Locata

TimeLoc

A New Ultra-Precise Synchronization Technology

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PNT Advisory Board Meeting

29 October 2015

Introduction – technology development

- Locata has invented a fundamental advance in synchronization for wireless transmitters
- We call it **TimeLoc**
- TimeLoc was developed because we were creating a "local, terrestrial replica of GPS" which would deliver RTK-level positioning indoors, in GPS-denied environments and in all the places GPS did not function adequately
- **Our development effort was successful.**
- **Our <u>LocataNets</u> are selling today into early stage markets, with partners like USAF, NASA, Leica Geosystems, and many more.**

How we got to now

- Importantly…

We were NOT trying to "replace GPS"

We WERE trying to "make GPS better"

- To fill the holes we needed to enable an independent, easily-deployed, inexpensive replica of RTK-level GPS
- A great analogy….

Locata is to GPS as wi-fi is to the cellphone system

- To achieve this, **of course**, we had to invent a way to very precisely synchronize our wireless transmitters

without satellites

without atomic clocks

This device creates the solution

UNIQUE – the LocataLite is a world first

REVOLUTION – generates TimeLoc synchronization

FOUNDATION – of a new enabling technology platform

First long-range TimeLoc trials

TIMELOC TIME TRANSFER at nanosecond level had been demonstrated by UNSW

- First demonstration of "cascaded" TimeLoc
- UNSW **conference papers** on ~73 km radius TimeLoc (covers over 16,500 km^2)
- Demonstrated potential for cell tower & precise timing over large areas (e.g. city)
- For sync of digital communications systems in "GPS-challenged" environments
- 2 "TimeLoc hops"... 50km and then 23km

Early Locata Technology development

The fundamental problem with ground-based transmitters is synchronization of the signals for both ranging and pulsing

- **TimeLoc**, the method used to synchronize one LocataLite to any other LocataLite, solves that synchronization problem.
  - TimeLoc provides frequency, phase, and time alignment at the point of transmission (the transmit antenna phase center)
  - Once TimeLocked, the LocataLite's signals are usable for any standard GPS type measurement processing from least squares PR solutions to any carrier phase techniques including ambiguity resolution (AR).
  - Early positioning demonstrations used a fixed point ambiguity resolution to demonstrate centimeter level performance. Current architectures use geometry change AR and combined GPS+Locata AR solutions.
- The first generation prototype LocataLites transmitted on L1 and used a commercial GPS receiver with modified software.
- All synchronization in the early stages was internal to the LocataNet.

The KEY to TimeLoc

Figure 9 Block Diagram and associated patent description details the way Locata's co-founder, **David Small**, invented the **Time Lock Loop** (TLL)

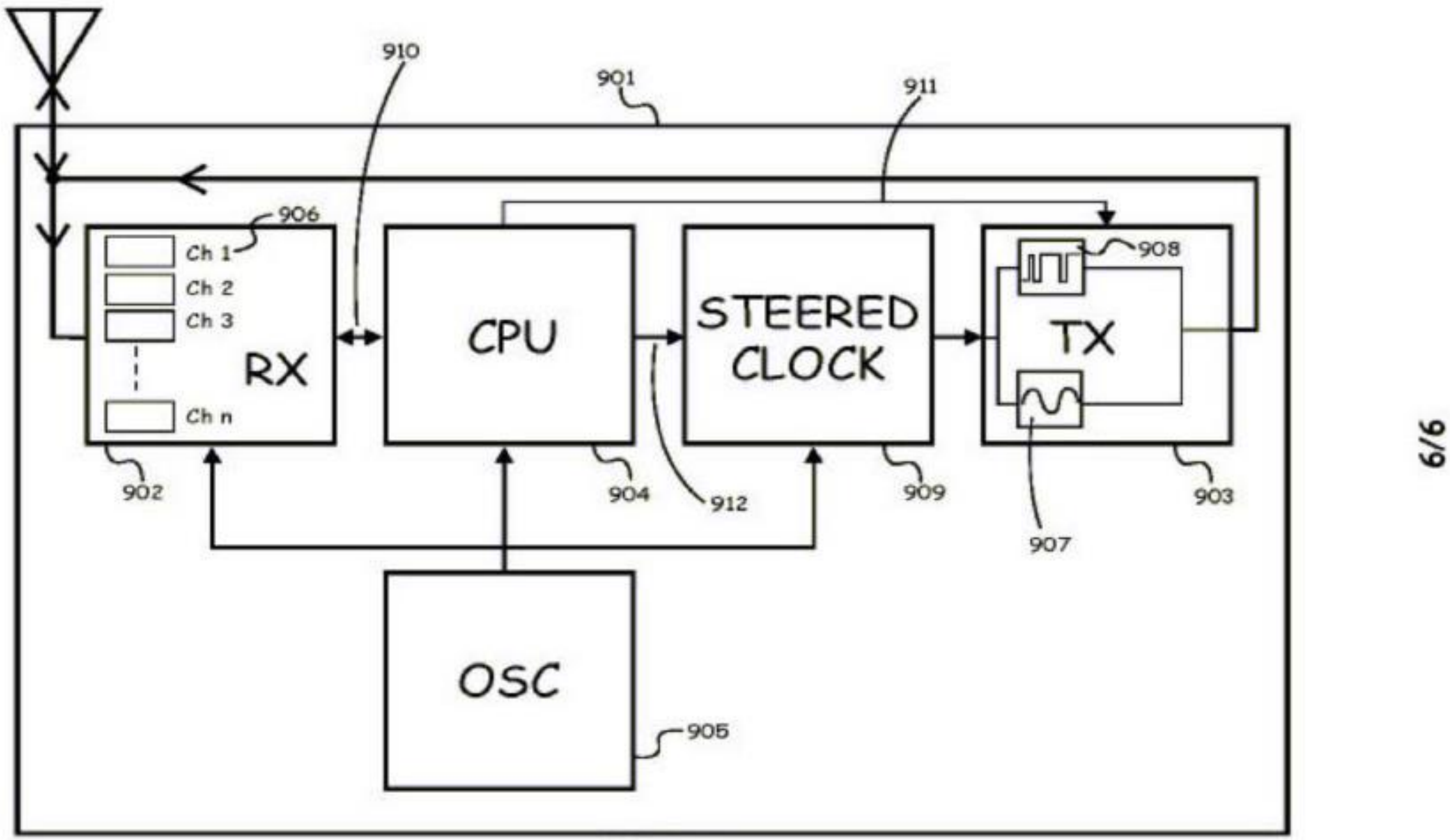
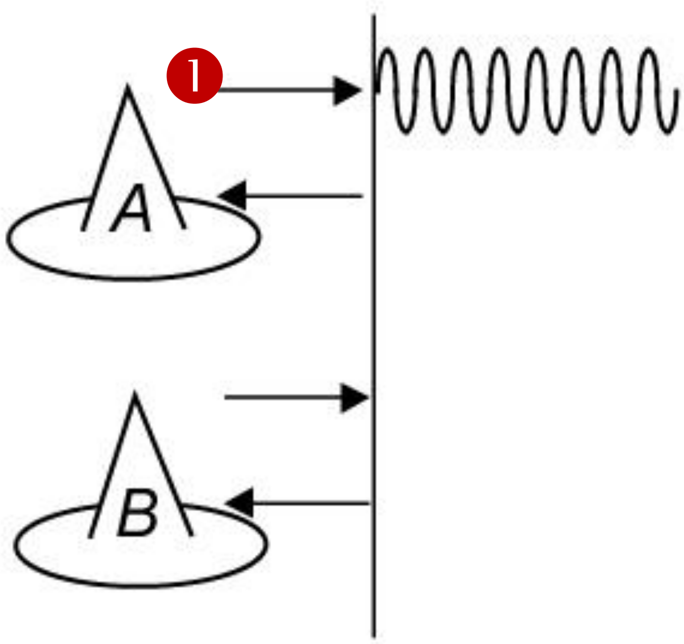


FIG 9

A LocataLite: Figure 9 of US Patent #7,616,682

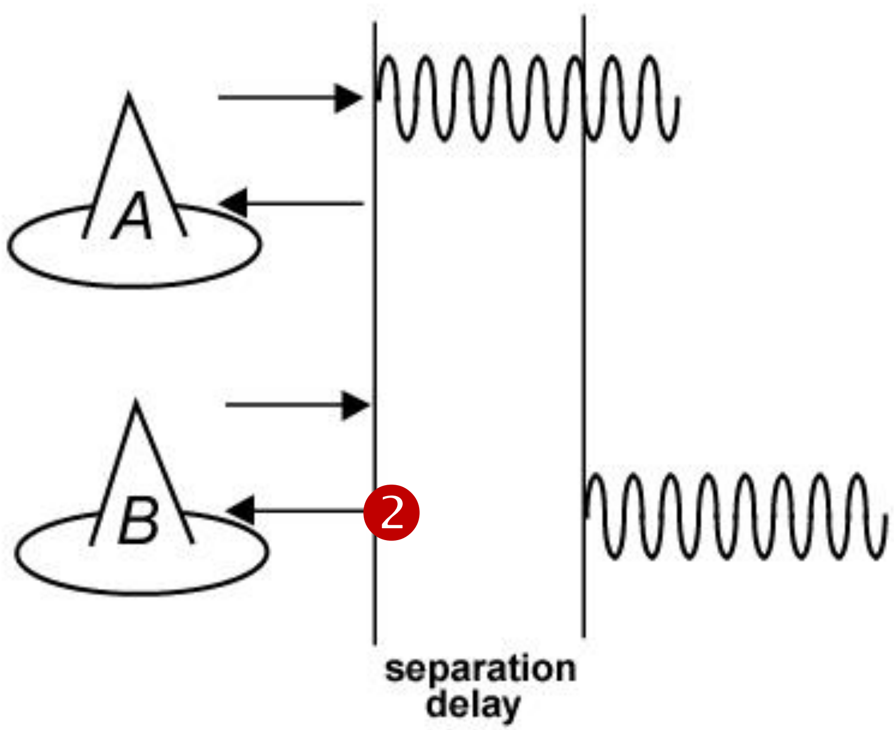
TimeLoc: Step 1

LocataLite A transmits carrier-phase and C/A code on a particular PRN code.



