Power Matters.

A Hybrid Time Transfer Approach for Robust Network Time Transfer

George Zampetti, Chief Scientist FTD

Does anyone really know what time it is?

Ye Olde Two Way Time Transfer

At 13.00 exactly, **the ball falls**, and so provides a signal to anyone who happens to be looking.

the first stroke of the hour bell should register the time, correct to within one second per day, and furthermore that it **should telegraph** its performance twice a day to Greenwich Observatory, where a record would be kept."

Errors are normally fixed by adding and removing old coins in the pendulum to adjust the rate at which it swings.

http://time.com/4010170/big-ben-running-slow/

Some Observations

Ye Olde Two Way Time Transfer

1. Goal Both Clocks should always Agree
2. Royal Observatory is always right (always drops the ball at the right time).
3. Big Ben has no influence on time beyond a day it just follows.

Some Potential Problems

Ye Olde Two Way Time Transfer

1. Ball drops at the wrong time
2. Write down wrong timestamp
3. Too foggy to see ball (jamming)
4. Someone messes with the telegraph (spoofing)
5. Big Ben degrades

At 156, Big Ben is allowed some tantrums. A spokesperson was sympathetic to the clock's missteps, acknowledging Ben "Does have a little fit every now and then," but asking people to "Imagine running your car for 24 hours a day, 365 days a year for the last 156 years /http://time.com/4010170/big-ben-running-slow/

Solution: The More the Merrier

Ye Olde Two Way Time Transfer

1. More Royal Observatories
2. More Balls
3. More Telegraphs

So ….

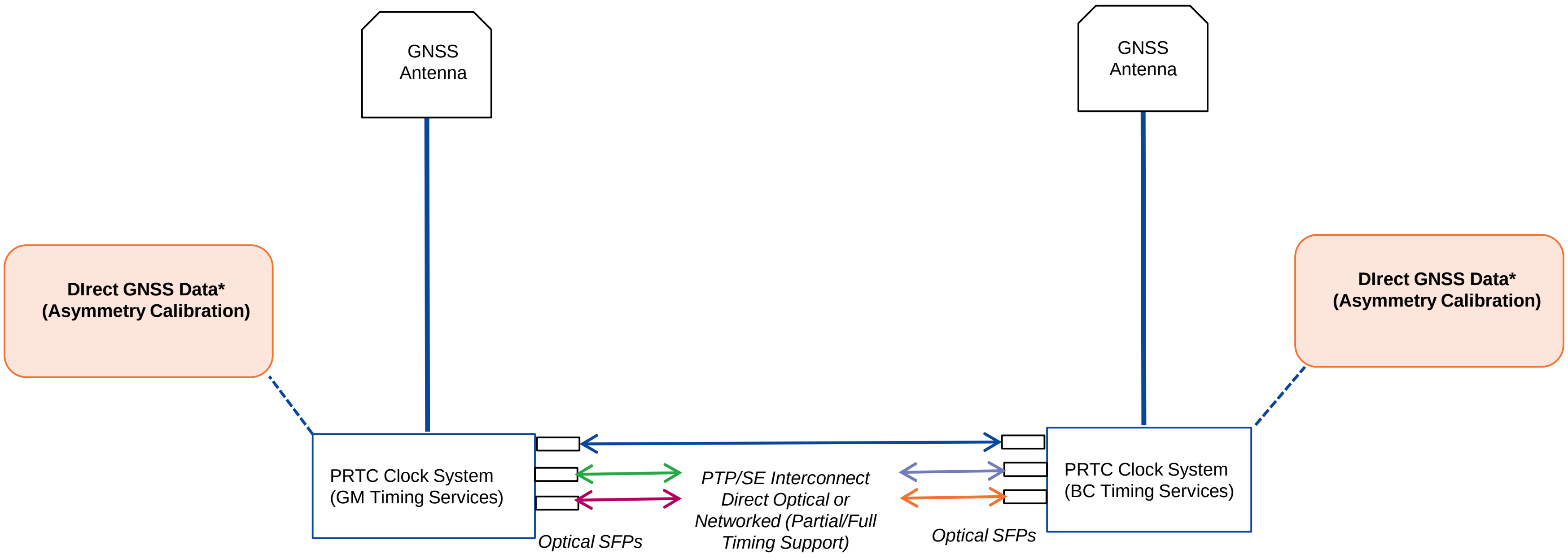
What can be done for a practical solution?

