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Title:	Comparison of various clocks at the ~~Los Alamos National Laboratory Portable Pulser~~ Facility LANL LAPP
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Form 836 (7/06)

Comparison of various clocks at LANL LAPP Facility

Presented at SSRP, PAFB, Nov 2-4, 2010

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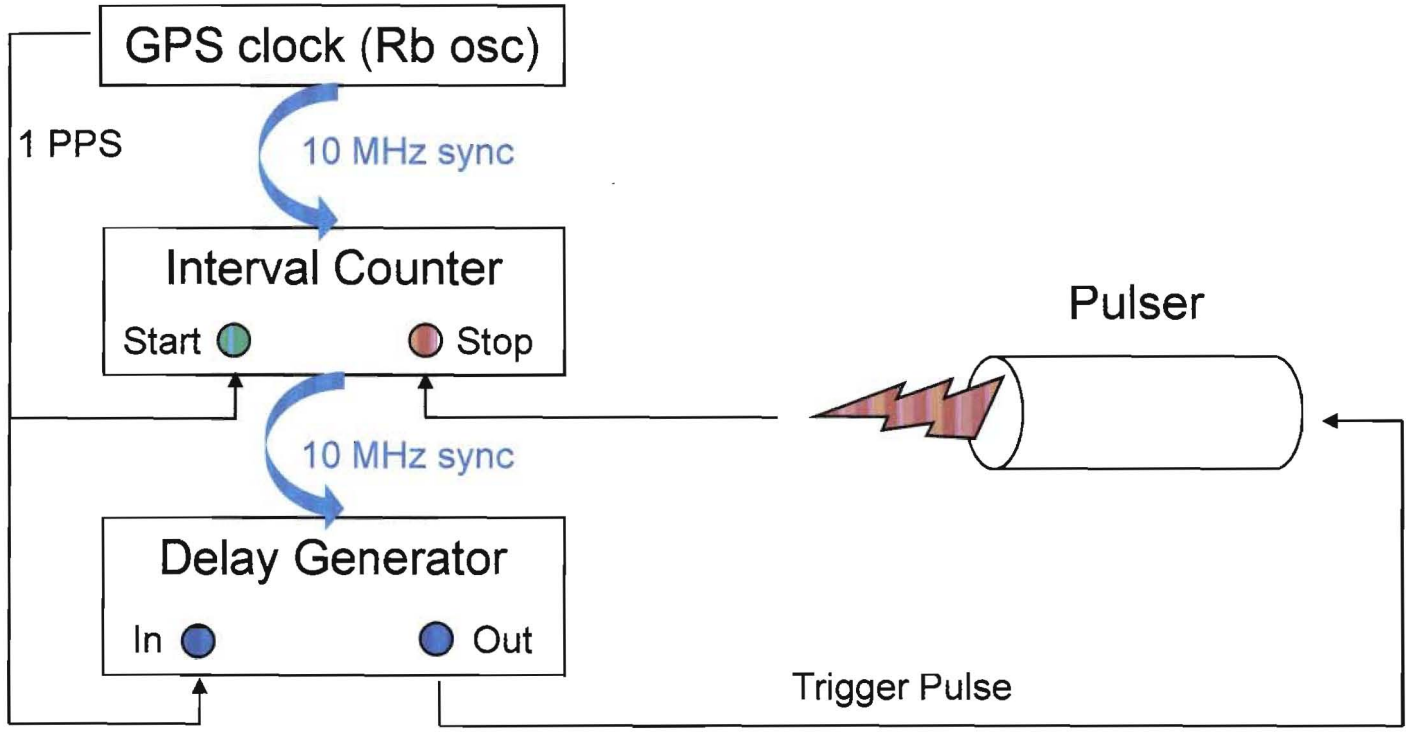
LA - UR – XXXX-XXX

Motivation for conducting this study

Quarterly LAZAP/RZAP Ops:

- SLREs with values of xxx +/- yyy sec are routinely observed
- 'Jump' in SLREs observed in 2005
- Question: can these 'jumps' be attributed to change in operational LAPP clock?
- Characterize the stability of the Operational clocks