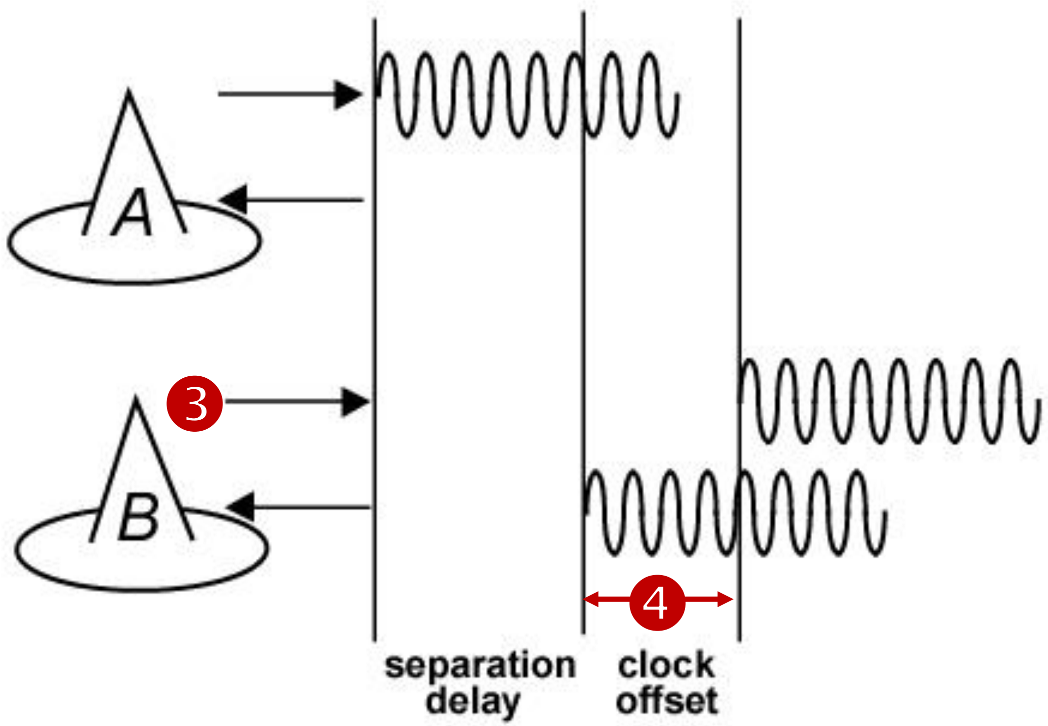
TimeLoc: Step 2

LocataLite B receives and measures signal generated by A at a later time due to separation of *LocataLites.*



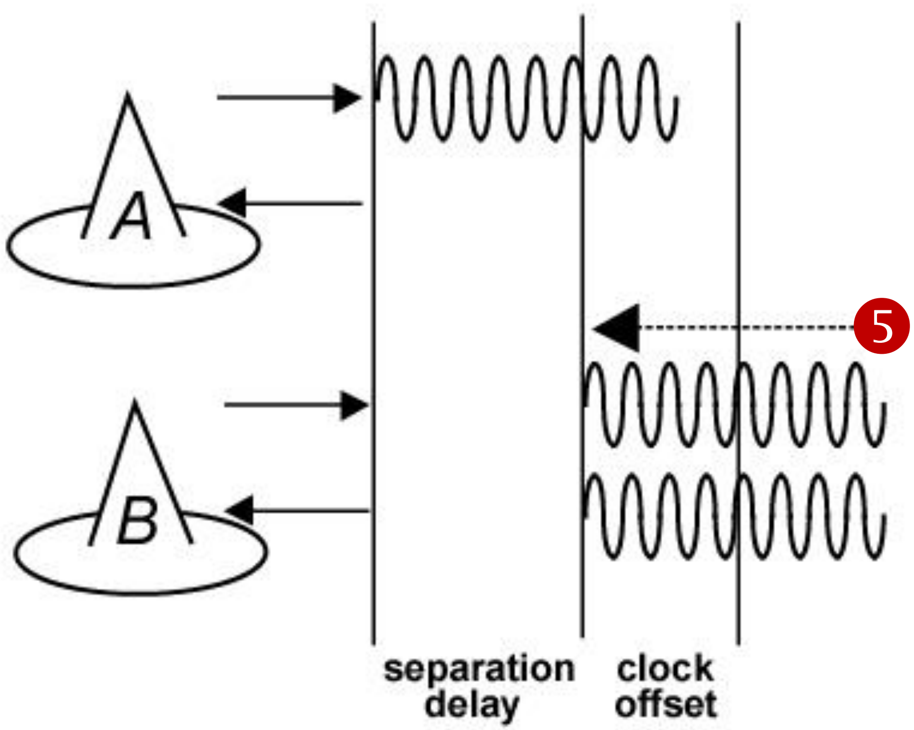
TimeLoc: Steps 3 & 4

3. *LocataLite* B transmits carrier-phase and C/A code on a different PRN code to A.
4. Compute difference between transmitted and received signal.



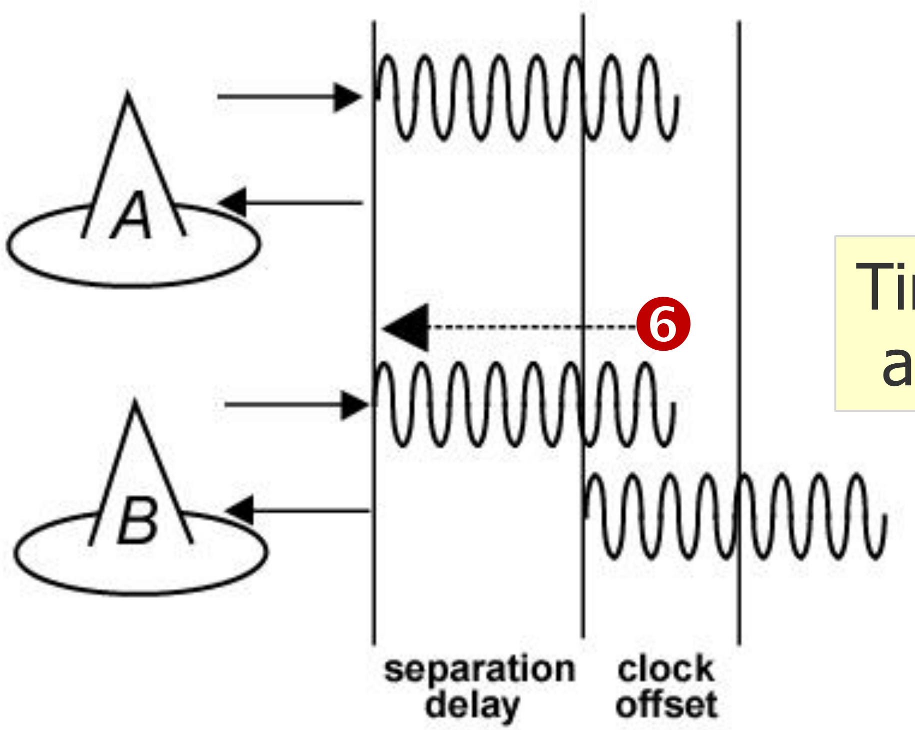
TimeLoc: Step 5

LocataLite B adjusts its local oscillator to bring carrier-phase and code differences between received and transmitted to zero.



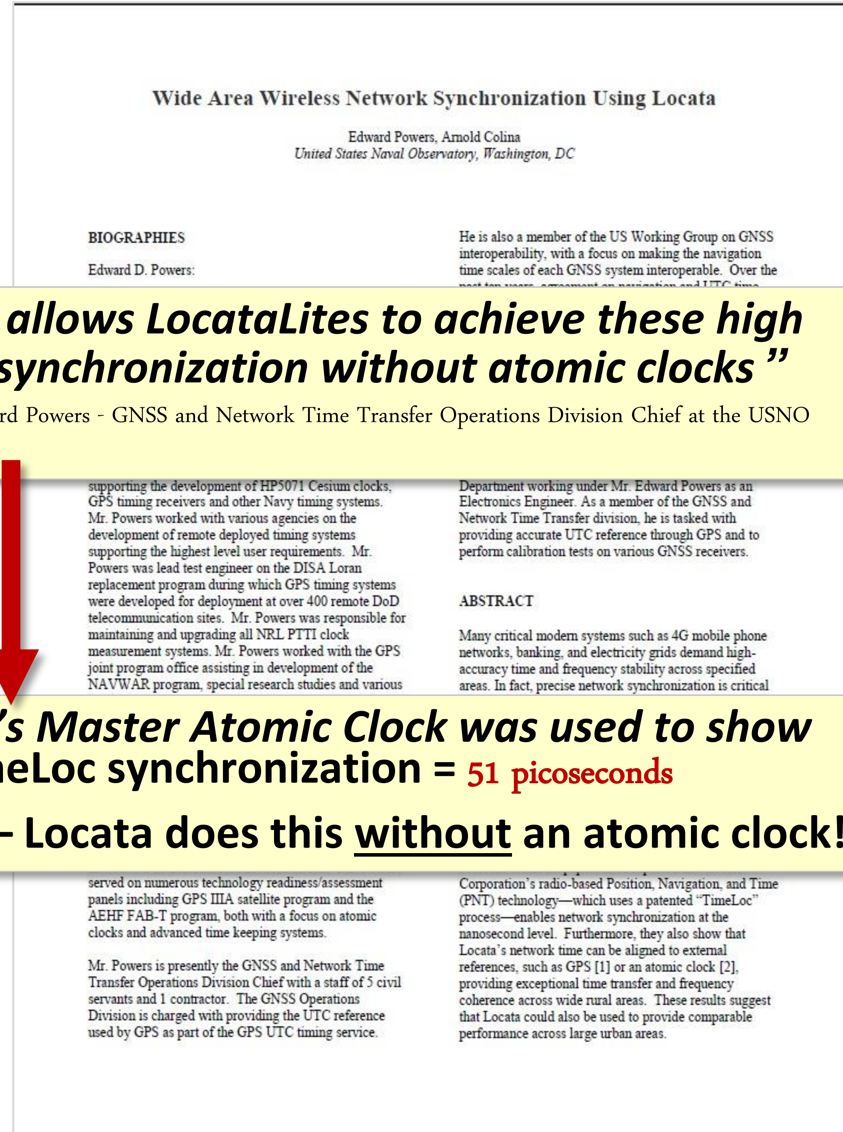
TimeLoc: Step 6

LocataLite B removes delay due to separation of LocataLites - LocataLites are now time synchronised.



