UrsaNav

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Wide Area Time distribution Via eLoran

NASPI WG Meeting

March 22 2017

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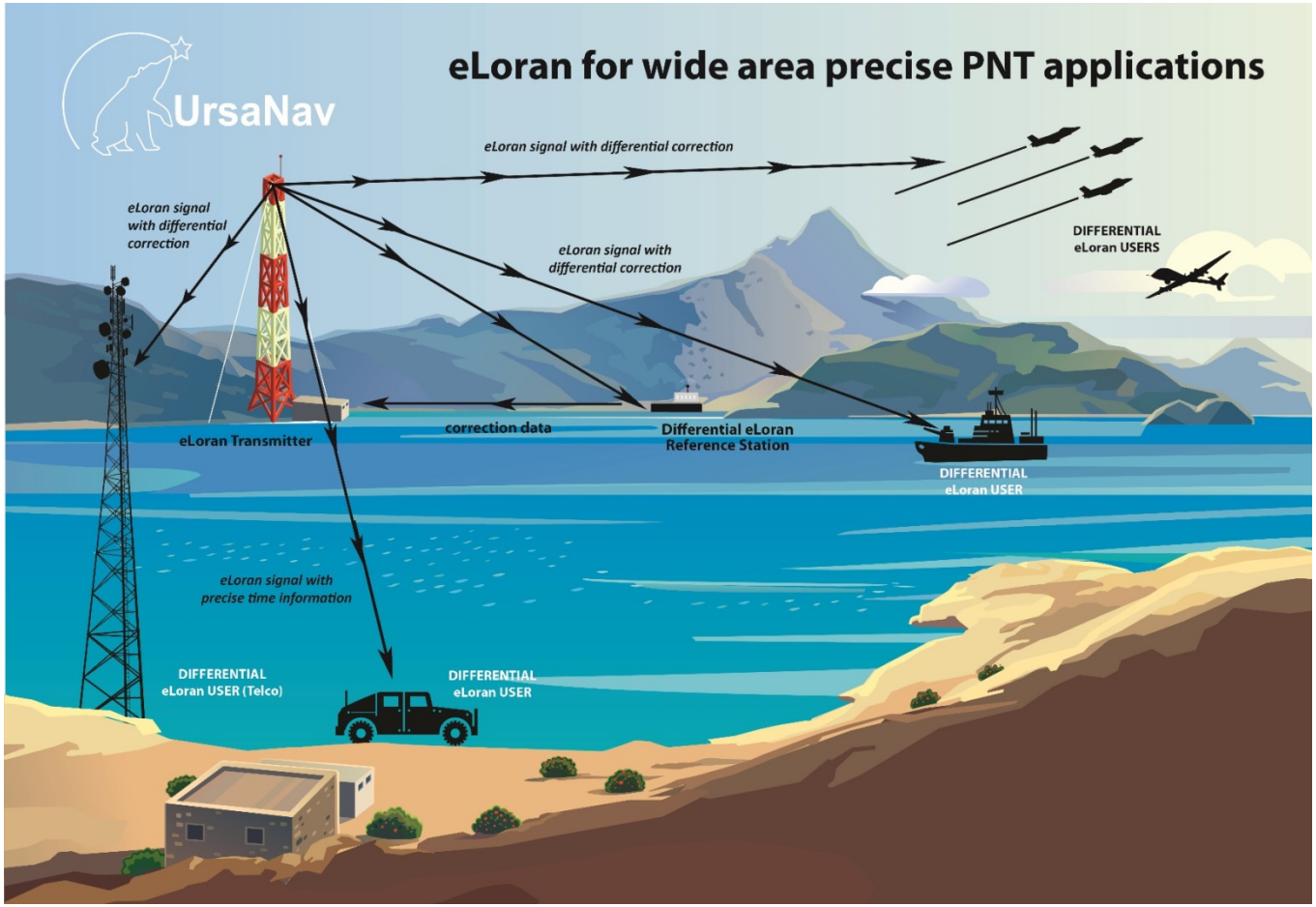
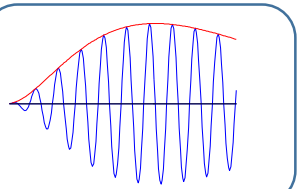
Agenda