LAPP / NDS timing system is well-characterized

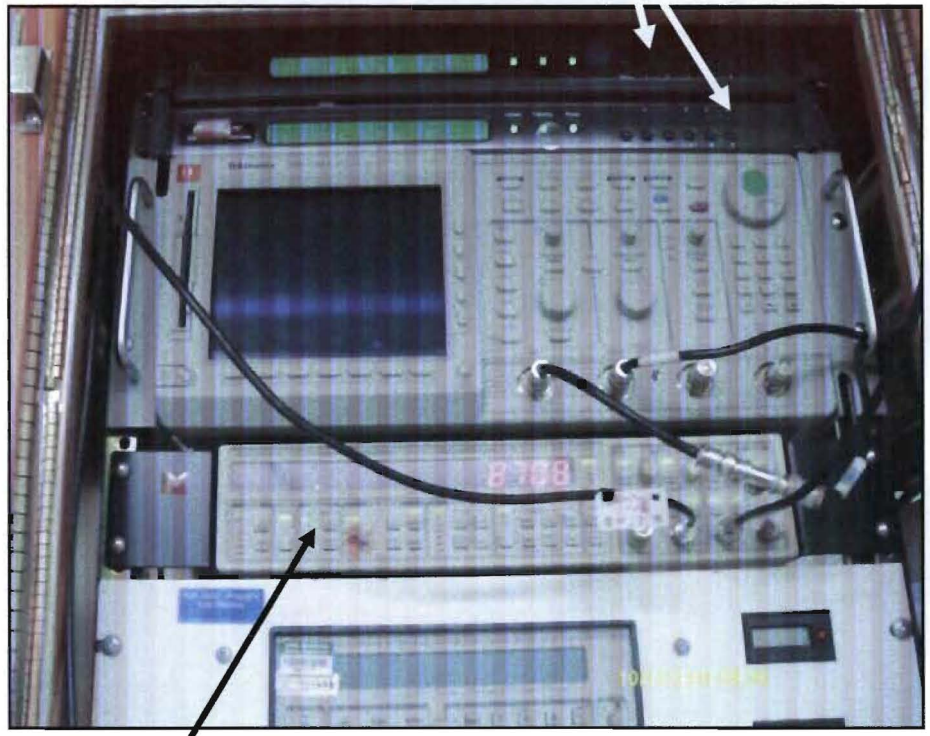


LAPP / NDS timing system: 2005- 2010

TSC 4400 Rb clock

Delay Generator

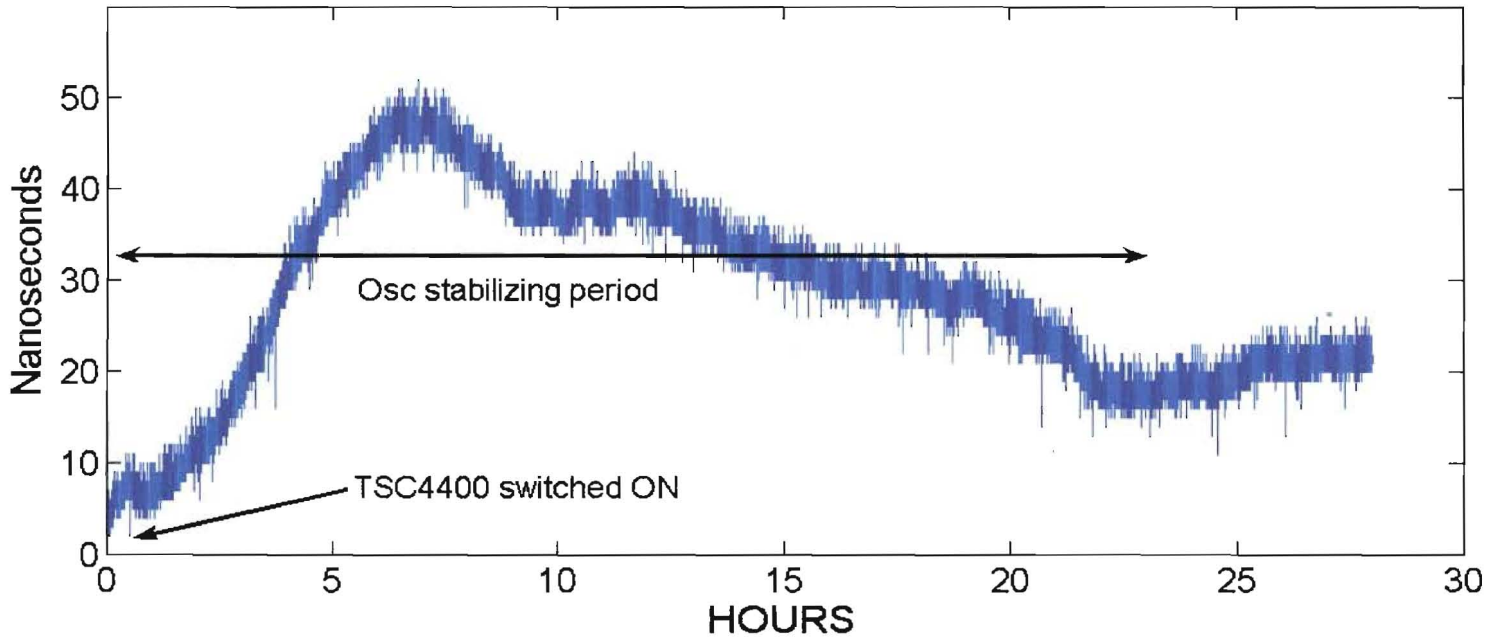