TimeLoc is achieved

TimeLoc is **now ready for Prime Time**



Wide Area Wireless Network Synchronization Using Locata

Edward Powers, Arnold Colina
United States Naval Observatory, Washington, DC

BIOGRAPHIES

Edward D. Powers:

supporting the development of HP5071 Cesium clocks, GPS timing receivers and other Navy timing systems. Mr. Powers worked with various agencies on the development of remote deployed timing systems supporting the highest level user requirements. Mr. Powers was lead test engineer on the DISA Loran replacement program during which GPS timing systems were developed for deployment at over 400 remote DoD telecommunication sites. Mr. Powers was responsible for maintaining and upgrading all NRL PTTI clock measurement systems. Mr. Powers worked with the GPS joint program office assisting in development of the NAVWAR program, special research studies and various

served on numerous technology readiness/assessment panels including GPS IIIA satellite program and the AEHF FAB-T program, both with a focus on atomic clocks and advanced time keeping systems.

Mr. Powers is presently the GNSS and Network Time Transfer Operations Division Chief with a staff of 5 civil servants and 1 contractor. The GNSS Operations Division is charged with providing the UTC reference used by GPS as part of the GPS UTC timing service.

He is also a member of the US Working Group on GNSS interoperability, with a focus on making the navigation time scales of each GNSS system interoperable. Over the

Department working under Mr. Edward Powers as an Electronics Engineer. As a member of the GNSS and Network Time Transfer division, he is tasked with providing accurate UTC reference through GPS and to perform calibration tests on various GNSS receivers.

ABSTRACT

Many critical modern systems such as 4G mobile phone networks, banking, and electricity grids demand high-accuracy time and frequency stability across specified areas. In fact, precise network synchronization is critical

Corporation's radio-based Position, Navigation, and Time (PNT) technology—which uses a patented "TimeLoc" process—enables network synchronization at the nanosecond level. Furthermore, they also show that Locata's network time can be aligned to external references, such as GPS [1] or an atomic clock [2], providing exceptional time transfer and frequency coherence across wide rural areas. These results suggest that Locata could also be used to provide comparable performance across large urban areas.

"TimeLoc allows LocataLites to achieve these high levels of synchronization without atomic clocks"

Dr. Edward Powers - GNSS and Network Time Transfer Operations Division Chief at the USNO

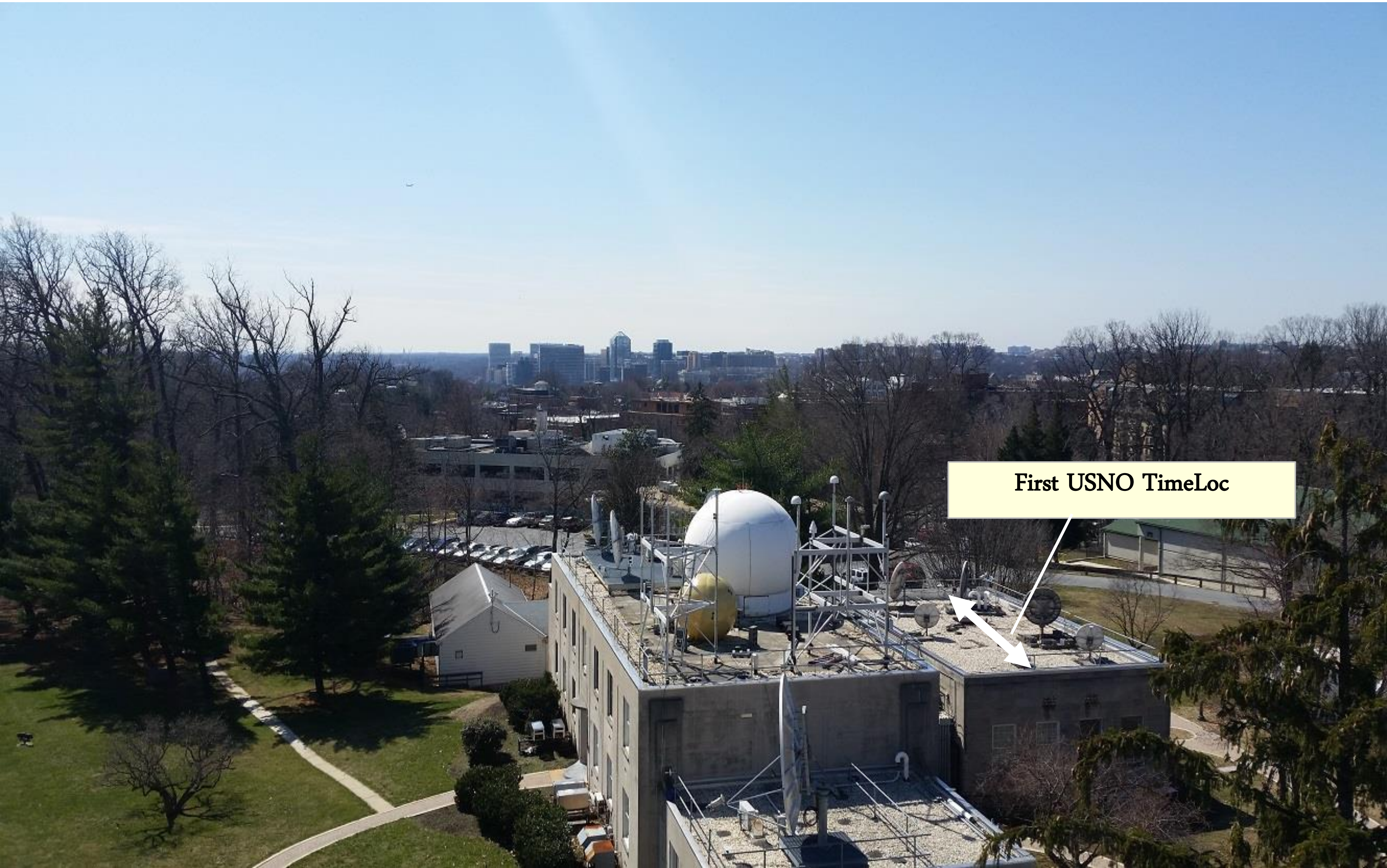
US Nation's Master Atomic Clock was used to show **TimeLoc synchronization = 51 picoseconds**

Remember – Locata does this without an atomic clock!