Hybrid Time Transfer Key Principles

- To sensibly use all resources (PTP and GNSS and Sync E and ….) not (PTP vs. GNSS vs …)

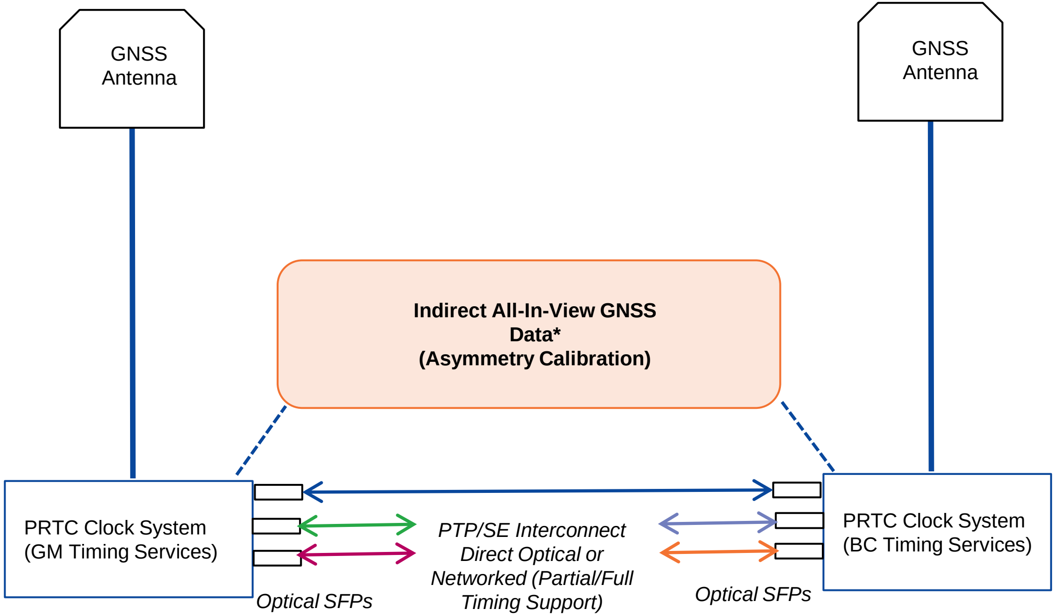
- Leverage the strength of each method to generate a hybrid method that is "stronger than the sum of the parts".

Hybrid Timing Architecture



* Utilizing Advanced Asymmetry Calibration patented Microsemi IP.

Hybrid Timing Architecture



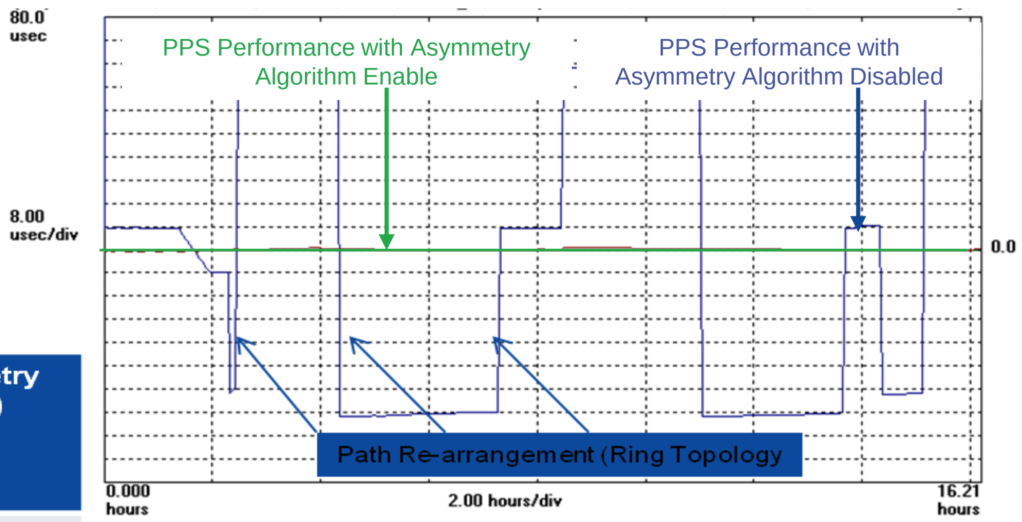
* Utilizing All-In-View in a composite interconnect approach is patented Microsemi IP.