2 Datum ET6000 Rb clocks



Time Interval Counter

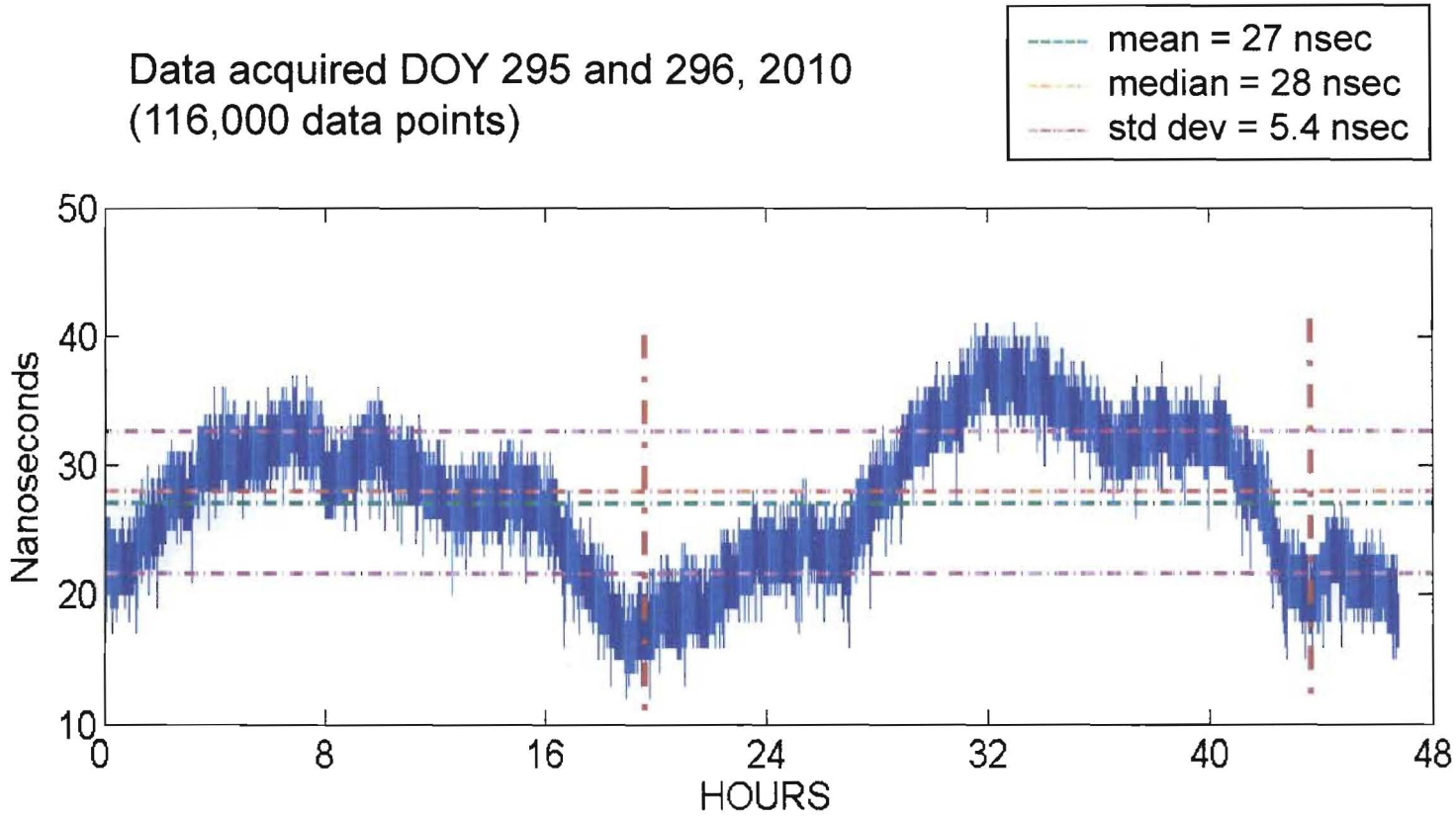
Comparison of TSC4400 and Operational LAPP clock

Data acquired on DOY 291, 2010
(76,000 data points)