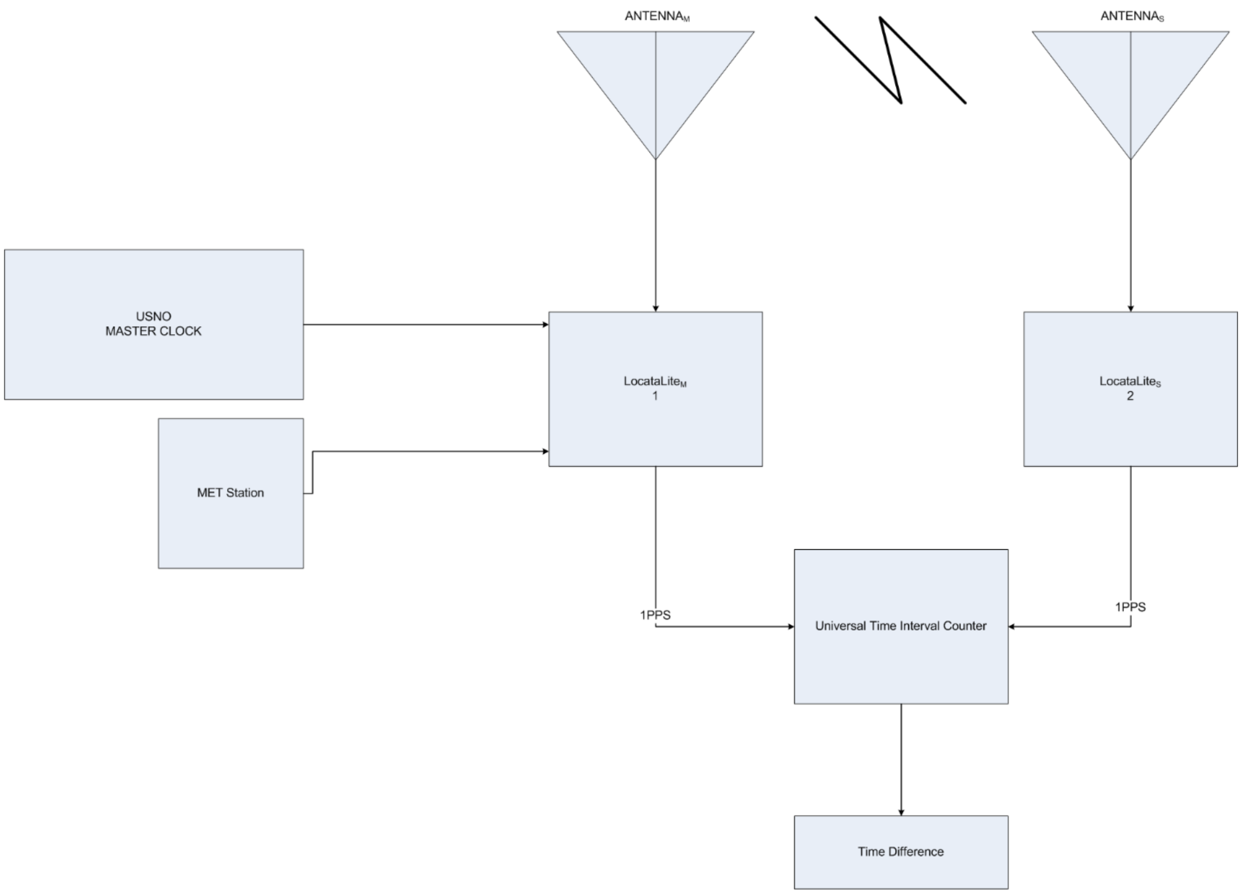
LOCATA setup at USNO

TOP: Primary "Master" LocataLite
BOTTOM: Secondary "Slave" LocataLite

Very first USNO trial…

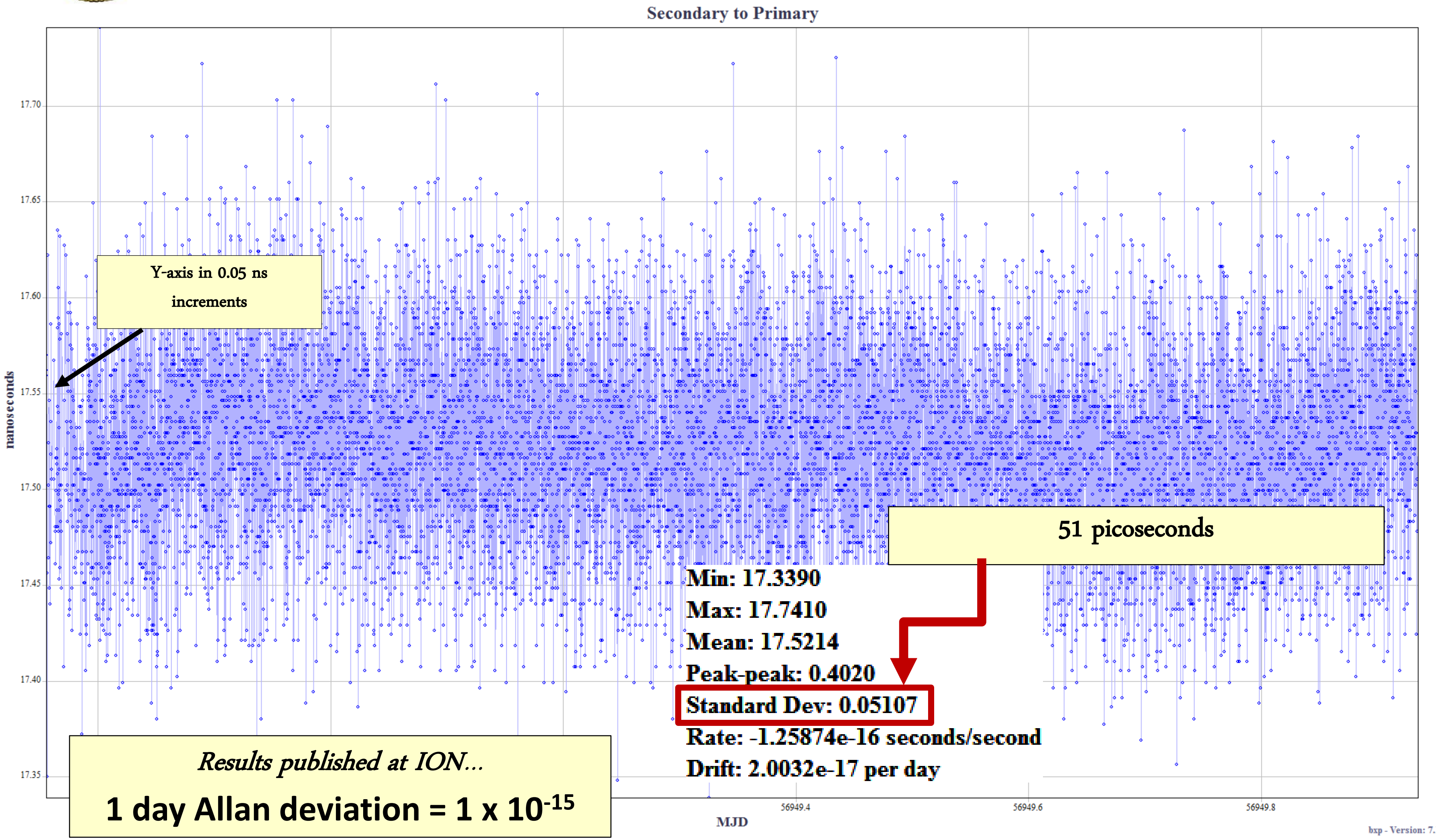


USNO measurement configuration



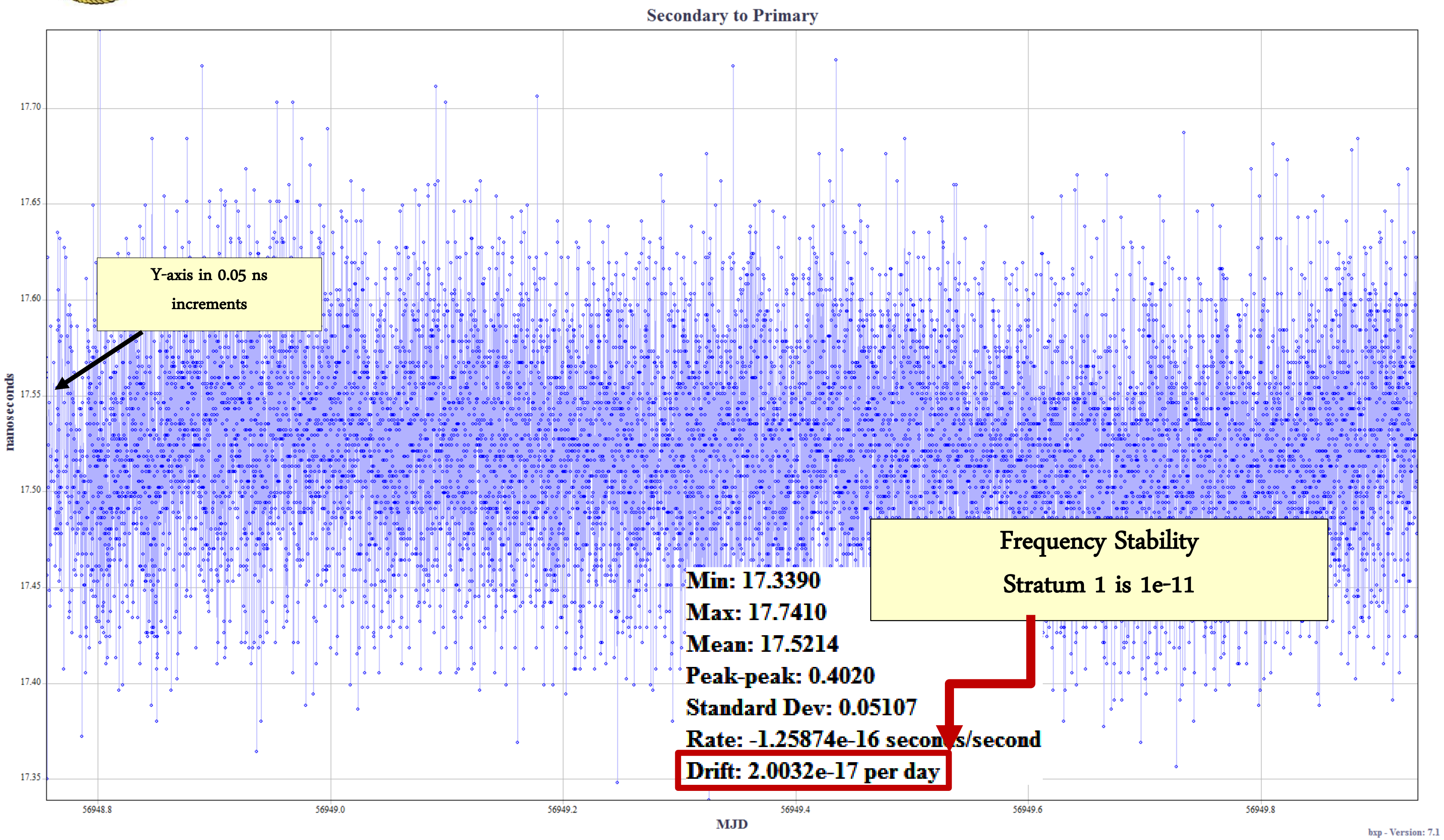
2-Node Setup (Total Range: 15.24m/50ft)