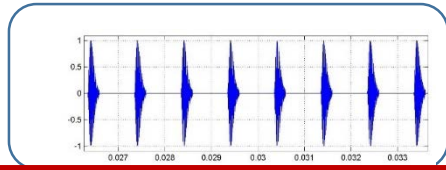
- eLoran in Brief
  - Overview
  - Differences between Loran-C and eLoran
  - Capabilities
- eLoran CRADA Results
  - Description
  - Detailed Results
  - What Does it mean?
- eLoran Timing coverage in the US
  - Potential <1 µs Coverage
  - Potential <100ns Coverage
  - Challenges in high RF environments

What is Loran eLoran?

eLoran-21







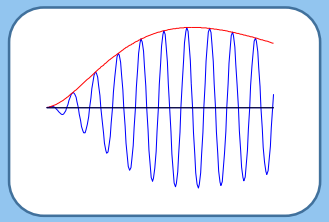
What is Loran-C?

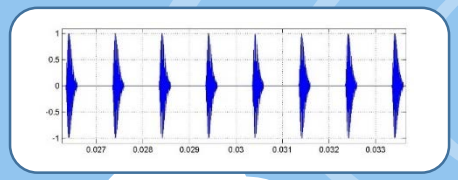
eLoran-21

Loran-C:

- Developed by **DOD**
- Global PNT standard: 1957-1994
- Regional PNT standard: 1994 - present
- Radio Frequency (RF) system
- 90 – 110 kHz internationally protected spectrum
- **Ground wave** signal
- Very **high power**

- Pulsed
- Stratum-1e frequency standard
- Positioning, Navigation, Timing





What is Enhanced Loran (eLoran)?

eLoran-21

Enhanced Loran:

All the good stuff from Loran-C, plus:

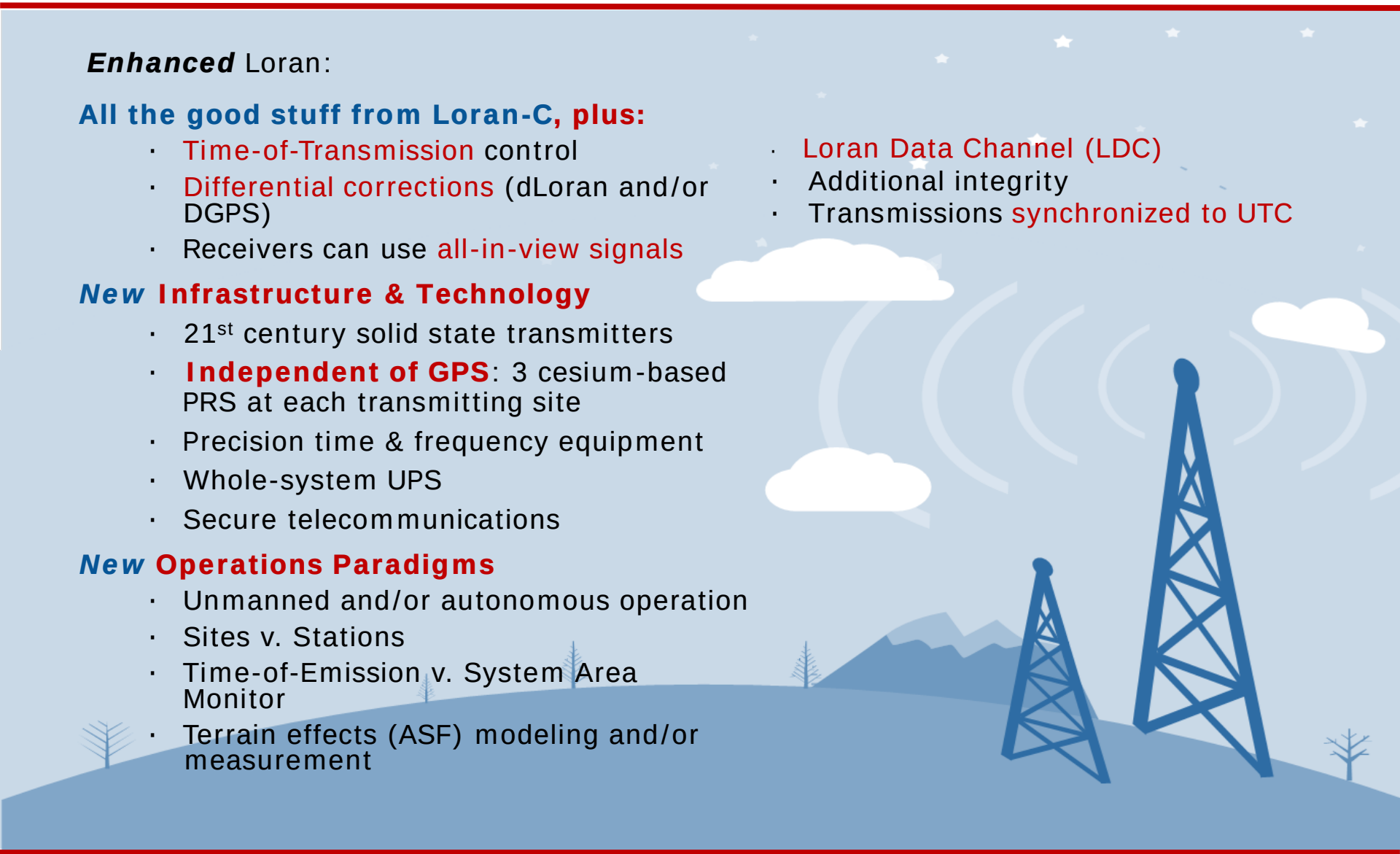
- Time-of-Transmission control
- Differential corrections (dLoran and/or DGPS)
- Receivers can use all-in-view signals
- Loran Data Channel (LDC)
- Additional integrity
- Transmissions synchronized to UTC

***New* Infrastructure & Technology**

- 21st century solid state transmitters
- **Independent of GPS**: 3 cesium-based PRS at each transmitting site
- Precision time & frequency equipment
- Whole-system UPS
- Secure telecommunications

***New* Operations Paradigms**

- Unmanned and/or autonomous operation
- Sites v. Stations
- Time-of-Emission v. System Area Monitor
- Terrain effects (ASF) modeling and/or measurement



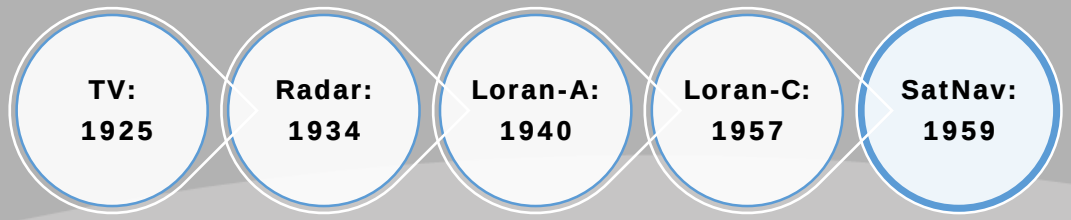
GPS and (e)Loran

How are they *similar?*

- Developed by / for DOD
- Time traceable to UTC
- Provide PNT
- Better with Augmentations
- Stratum-1e

- Hyperbolic
- Global Standards
- Free (when Government provided)
- Azimuth / Compass
- Ground Infrastructure

Old / Antiquated?



GPS (GNSS) and (e)Loran

How are they *different*?