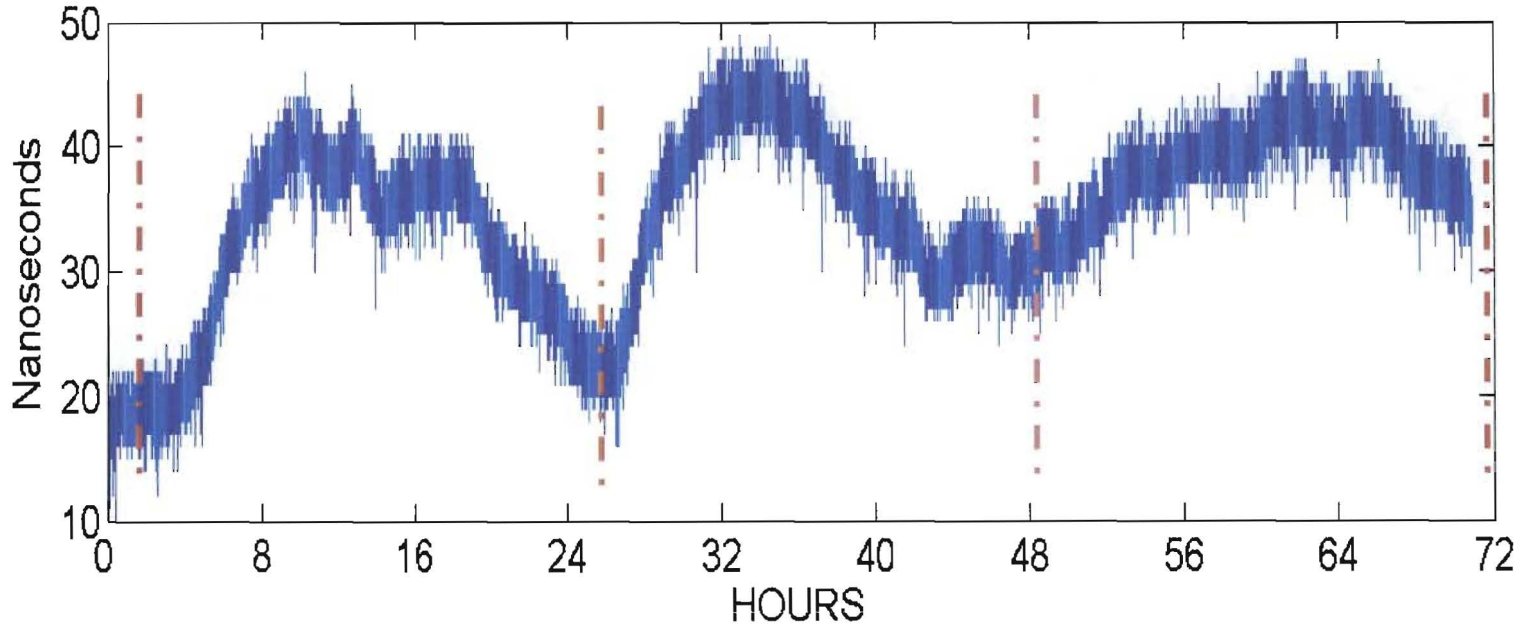
Today's Operational clocks show variation of ~ 27 nsec

Data acquired DOY 295 and 296, 2010
(116,000 data points)

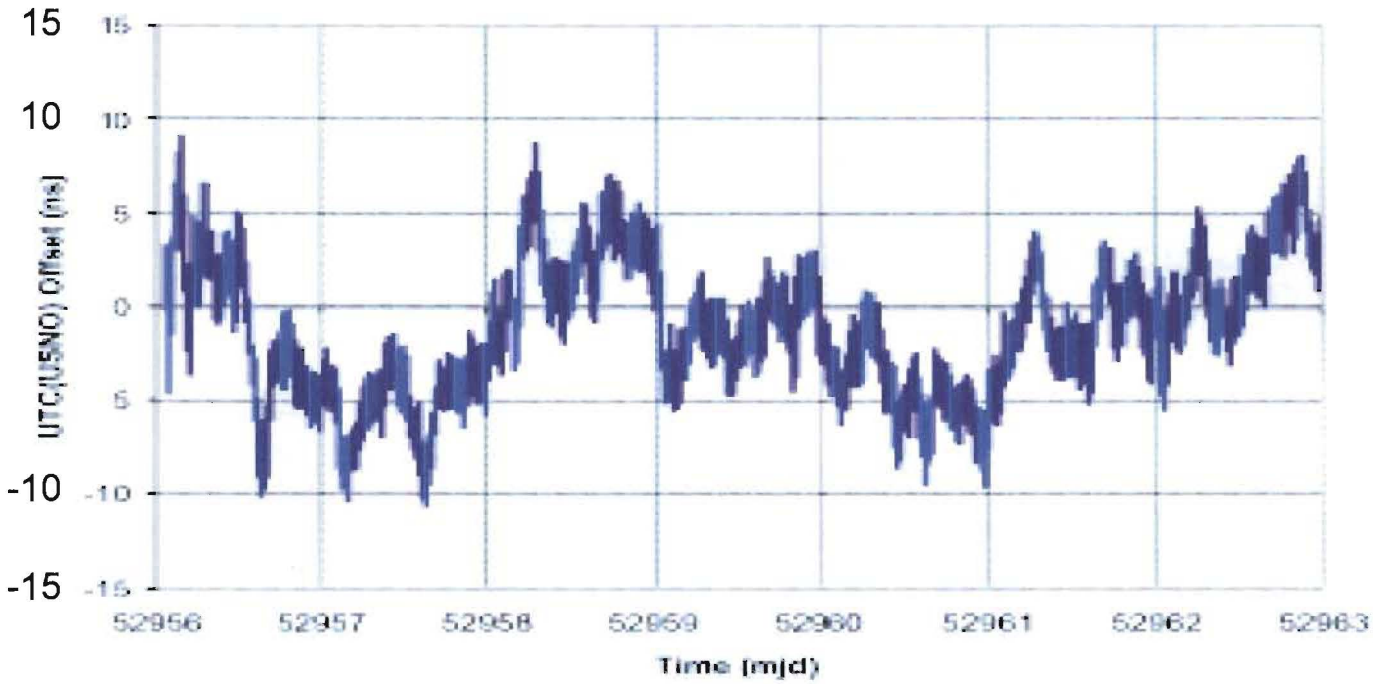


Another (longer) data set

Data acquired DOY 297, 298 and 299, 2010
(177,000 data points)