LOCATA results: first USNO private trial



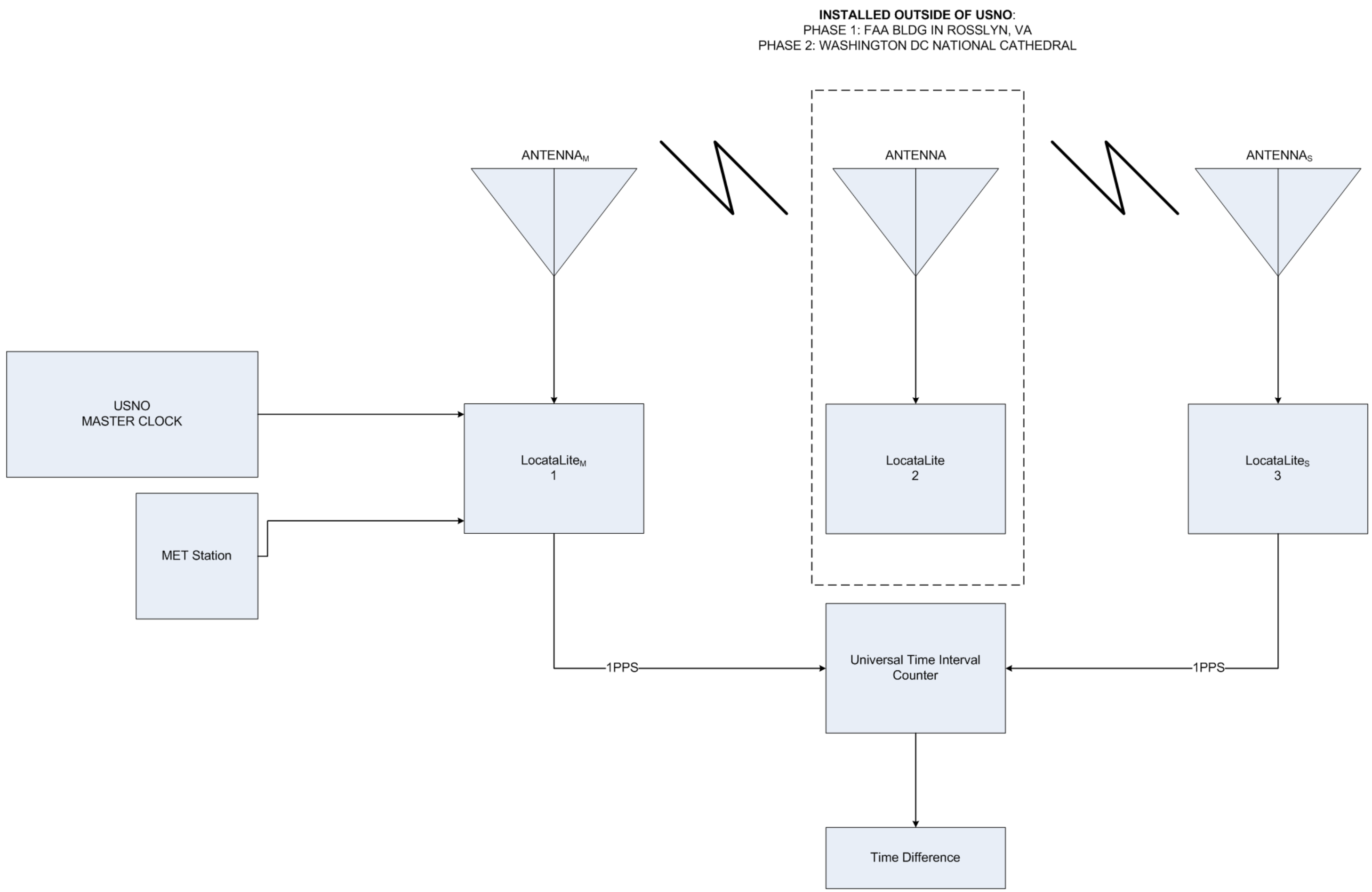
Locata

LOCATA results: first USNO private trial



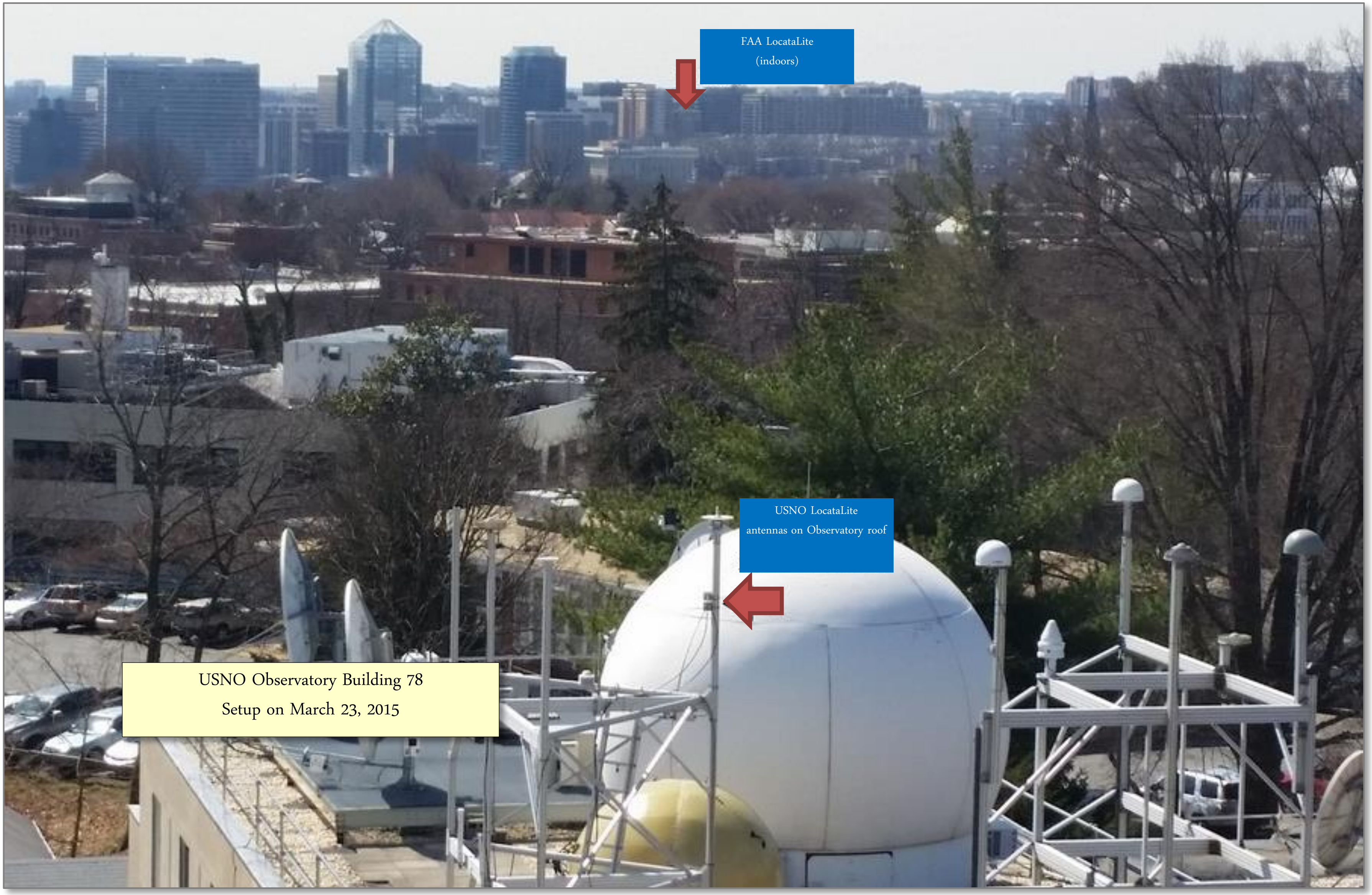
Locata

USNO measurement configuration

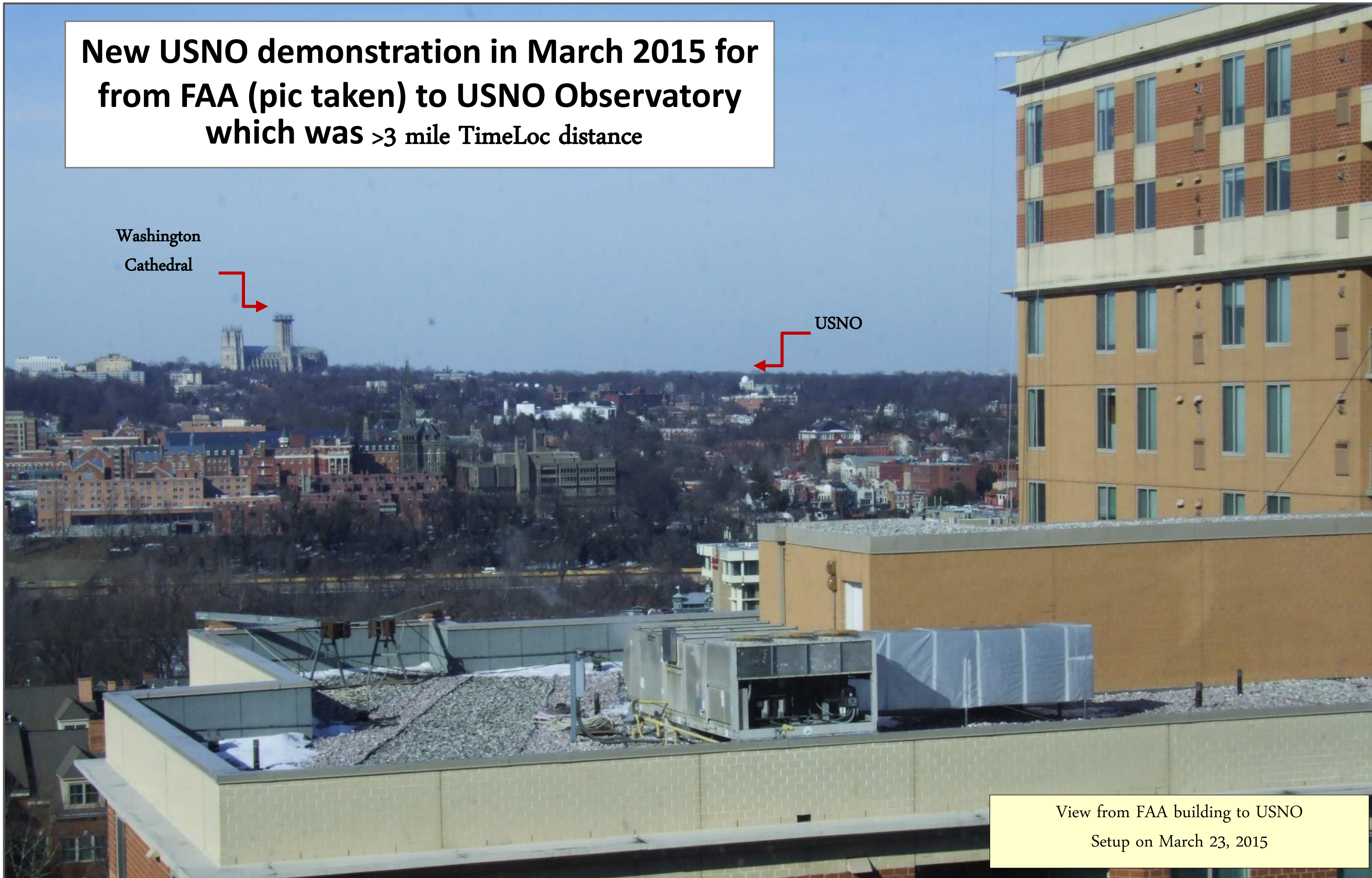


3-Node Setup (Total Range: 5.794km/3.6mi)