Advanced Asymmetry Calibration combined strength of PTP and GNSS

- **Asymmetry Correction Algorithm supplies external correction factor defined in 1588 standard.**
- **Algorithm learns asymmetries while GNSS is valid to prevent in-accurate time output**
- **Asymmetry Table with N=32 Calibrated Path Records maintain for each GM source**

Path Signature			Asymmetry Bias (ns)
Round Trip Delay	Observed Bias	Secondary Path Parameters	
Path Signature A			AAA.A
Path Signature B			BBB.B
Path Signature C			CCC.C

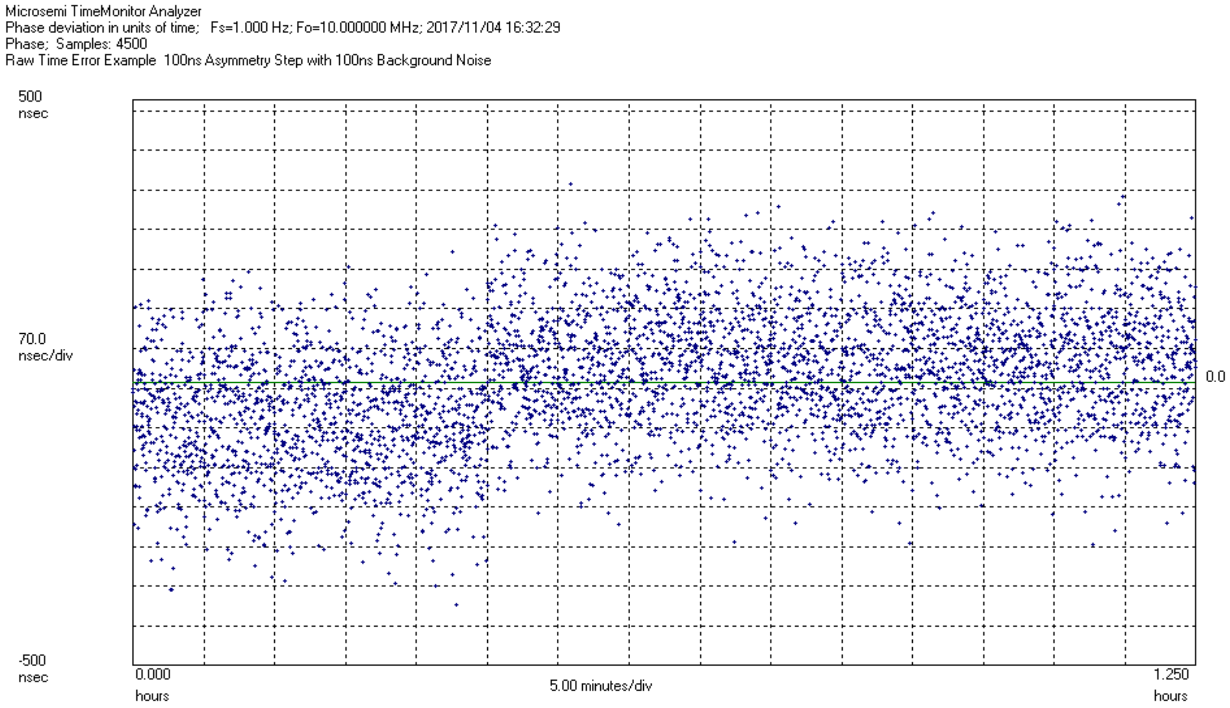
Performance in Live Network Environment



Asymmetry Clustering Time Calibration Estimation Example

Example to Illustrate Robust Asymmetry Time Calibration. The graph shows raw time error PPS data between the PTP PPS and the GNSS PPS.

Note there is a 100ns change in asymmetry at 1500 second. There is also 100ns of path noise that hides the step.