TSC4400 specs - from manufacturer's datasheet



Factors that limit the accuracy of ANY timing system

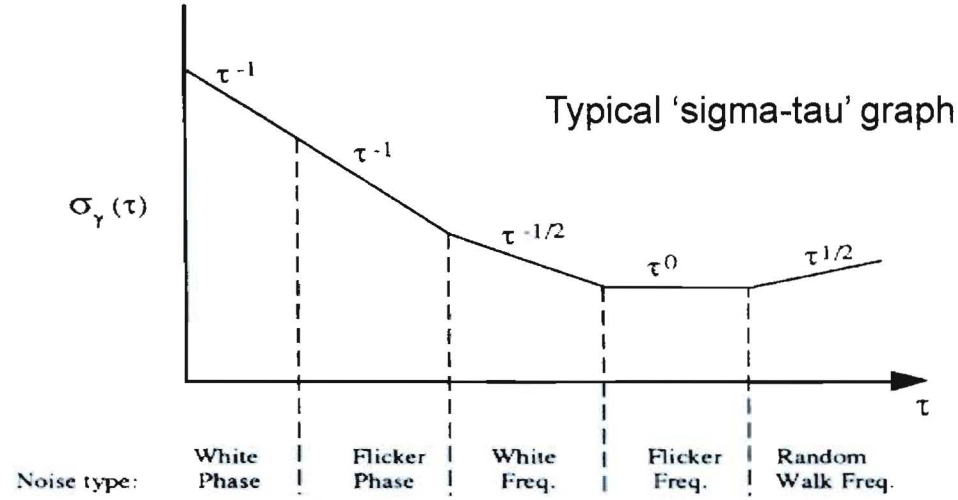
- Errors in antenna coordinates, especially altitude
- Real time ionospheric and tropospheric corrections
- Estimation errors in antenna, cable, receiver and instrument delays
- Multipath
- Influence of temperature on outdoor instrumentation (antenna, cables)

Allan variance (AVAR)

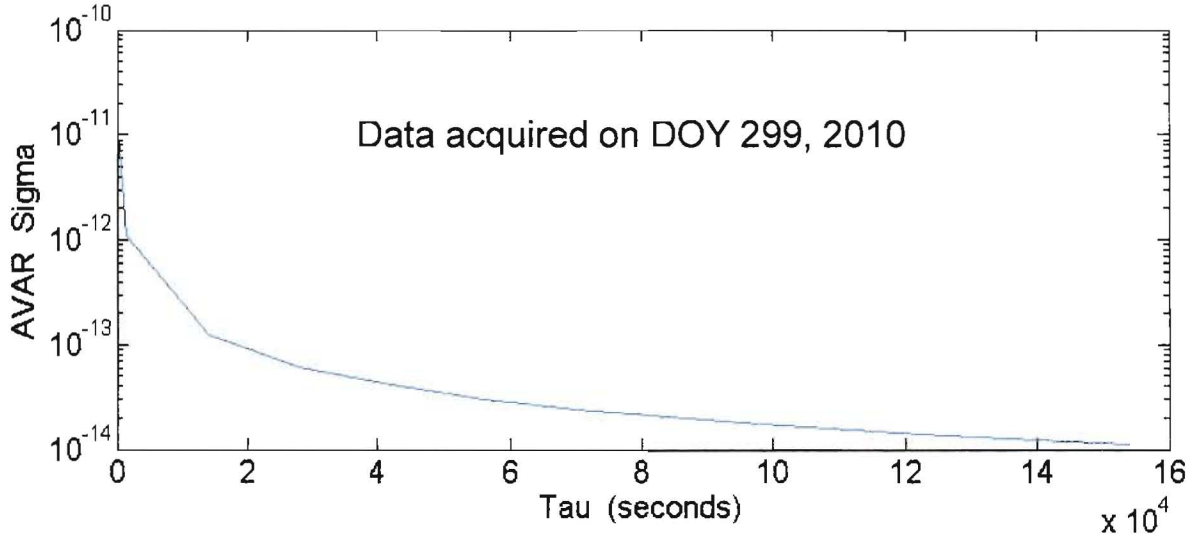
- Allan variance (appropriately called Allan deviation) is used to characterize stability of oscillators. The slope of the Allan deviation line can identify amount of averaging necessary to remove the various noise types. AVAR is given by:

$$\sigma_y(\tau) = \sqrt{\frac{1}{2(N-2)\tau^2}\sum_{i=1}^{N-2}\left[x_{i+2} - 2x_{i+1} + x_i\right]^2}$$

where, x is array of time samples (in our case: the difference in 1PPS of the clocks)
N is the number of samples
tau is the time interval of the collect



AVAR of LAPP / NDS Operational clock



- Based upon this theory, the longer oscillators run undisturbed, the stability of the output is more predictable
- Operational clocks have been running undisturbed, and continuously, for ~ 5 months

Physics Laboratory
Time & Frequency Division

NIST National Institute of Standards and Technology

GPS monitoring data for the 100 day period ending 2009-08-17 (as received at NIST in Boulder, Colorado)

Archive Home | 1 Day Averages | 1 Hour Averages | 10 Minute Averages | Next Date | Last Date