LOCATA layout: USNO to FAA and return…



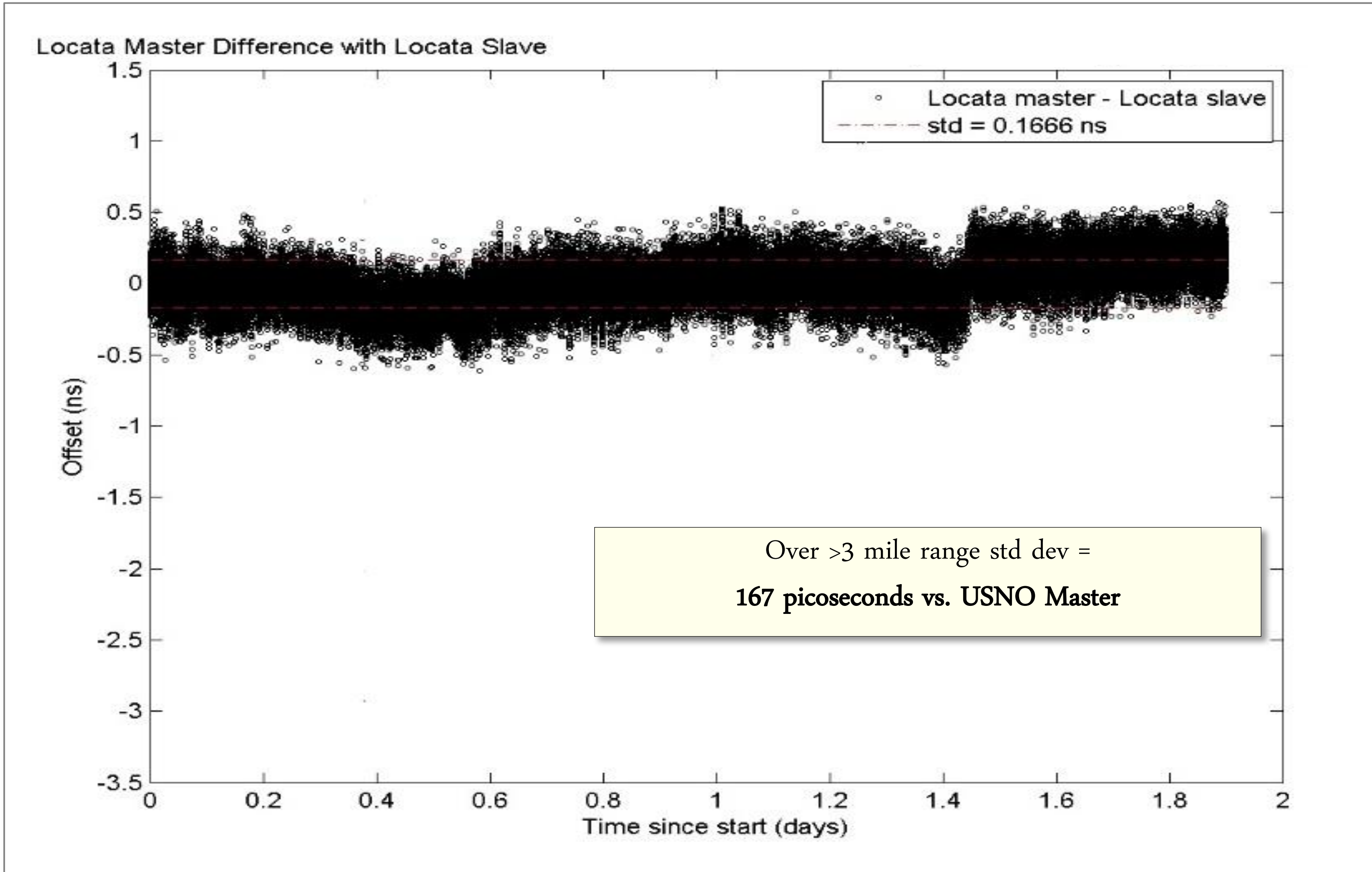
LOCATA layout: USNO to FAA and return…



LOCATA layout: USNO to FAA and return…

One of the layouts used for the TimeLoc tests conducted by the USNO in March 2015. The out & back TimeLoc distance in this layout is 3.6 miles (5.8 km). **Synchronization result was 127 picoseconds**