System:	GNSS | eLoran
Frequency:	High | Low
Power:	Very Low | Very High
Transmissions:	Space | Terrestrial
Jamming:	Easy | Very Hard
Spoofing:	Easy | Very Hard
Integrity:	None | Built In
Data Channel:	None | At least one
Reach:	Global | Continental
Accuracy:	Best | Good
Positioning:	3D | 2D*
Propagation:	Atmosphere | Ground
View Required:	Clear | Obstructed OK

*3D with altimeter

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  - Potential <100ns Coverage
  - Challenges in high RF environments

Evaluate eLoran as a Wide Area Timing Source

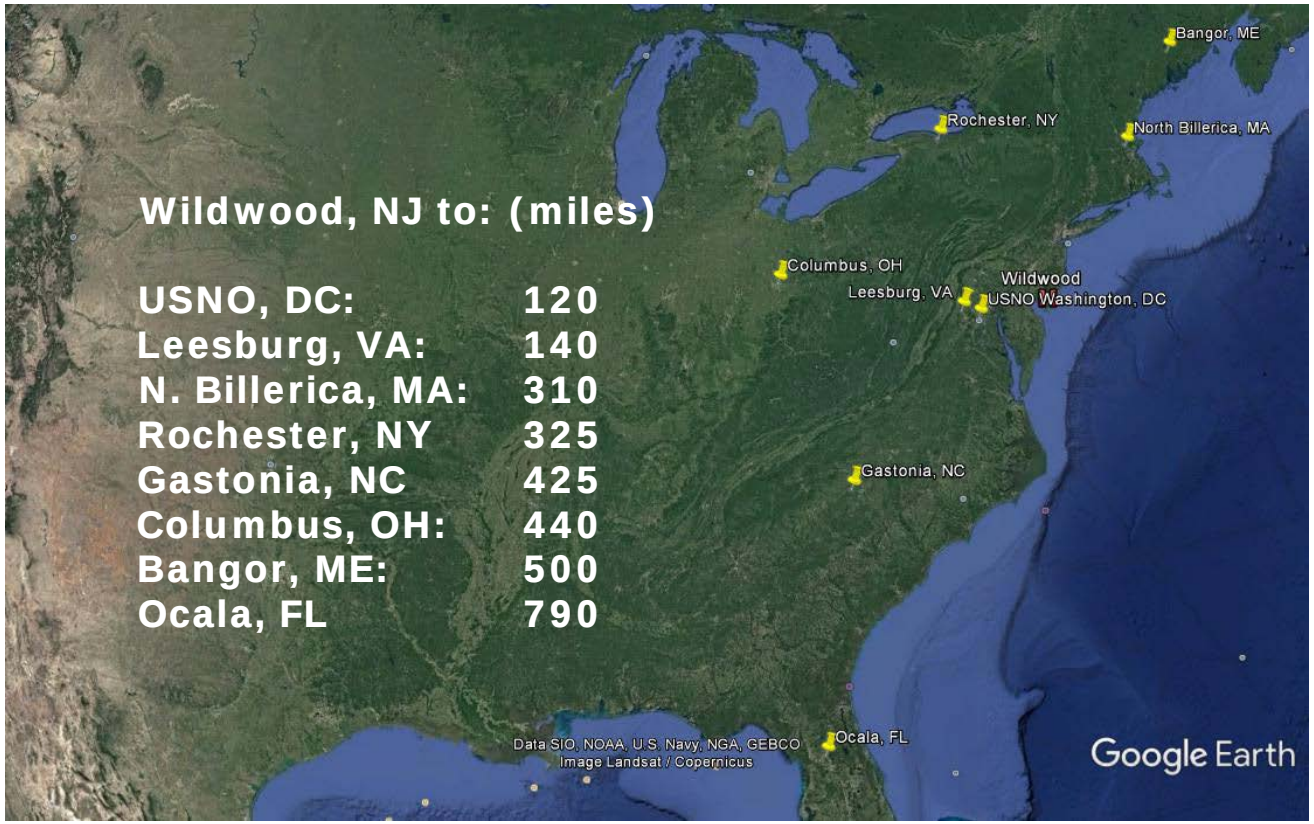
- Transmissions from former USCG Loran Support Unit site at Wildwood, NJ
  - 360 KW Effective Radiated Power
  - Two Way Satellite Time Transfer (TWSTT) UTC reference from the US Naval Observatory

