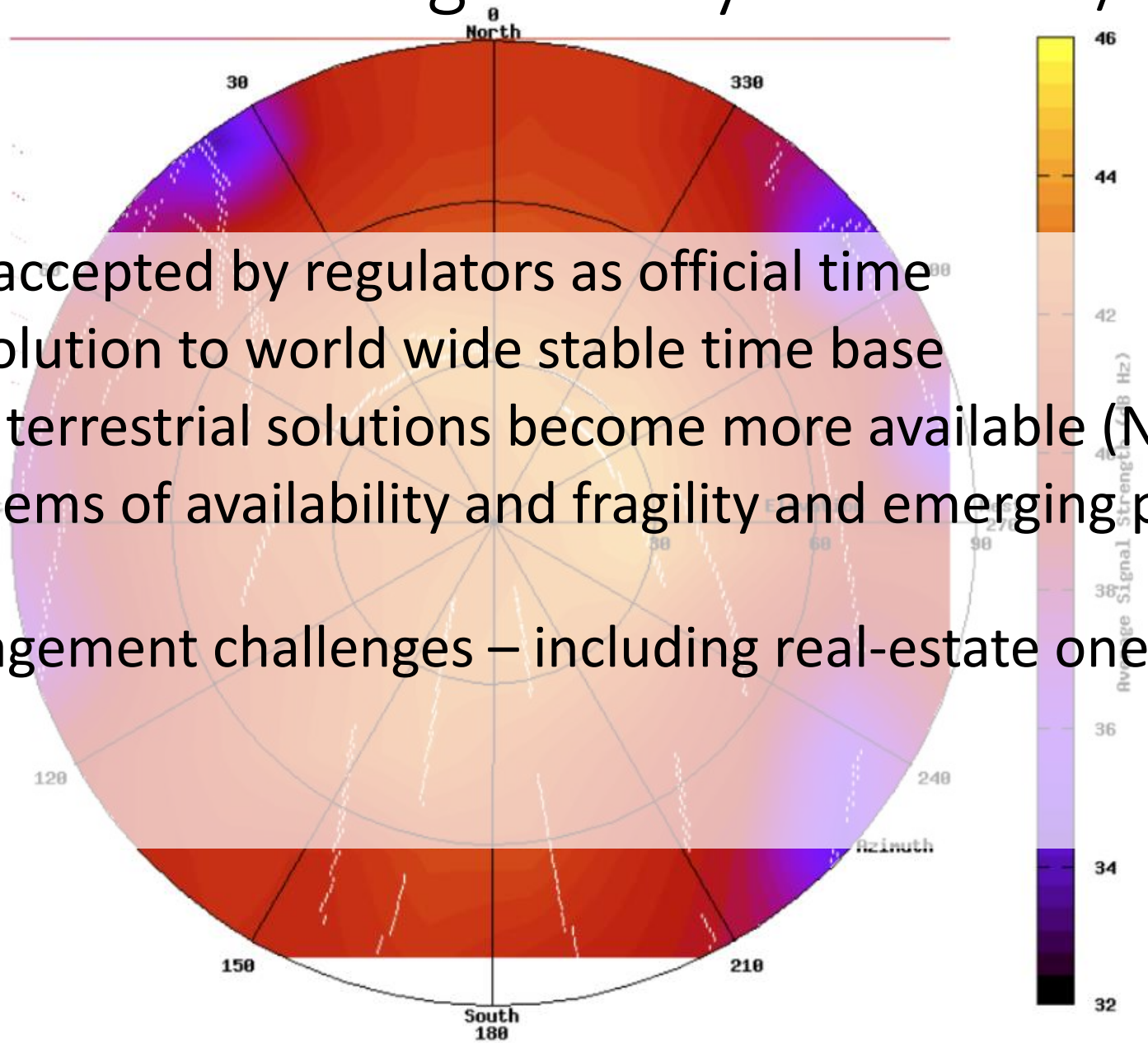
Authoritative time generally from GPS/GNSS