USNO to FAA: 46 hours – Mar 21-23, 2015



Locata

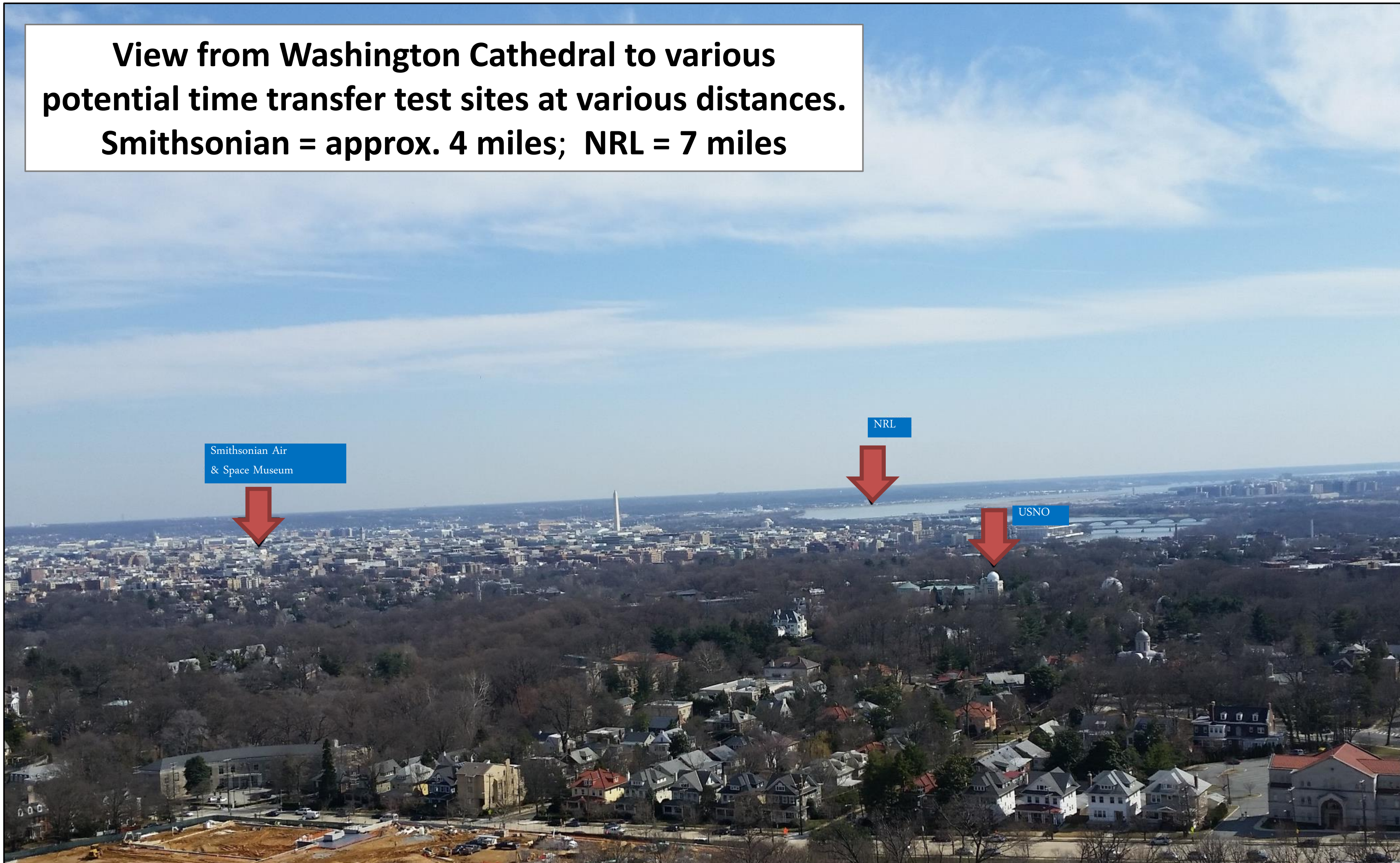
Moving to the National Cathedral

Moving to the National Cathedral

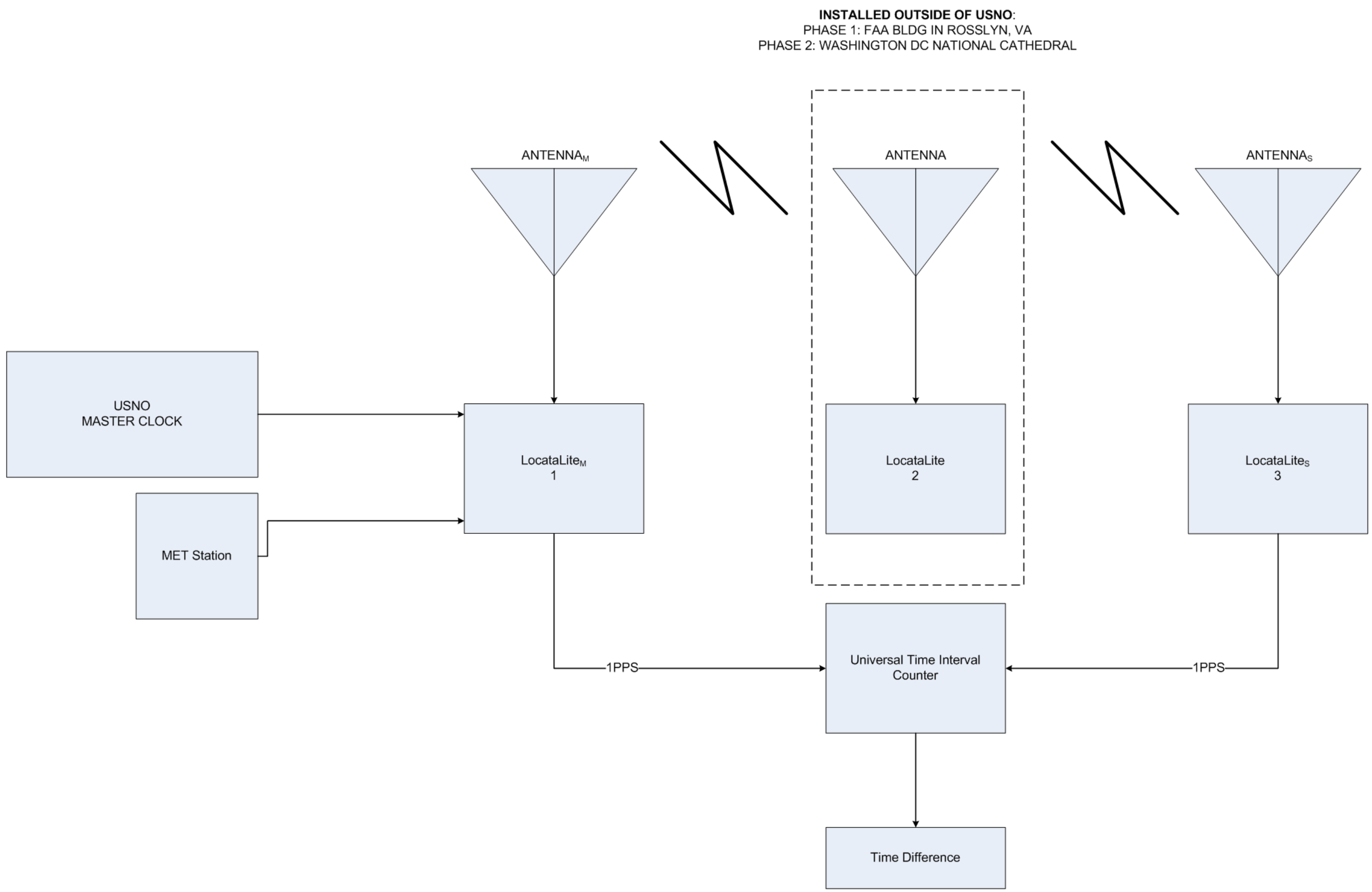
View of simple patch antenna setup

USNO to National Cathedral

USNO long term tests – May 2015

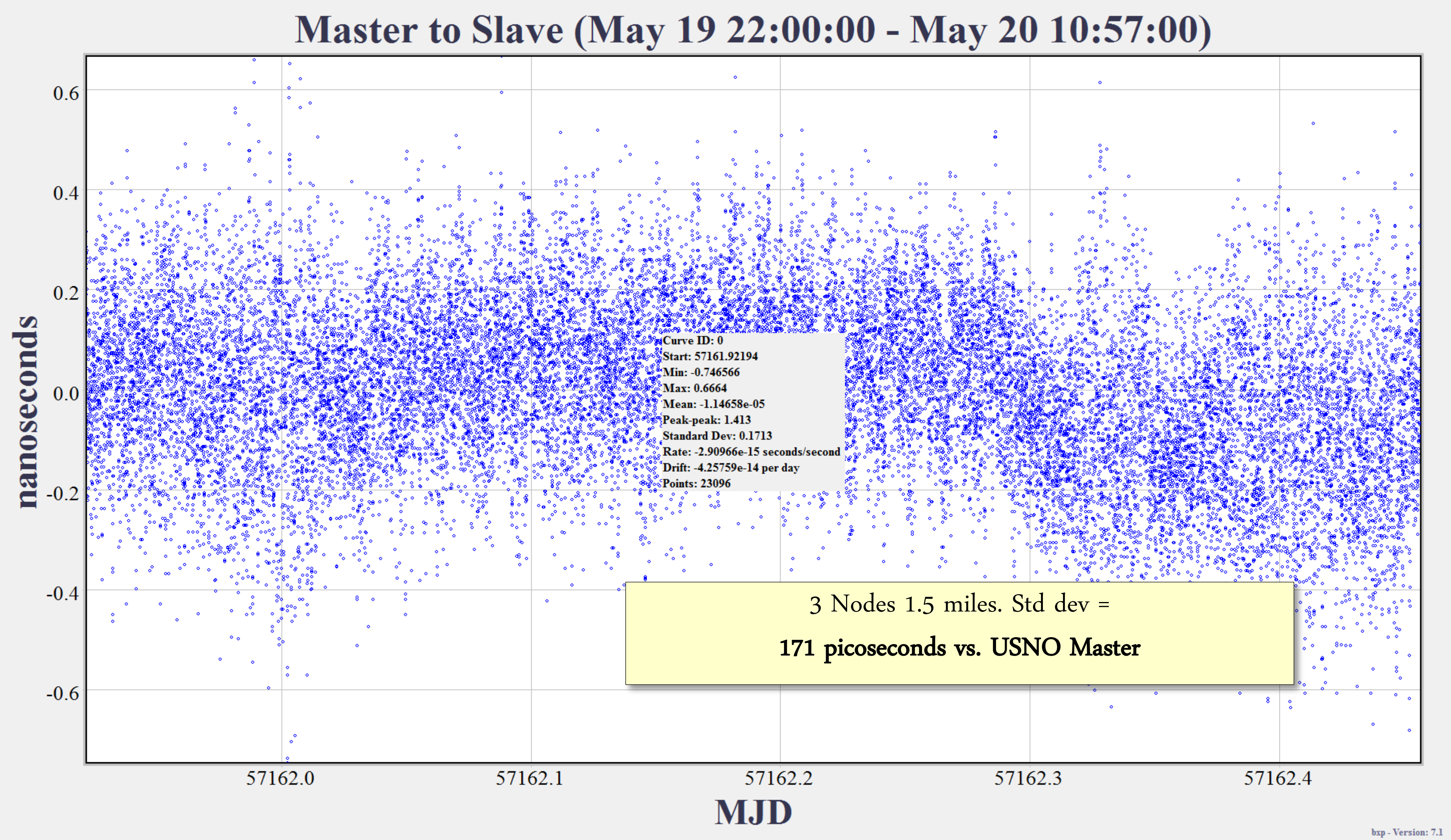


USNO measurement configuration



3-Node Setup (Total Range: 2.401km/1.49mi)

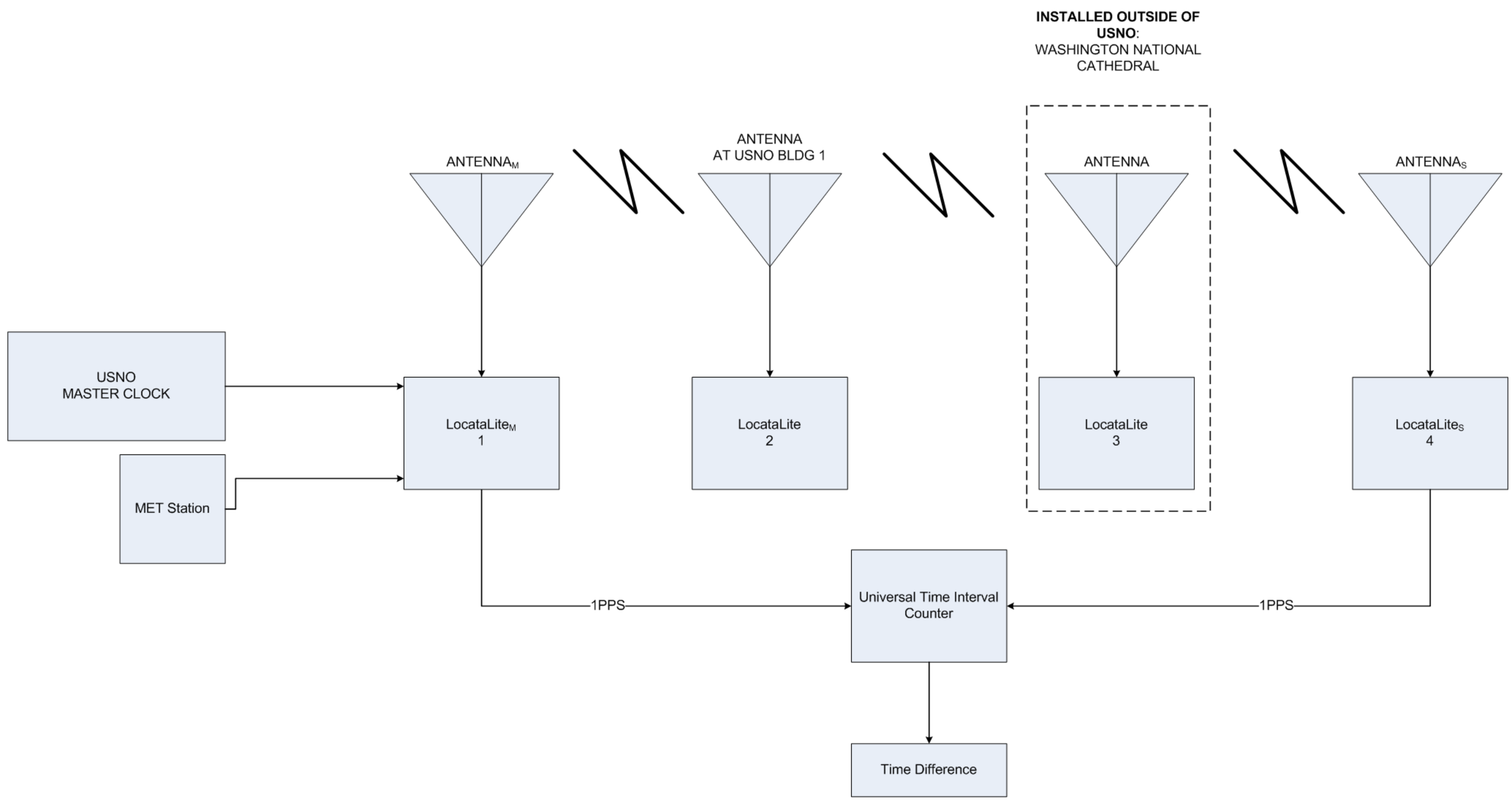
USNO Data Collection – May 19-20, 2015



3 Nodes 1.5 miles. Std dev =

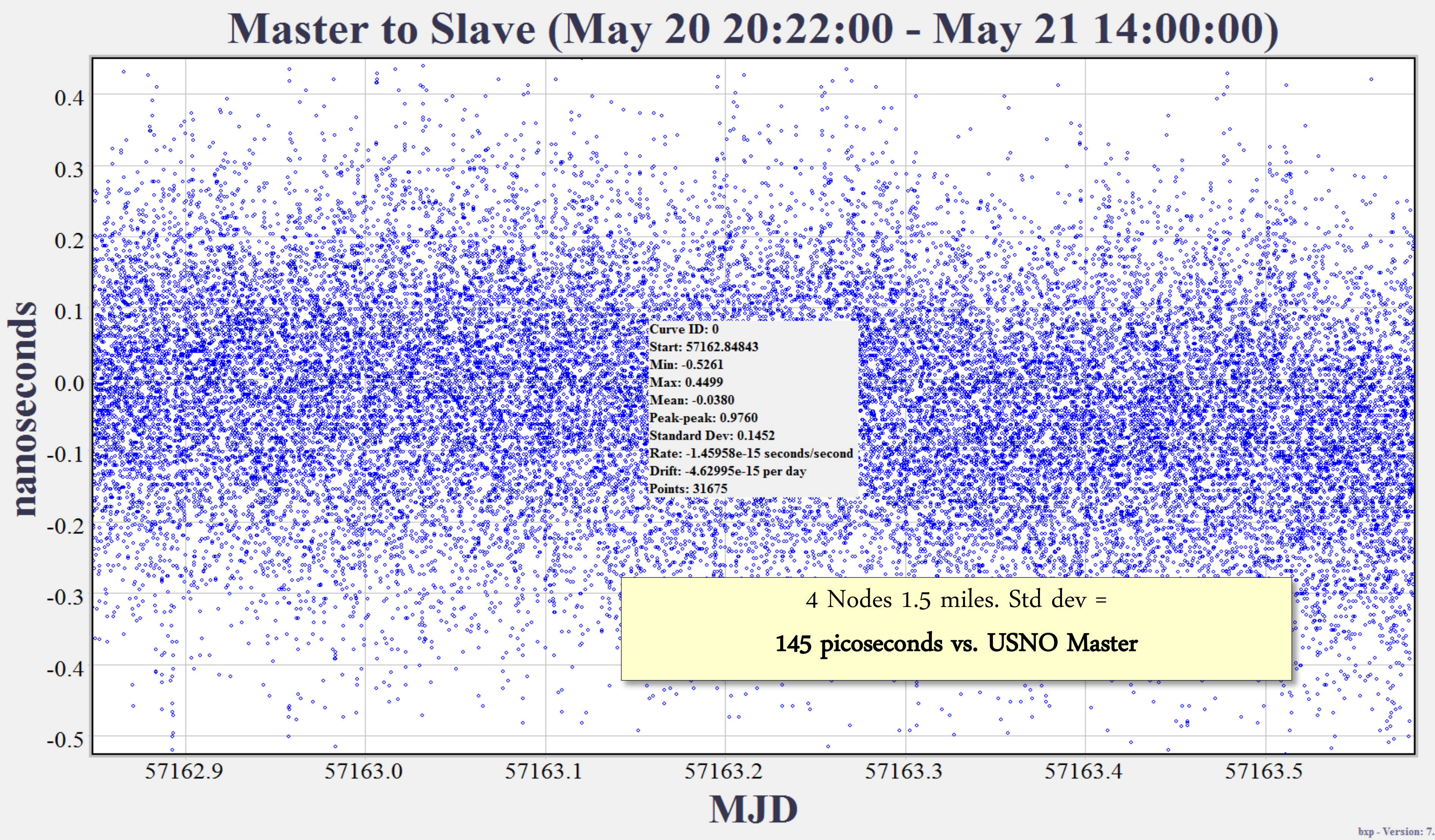
171 picoseconds vs. USNO Master

USNO measurement configuration



4-Node Setup (Total Range: 2.413km/1.5mi)