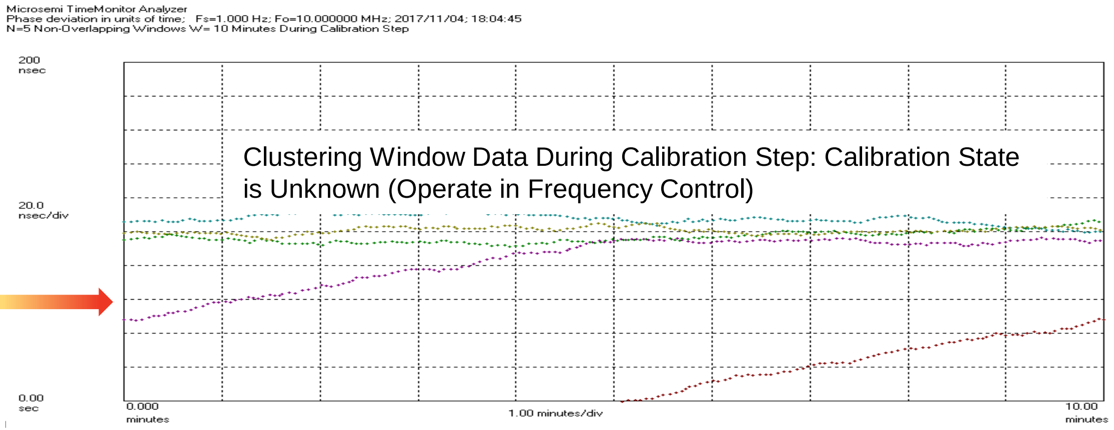


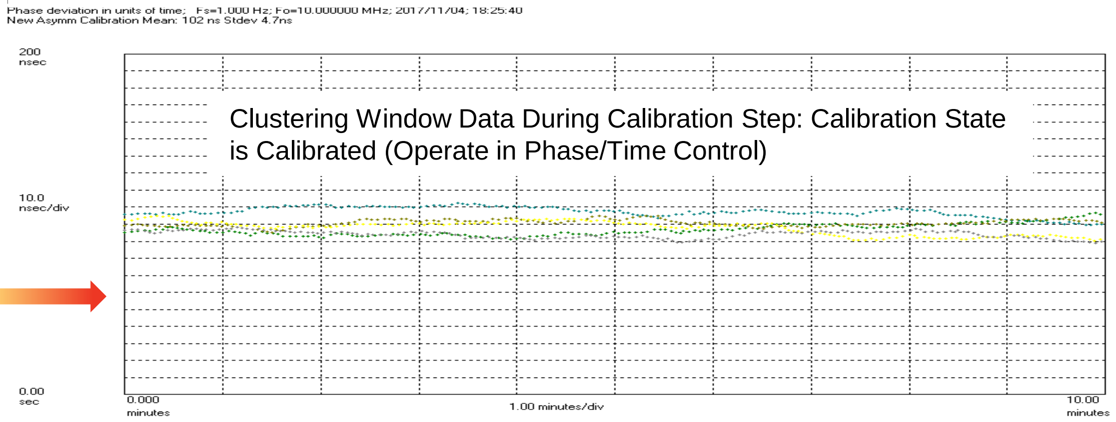
Asymmetry Clustering Time Calibration Estimation Example