- GPS/GNSS accepted by regulators as official time
- GNSS is a solution to world wide stable time base
- Alternative terrestrial solutions become more available (NPLtime in UK …)
- Usual problems of availability and fragility and emerging problem of spoofing
- More management challenges – including real-estate ones

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Accuracy requirements for clients vary

- Regulatory requirement depends on regulator and uses: goes from 100microseconds (Mifid2 high speed, SEC CAT exchanges) to 1 millisecond, to 50milliseconds, to 1 second
- Business logic requirements can be significantly more stringent: down to 100-200 nanosecond level

Clock accuracy in the application program is the key measure.

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Time is distributed by NTP and/or PTP

Y axis is 90 nanoseconds to -30 nanoseconds
X axis is over a one hour duration

- Contrary to folk myth: ≈100 Nanosecond accuracy from NTP is possible
- High accuracy requires smart filtering and smoothing – even in response to temperature changes in the server

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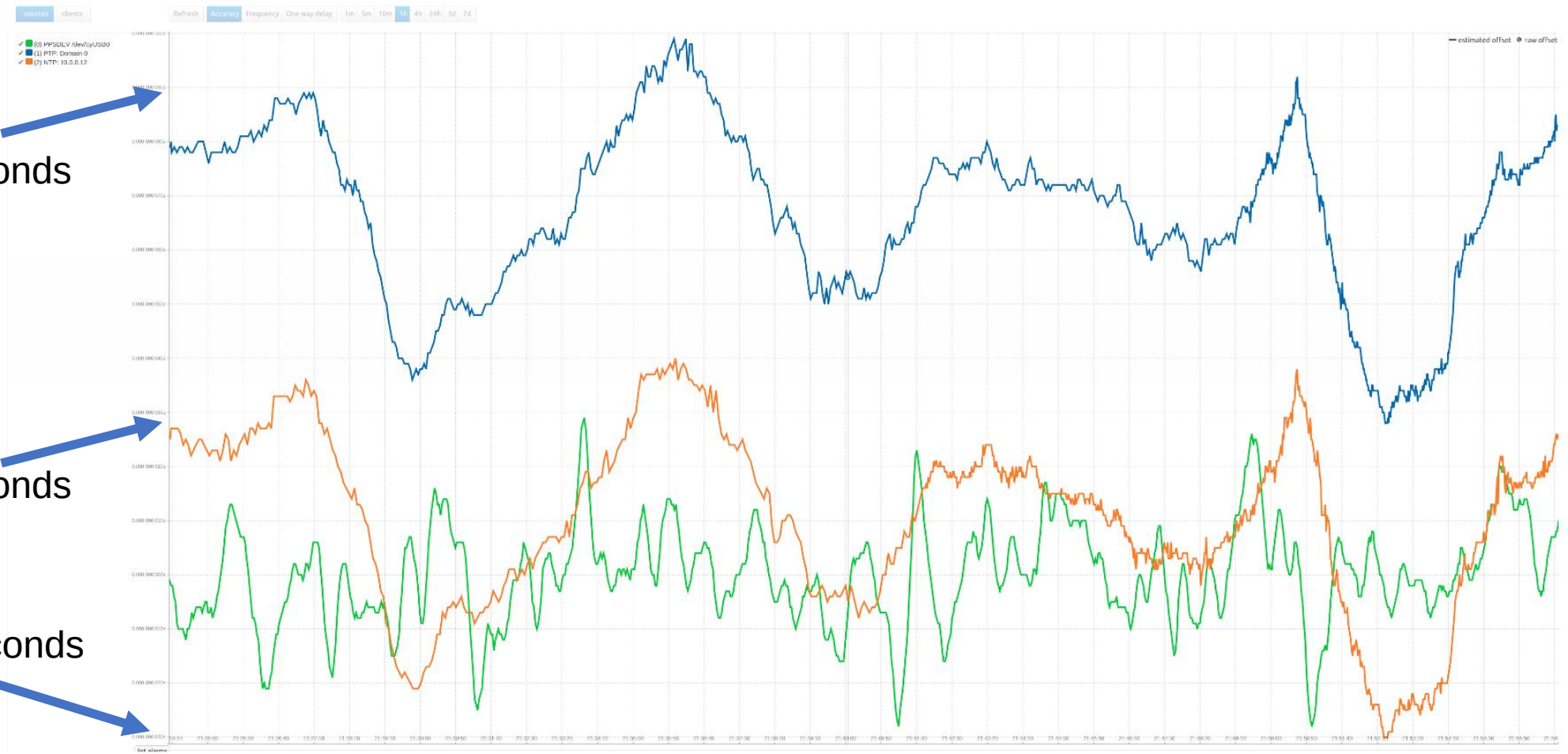
Example: GPS (green) PTP (blue) NTP (orange)