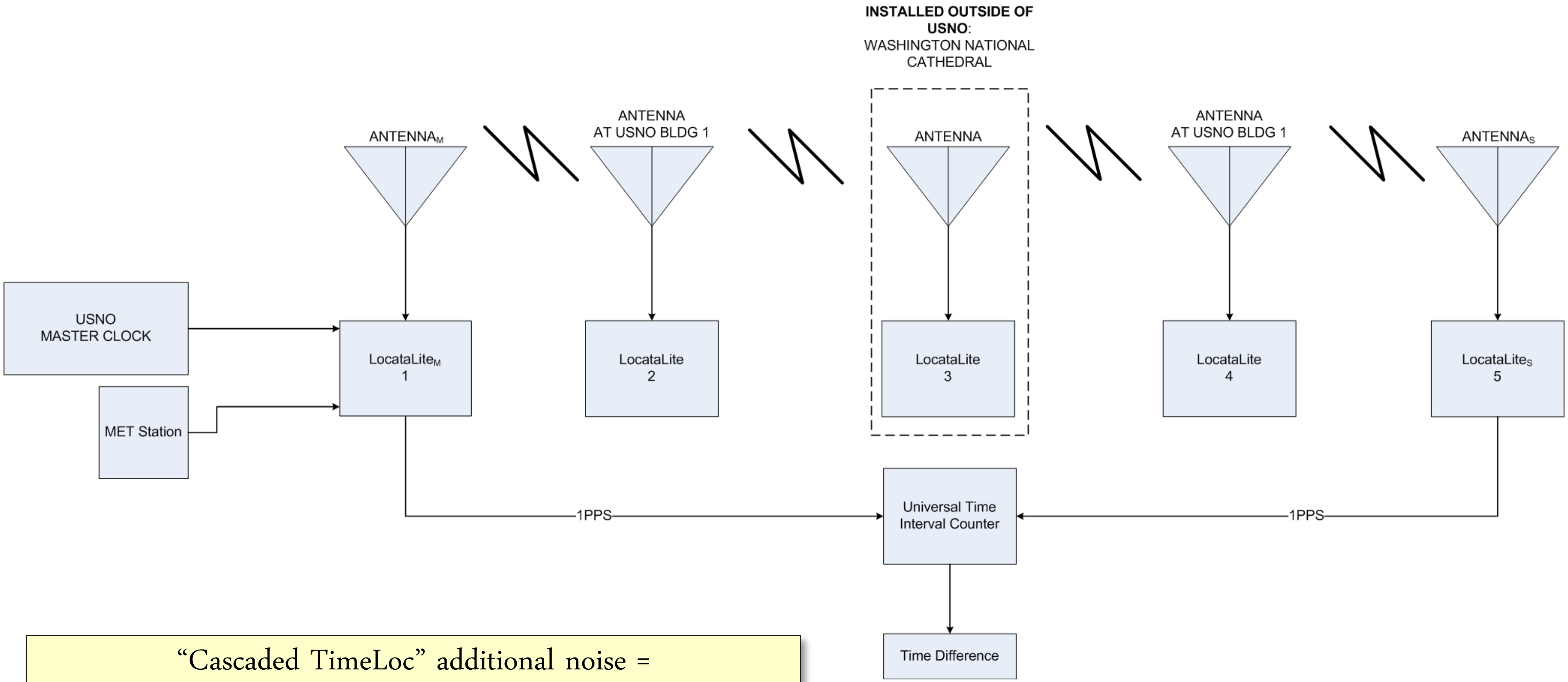
USNO Data Collection – May 20-21, 2015



4 Nodes 1.5 miles. Std dev =

145 picoseconds vs. USNO Master

USNO measurement configuration

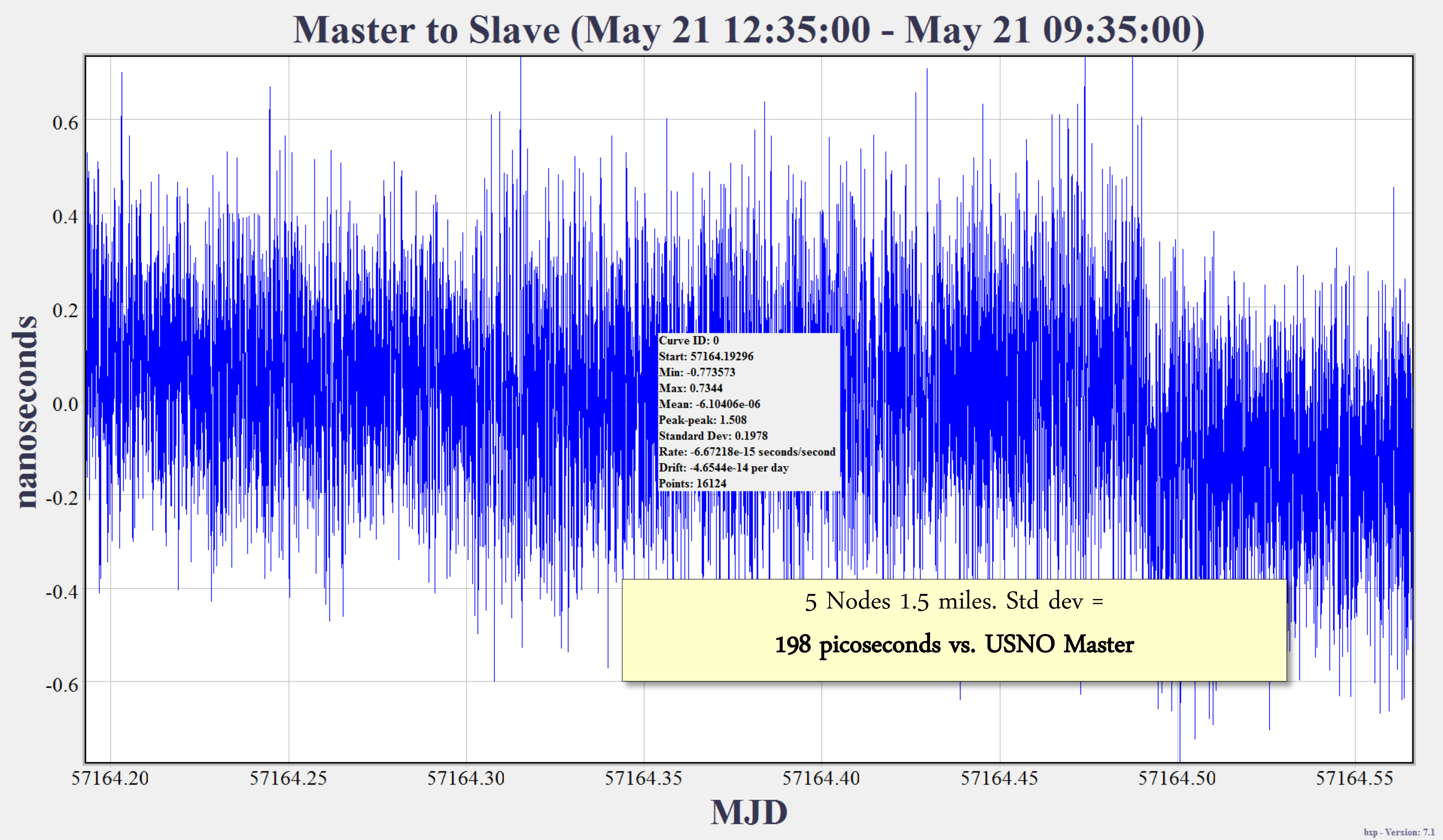


"Cascaded TimeLoc" additional noise =

25 picoseconds per hop

5-Node Setup (Total Range: 2.427km/1.51mi)

USNO Data Collection – May 21, 2015



Summary of Results from USNO testing

- Results from the USNO ION papers published September 2015
- Frequency stability was estimated at 1e-15
  - Stratum 1 is defined as 1e-11

Setup	Data Collected on Modified Julian Date (MJD)	Total Signal Distance from Master to Terminal Slave LocataLite	Standard Deviation (picoseconds)	Change in RMS from short baseline 2-node setup (picoseconds)
2-node (Fig. 10)	MJD 56948.756 to 56949.937	15.24m/50ft	**51.095**	N/A
3-node (Fig.11, FAA Bldg.)	MJD 57104.044 to 57104.583	5.794km/3.6mi	**127.333**	76.238
3-node (Fig. 12, Nat. Cath.)	MJD 57161.922 to 57162.457	2.401km/1.49mi	**171.325**	120.230
4-node (Fig. 13)	MJD 57162.848 to 57163.583	2.413km/1.5mi	**145.247**	94.152
5-node (Fig. 14)	MJD 57164.193 to 57164.566	2.427km/1.51mi	**197.766**	146.671

TimeLoc Synch - operational modes

- The LocataNets today can be easily synchronized to GPS time via a GPS disciplined atomic clock
- This is generally used keep the Locata and GPS measurements time aligned for easy GPS integration
- When GPS is jammed or lost, the atomic clock provides hold-over to keep Locata and GPS time tightly aligned
- However…

  even if the clock is removed, the LocataNet still provides the exact same positioning accuracy and time synchronization in coverage area

- *Clearly* an excellent "backup for critical infrastructure"

Critical Infrastructure backup in cities

Example Illustration in NY

Time Synchronization

This is available now…

Thank you

Nunzio Gambale & Jimmy LaMance

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