Five Non-Overlapping Clustering Windows. 10 Minute Window Size

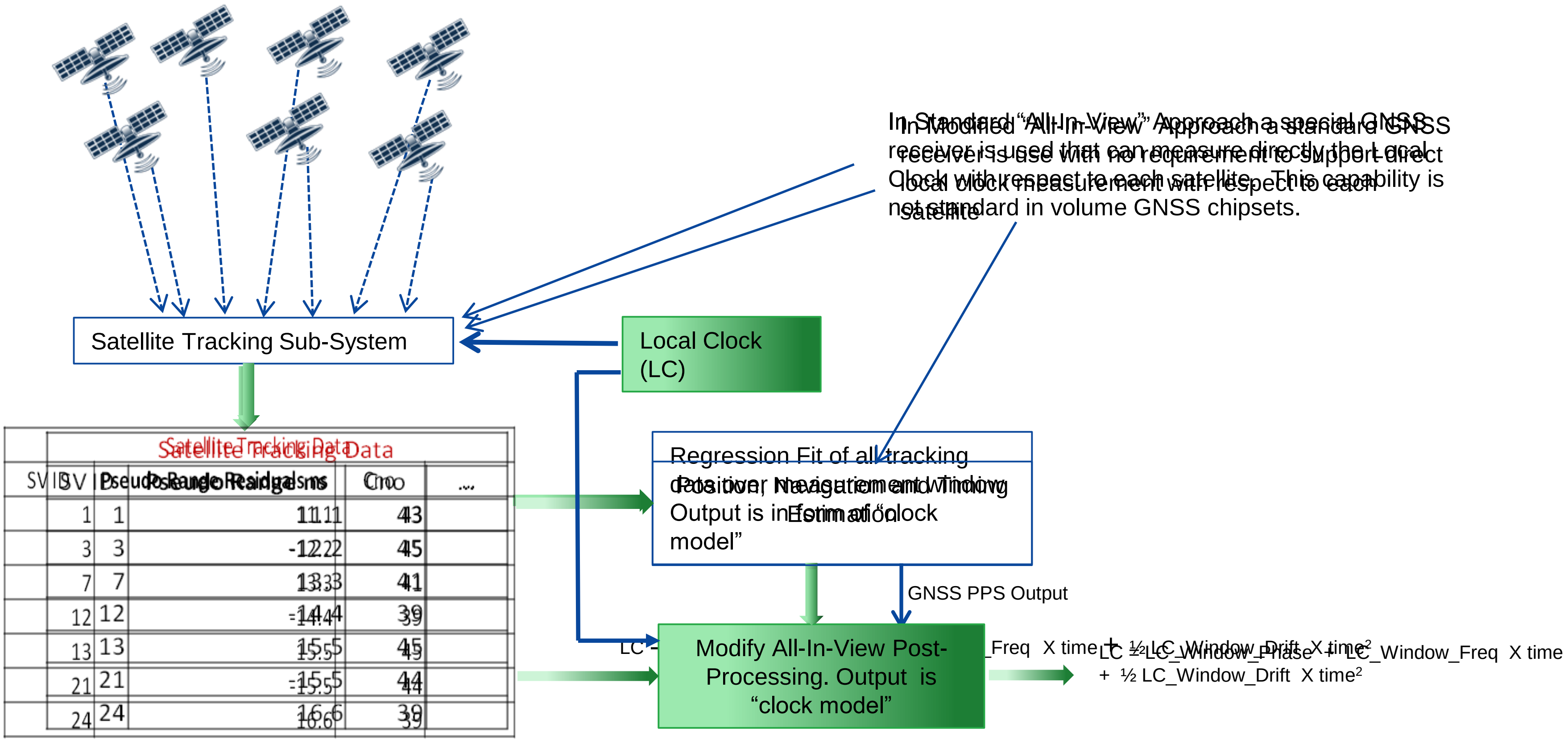
First Graph show overlapping window data with asymmetry calibration step in middle.

Second Graph show overlapping window data with asymmetry calibration after step. Robust Estimate Time Calibration: 102ns Path Noise 4.7ns.





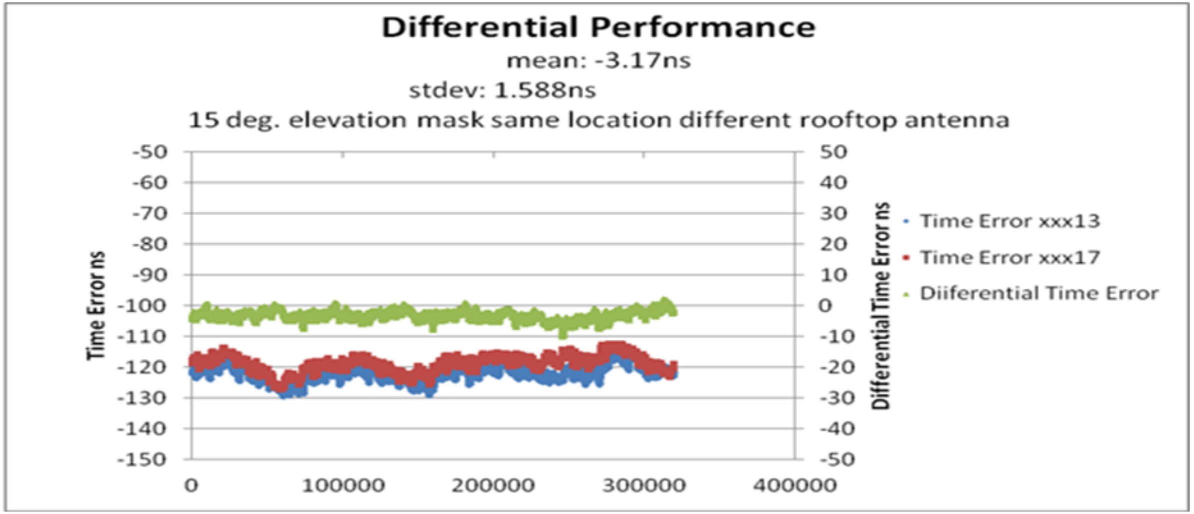
"All-In-View Approach"