- Receivers
  - Bangor, ME (500 Miles)
  - N. Billerica, MA (310 Miles)
  - Columbus, OH (440 Miles)
  - Washington, DC (USNO) (120 Miles)
  - Leesburg, VA (140 Miles)
  - Ocala, FL (790 Miles)

- Technology
  - Outdoor E-Field antenna
  - Outdoor Loop antenna
  - Loran Data Channel (LDC) demodulation available
  - GPS and/or 5071A Cesium Primary Reference Standard used as comparison

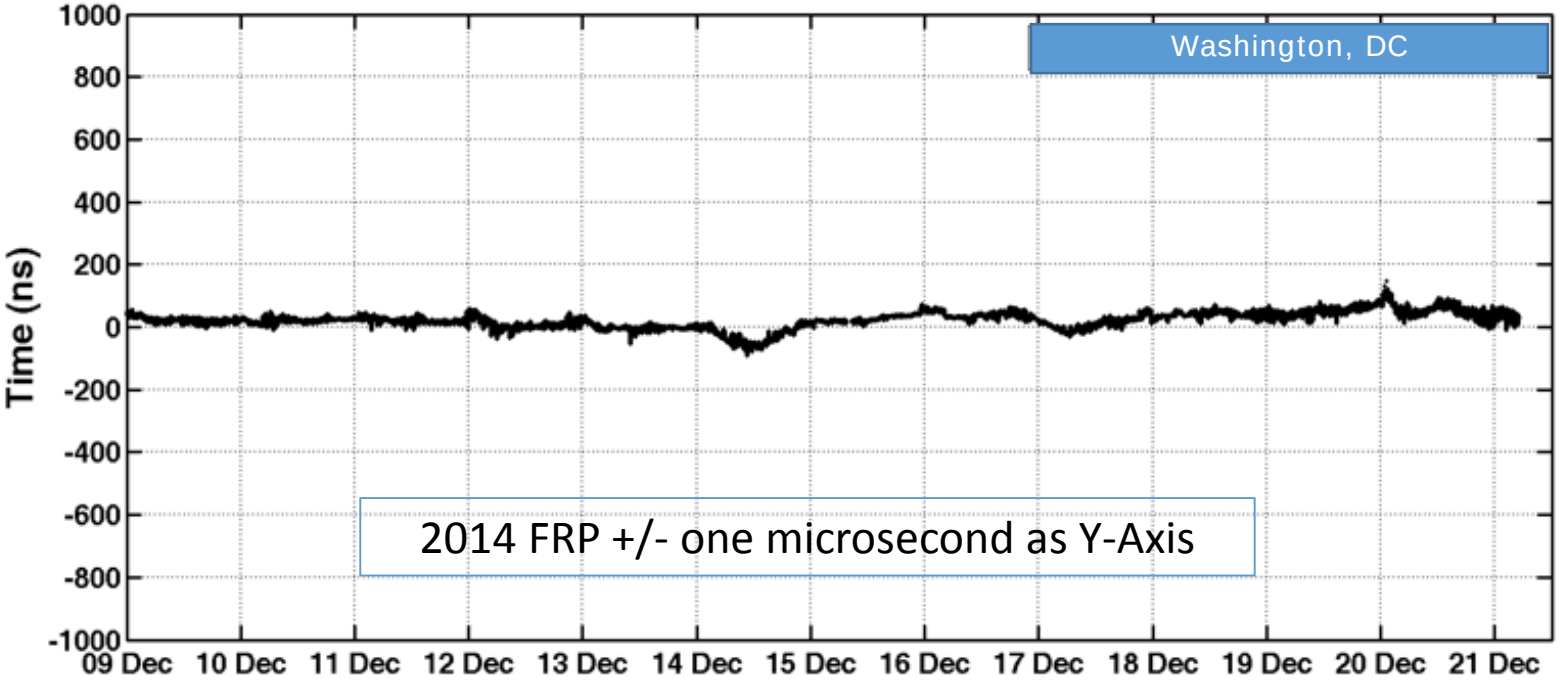
- Criteria
  - Meet one microsecond 2014 FRP timing user requirement