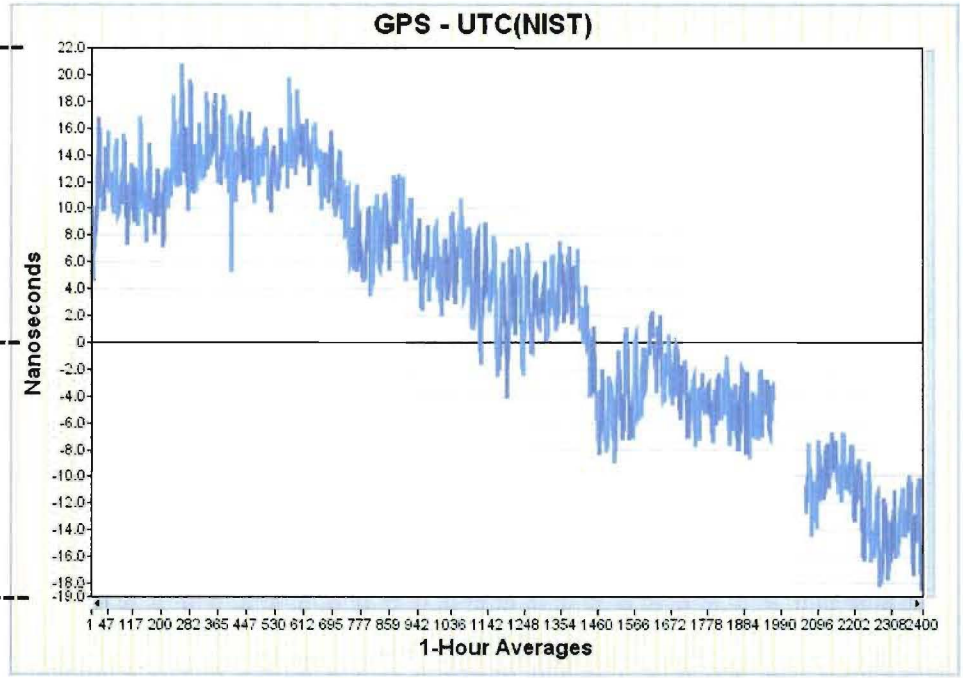
GPS - UTC(NIST)
(one-hour averages using all satellites in view)

Hours	Mean Time Offset (ns)	Range (ns)	Frequency Offset	Confidence (r)
2302	3.09	39.27	-3.50×10^{-15}	-0.94

22.0 nsec -------

0 nsec -------

-19.0 nsec ------



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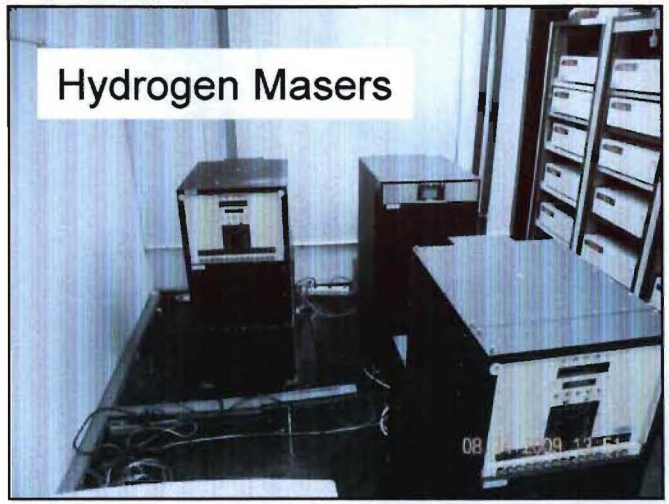
‘Clock vault’ at USNO, Washington, DC



Summary of study

- Several 40+ hour data records obtained in Oct 2010 from the LAPP Operational clocks show variations of ~ 27 nsec.
- Several 16+ hour data records obtained in Aug 2010 from non-operational clocks like those used operationally from 2005 to the present show variations of ~ 35 nsec.
- SLRE variability is xxx+/- yyy sec (std dev).
- SLRE occasionally show unusual events such as those discussed by Pongratz.
- We will continue to study and monitor.

BACKUP SLIDES

Conclusions drawn from this study

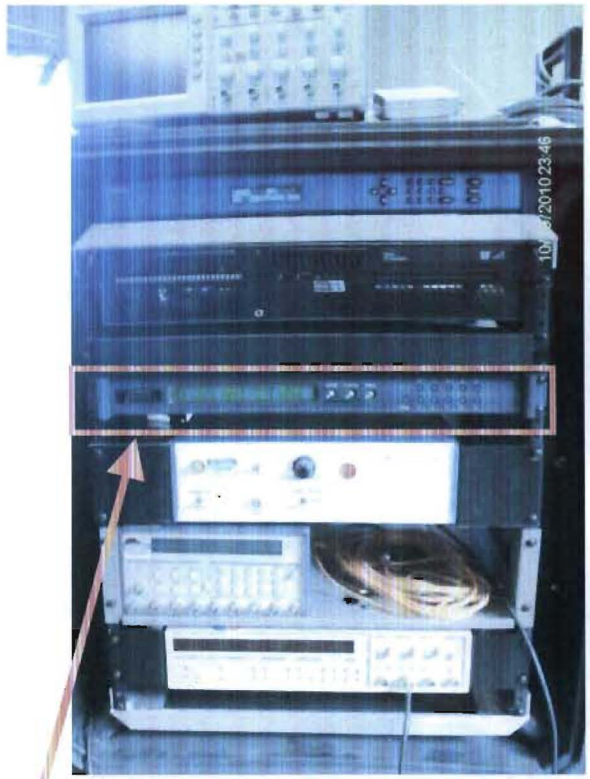
- Yes, the 'jump' seen in 2005 is real
- However, the singular inference derived from it may not be true (there is no 'smoking gun')
- The data presented in this talk clearly prove that the new clocks have not 'jumped' over the current observation period
- Operational clock used for time stamping LAPP/NDS firetimes is within 27 nsec of new dual channel TSC4400 clock