- For fault tolerance, multiple sources tracked in real-time over 1 hour

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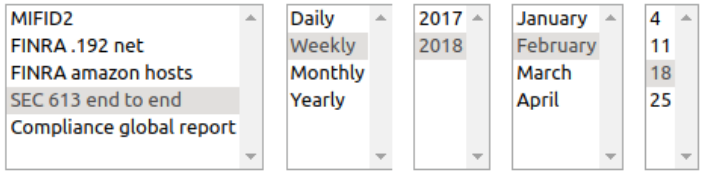
Record keeping is critical to meet regulatory requirements and to manage huge networks

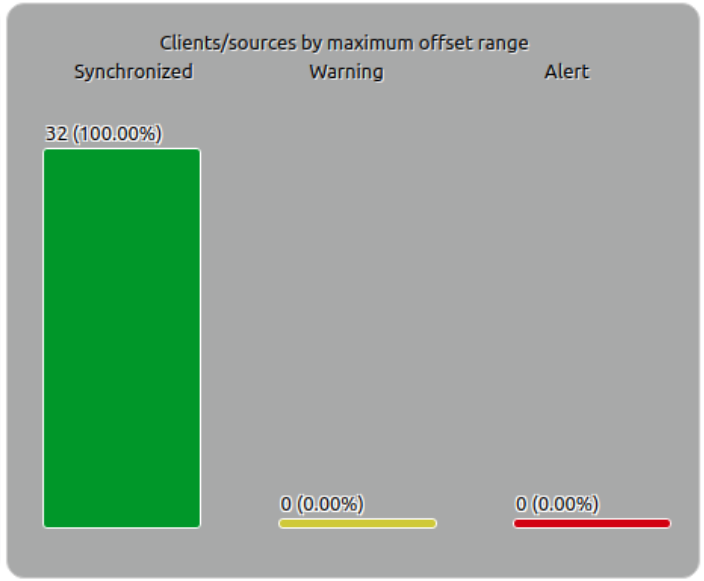
Example:
Database of clock sync data from network of clients/sources



Download weekly audit 'SEC 613 end to end (report 3)' for 2018-02-18

Synchronization report for 2018-02-18

Report start:	Sun, 18 Feb 2018 00:00:00 GMT (1518912000)
Report end:	Sun, 25 Feb 2018 00:00:00 GMT (1519516800)
Report title:	SEC 613 end to end (report 3)
Report type:	weekly
Client set:	*
End to end accuracy:	enabled
Min gap length:	180(s)
Warning threshold:	0.045 000 000
Min warning length:	0(s)
Time > warning:	0.00% client/source time in warning
Alert threshold:	0.050 000 000
Min alert length:	0(s)
Time > alert:	0.00% client/source time out of compliance