SV ID	Pseudo Range Residuals ns	Cno	...
1	11	43	
3	-12.2	45	
7	13.3	41	
12	-14.4	39	
13	15.5	45	
21	-15.5	44	
24	16.6	39	

Modified All-In-View 15 degree elevation Two L-Band Antenna Co-located on common rooftop.

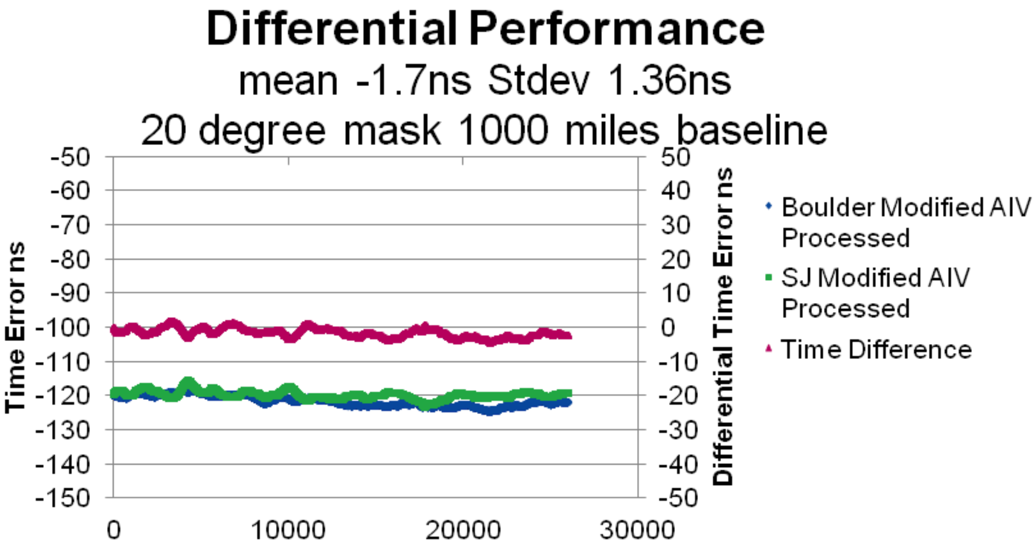
Long Weekend Test with two different antennas in same location.
Note high correlation between the two receivers (mean -3.17ns stdev 1.6ns)



Modified All-In-View 20 degree elevation Two L-Band Antenna 1000 miles apart.

In this test the two modified all-in-view system were configured with one in our San Jose Lab and the other in our Boulder Lap (nominally 1000 miles apart). We utilized our calibrated house reference time scale systems in both facilities as the local reference clocks. The test results:

1) At this baseline distance the "deterministic correlation" of both individual measurements (green and blue) is replaced by the expected all-in-view "melting pot" statistical correlation.
2) The observed average time difference is a very respectable 1.7 ns with a time error noise of 1.36ns. Visually the time difference error is less than 5ns.



Summary

•We need to sensibly use all resources (PTP and GPS and Sync E and ….) not (PTP vs. GPS vs …)

•A Hybrid Time Transfer GNSS/PTP/SE architecture

- •Addresses fundamentally constant time error asymmetry in PTP time transfer
- •Mitigates GNSS intentional or unintentional jamming/spoofing (can be bridged indefinitely with calibrated PTP backup)
- •Gains Resiliency (PTP backup maintains calibration as the algorithms builds a path history)
- •Leverages Frequency (In case where PTP backup is not calibrated algorithm reverts to frequency backup)