eLoran Timing Evaluation Technology Laydown



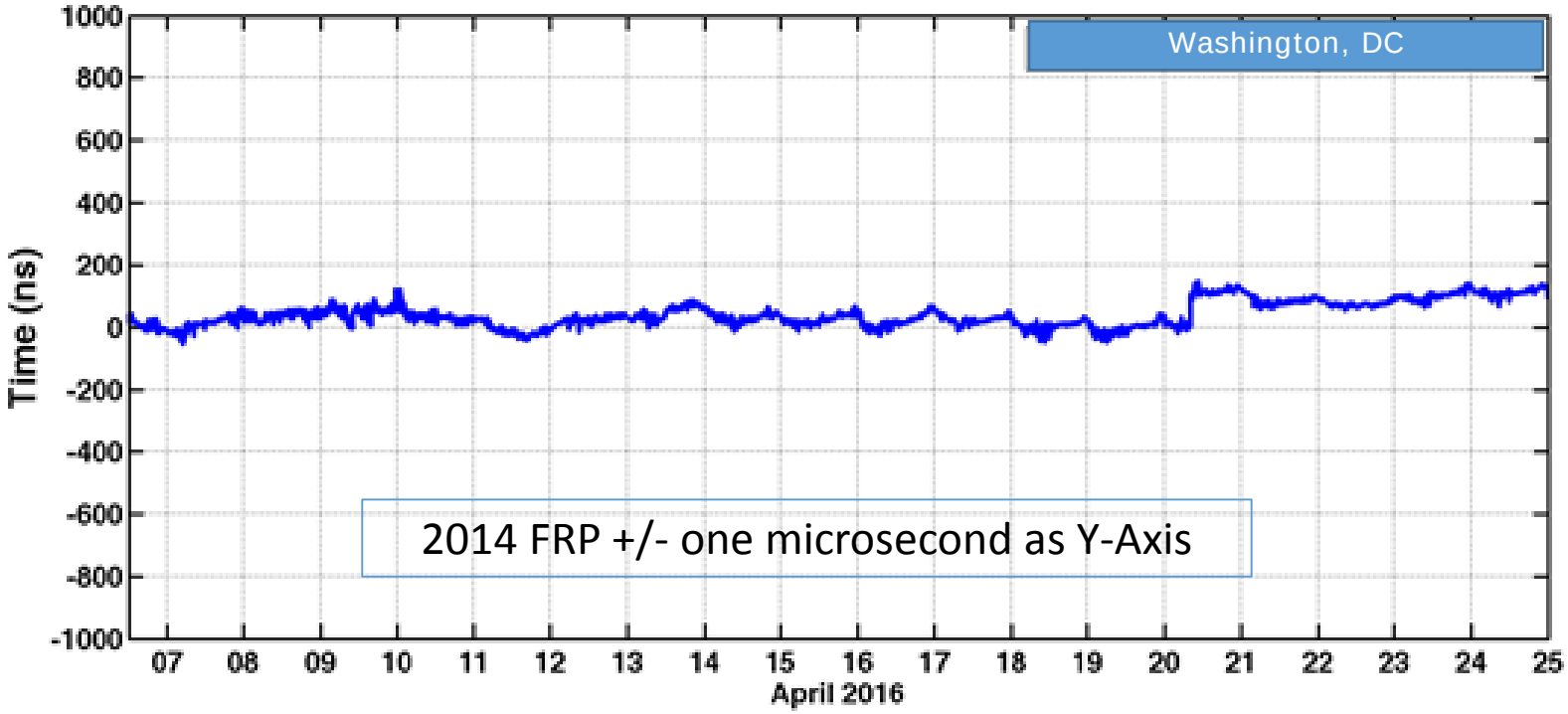
- eLoran transmitter at Wildwood, NJ
  - Synchronized to UTC via Two Way Satellite Time Transfer (TWSTT) provided by US Naval Observatory
  - 360KW of Effective Radiated Power
  - Broadcasting dual rated as 8970 Master and Secondary
  - LDC broadcast only on 8970 Secondary at raw data rate of 56 bps; effective rate of 21 bps
- Differential eLoran Reference sites at:
  - North Billerica, MA
  - Leesburg, VA
  - Gastonia, NC (Temporary)