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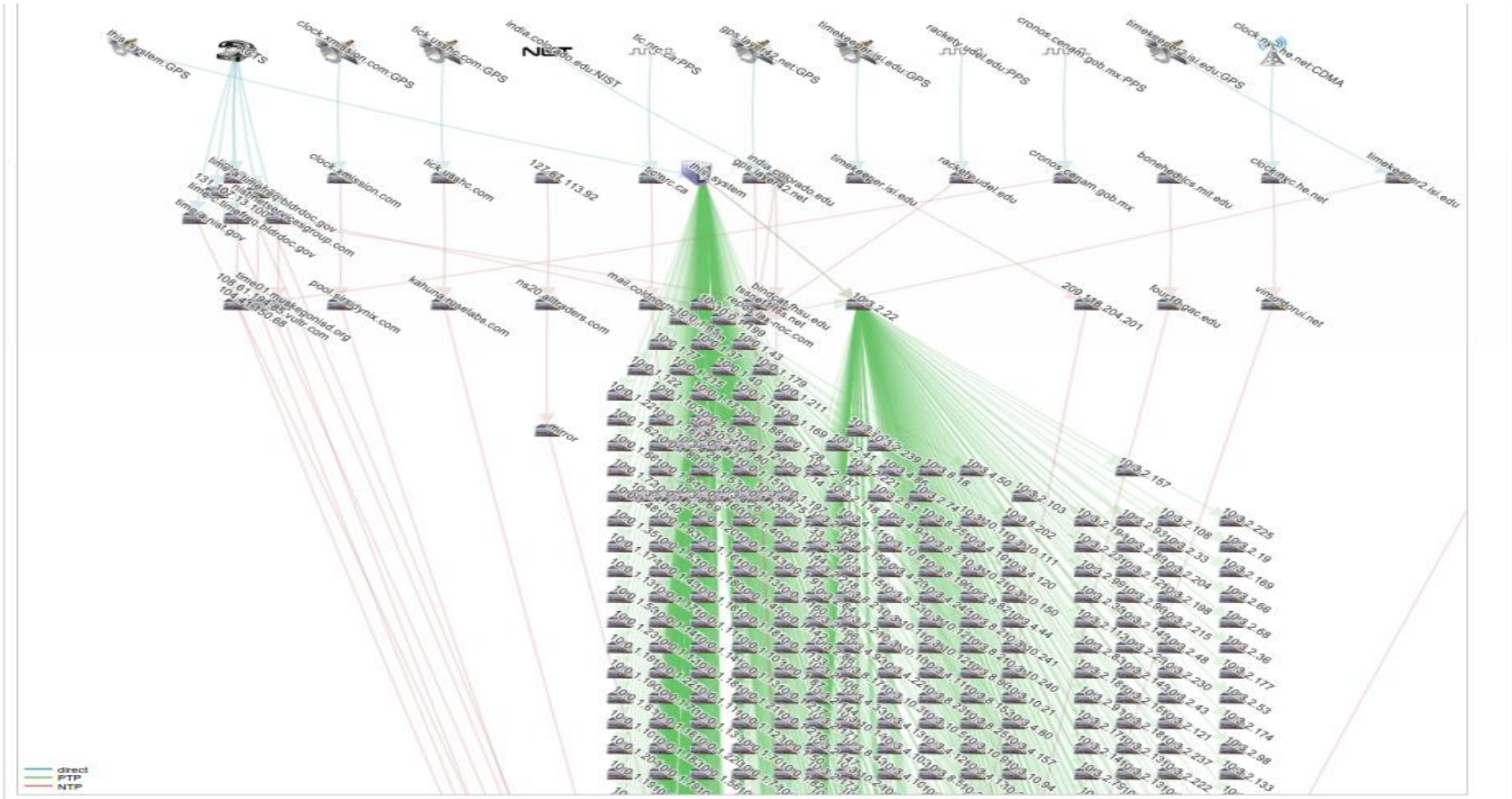
Managing these clock distribution networks is non-trivial