Conclusions (contd.)

- Operational clock was used in SLRE calculations to resolve SV47 timing 'studies' to within xxx sec accuracy (demonstrated in previous talk)
- Operational clock was used to identify bias in IIR and IIR-M SVs (demonstrated in previous talk)
- Std dev of SLREs in ANY given Quarterly is 'tighter' with new clock (demonstrated in previous talk)
- The one time large deviation in 2005 appears to be an 'offset' rather than a clock issue

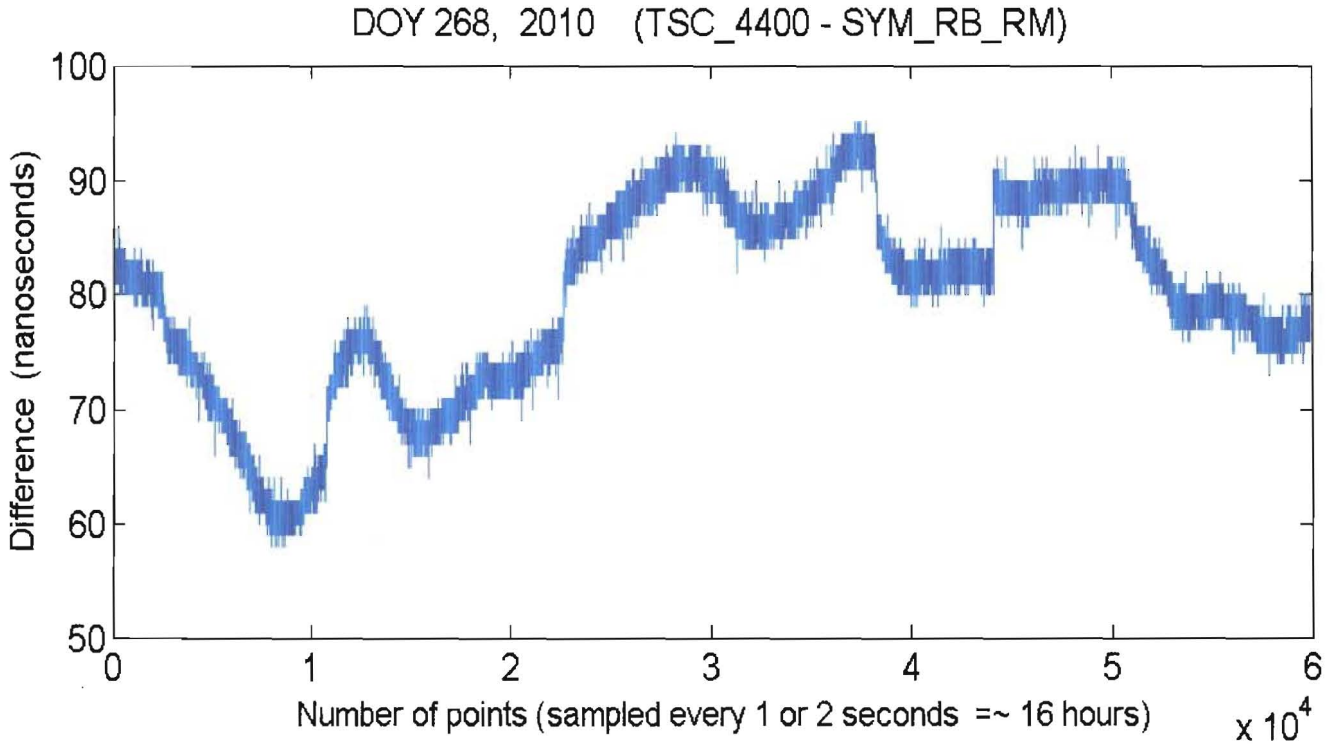
Experimental clocks (NOT used for LAPP / NDS operations)

Symmetricom TSC4400
(Dual channel $25K)