Green is PTP, red is NTP, blue is source



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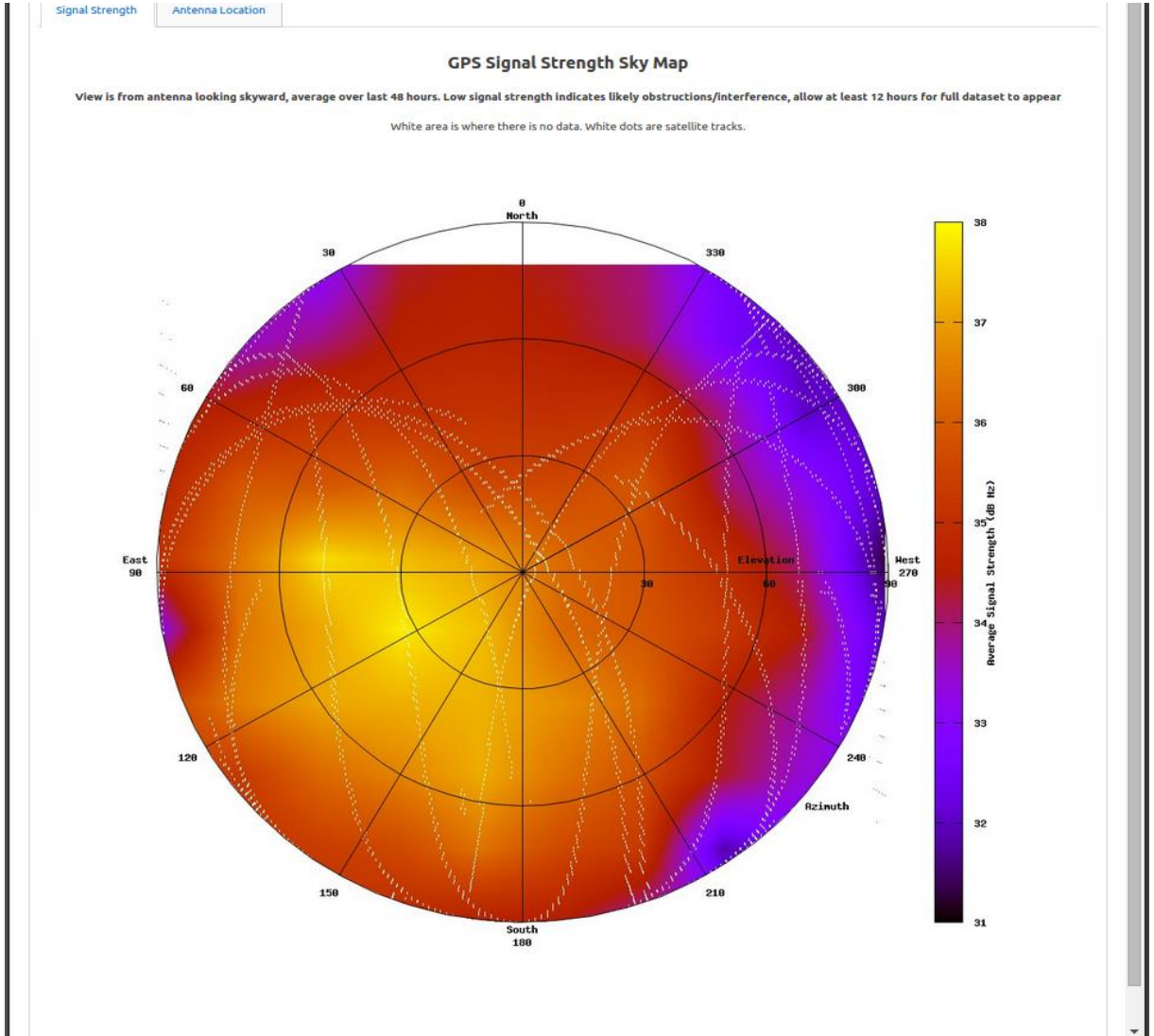
Diagnostics needed to help with GPS interference or jamming issues.

Build heat map from GPS signal data to show composite picture of signal strength. Purple areas show blocked reception.



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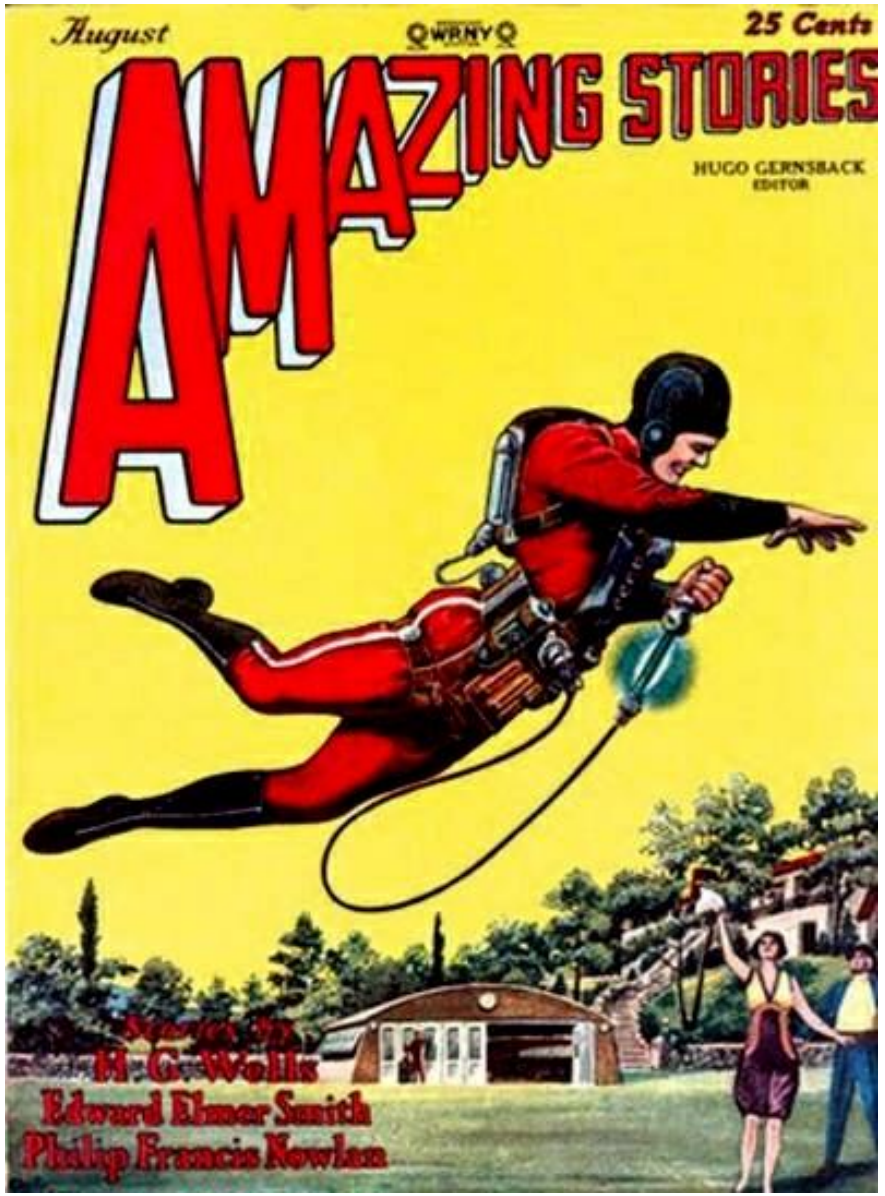
Future

- Transactions get faster so clock accuracy has to get better.
- More trading venues – more data to timestamp
- Huge databases of clock sync data to maintain and connect with trading data.