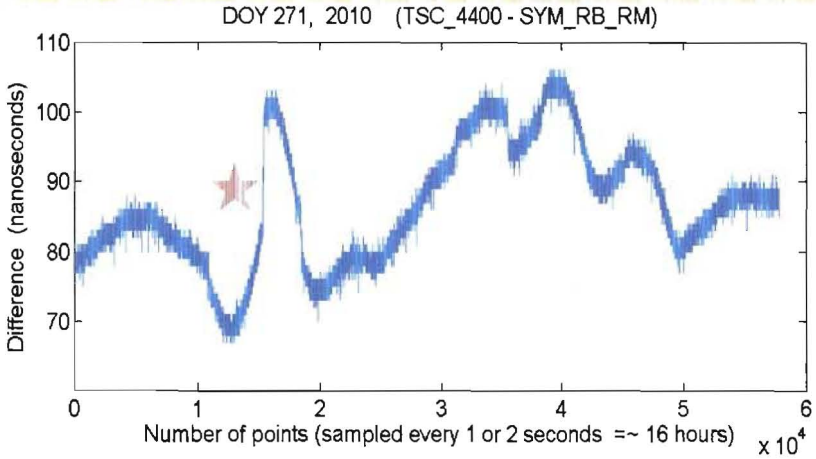
Symmetricom ET6000
(Single channel $8K)

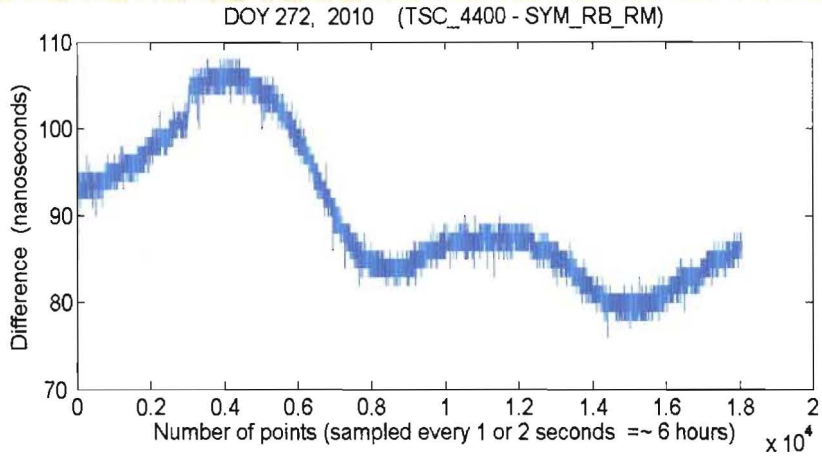
Typical difference in 1 PPS from 2 Rb clocks

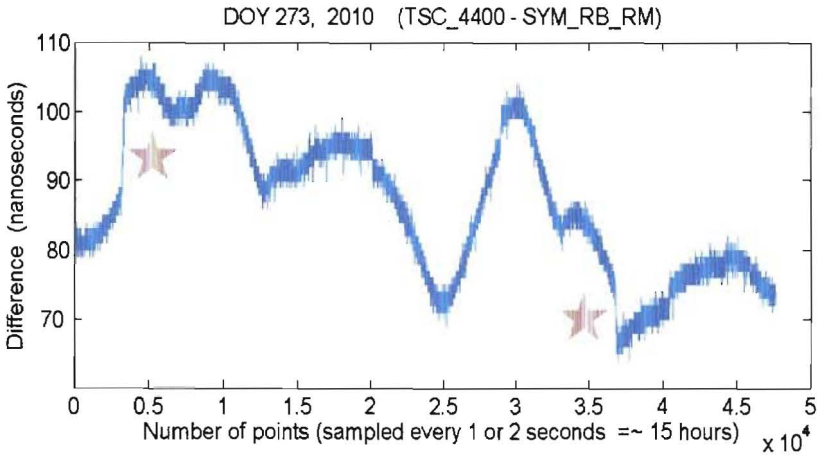


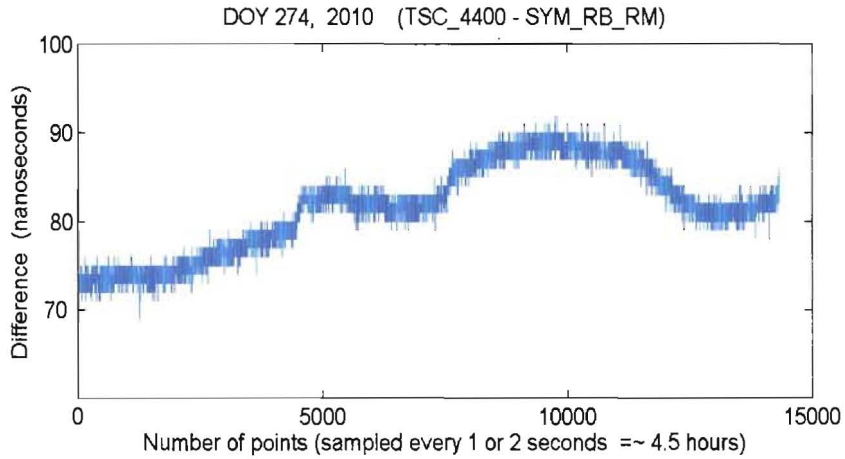
Note: cable delay of about 100 nsec not accounted for

'Non-operational' Rb clocks x, y show drifts of ~35 nsec over 24 hour periods









= known causes for these shifts