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Wider perspective: timestamp accuracy in finance is a solution to part of a more general problem of distributed system consistency

- Synchronizing “data” has been key topic in general computing for 50 years
- Traditionally solved by locking protocols and/or consensus prototols
- These can be prohibitively expensive at scale

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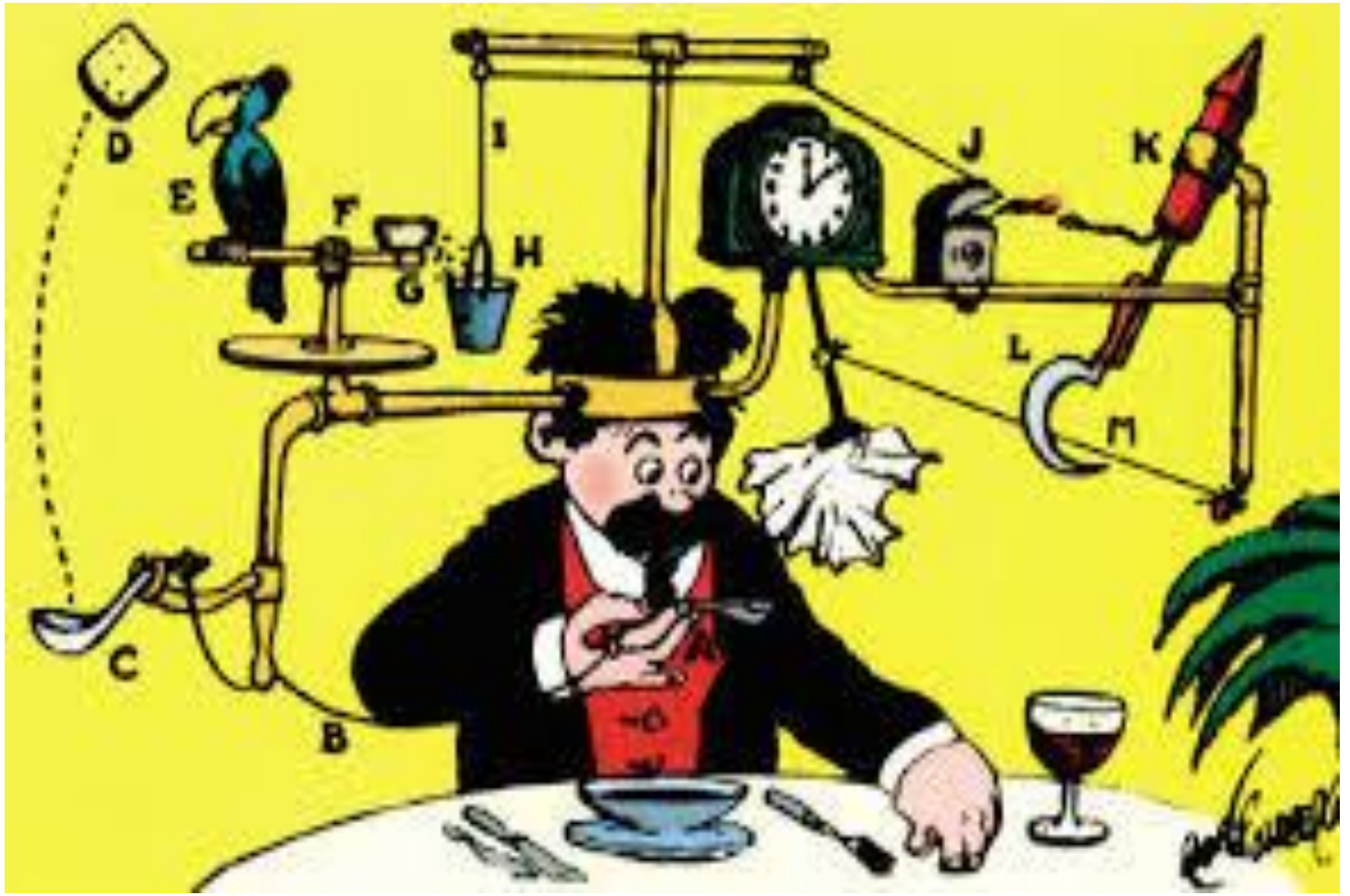
One problem is “coordinator election” and data consensus.

- Protocols like “Paxos” are widely used to make sure distributed databases remain consistent.



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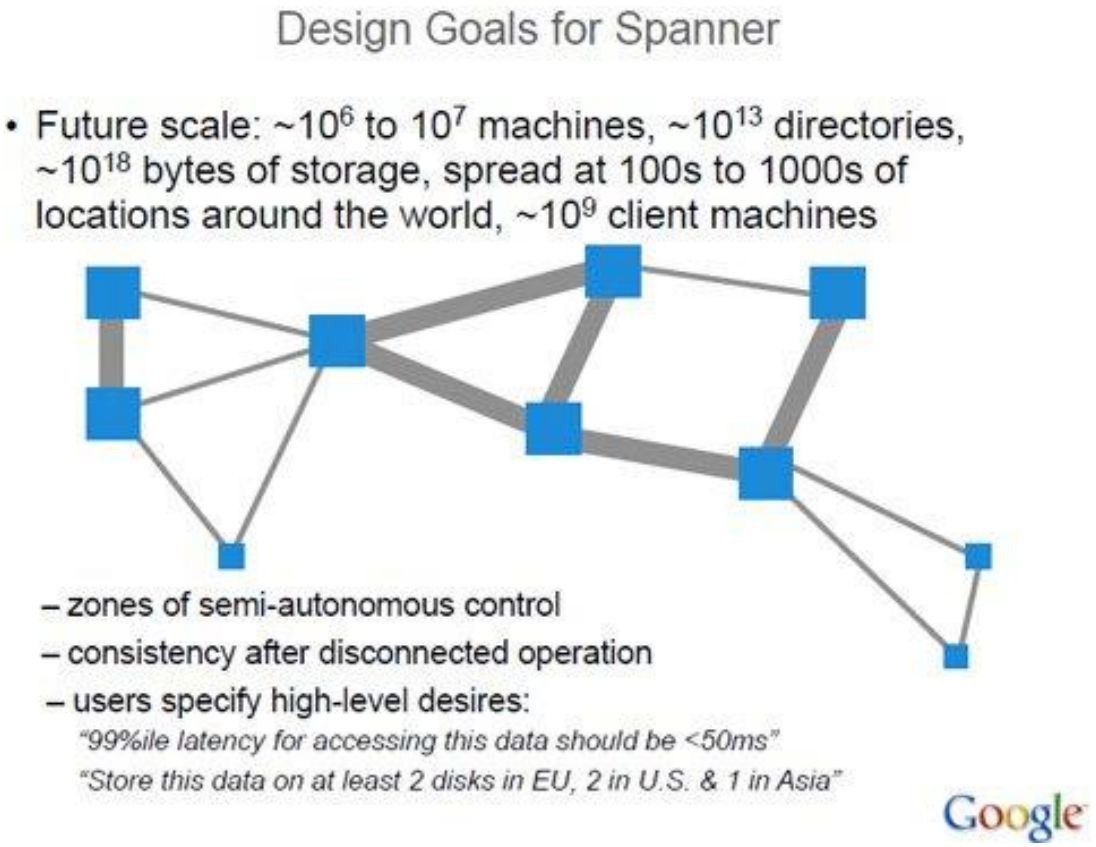
Recent rediscovery that synchronized clocks allow for major simplifications

- Google Spanner database relies on an underlying clock sync using a method similar to 1980s techniques
- Clocks are also used to manage congestion in large scale enterprise data centers



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So clock sync techniques developed for the big enterprise networks in finance are powering database consistency for general enterprise

Developments in general enterprise will, in turn, enable more sophisticated distributed trading systems to operate: increasing dependency on clock accuracy.

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- TimeKeeper Client Software
- TimeKeeper Server Software
- TimeKeeper Compliance Software
- TimeKeeper GrandMaster Gen 2

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