Wildwood, NJ to Washington, DC (USNO)



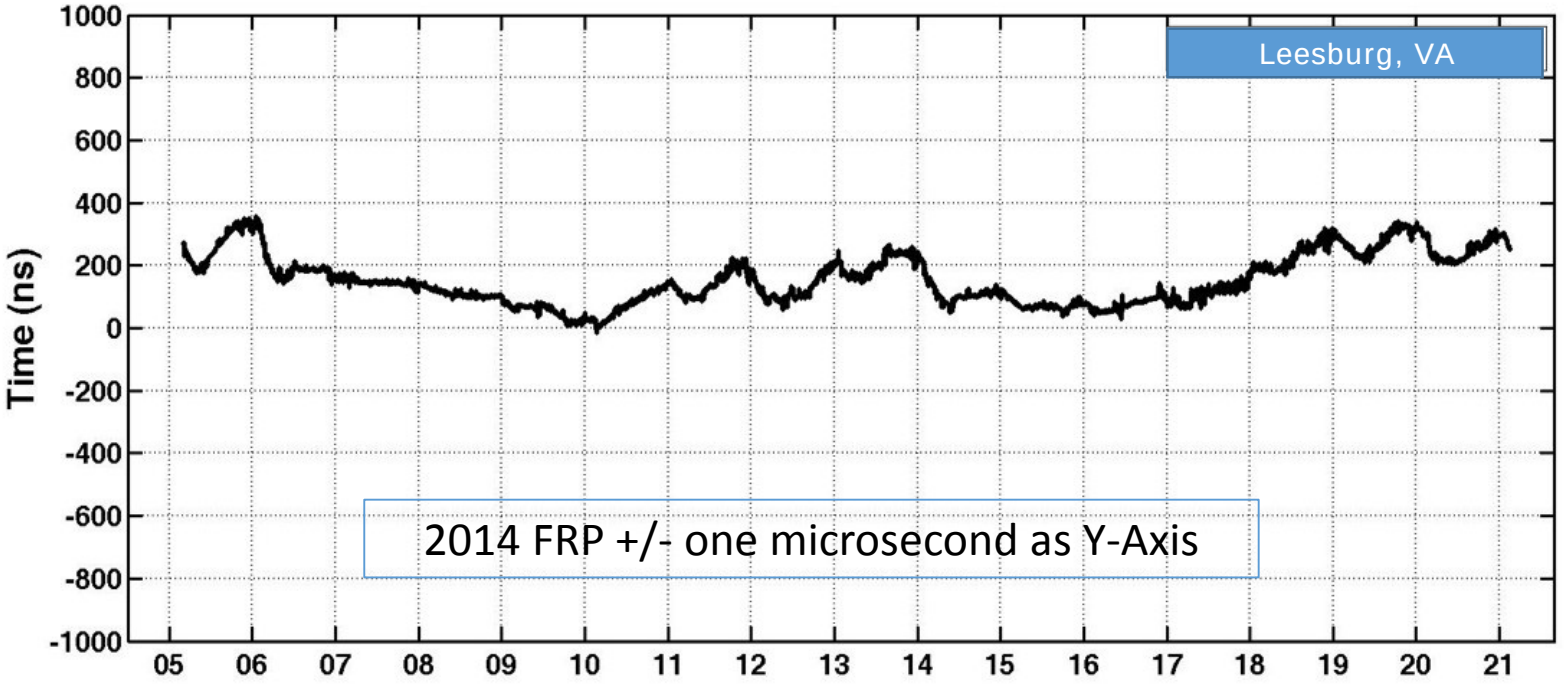
Period: December 2015
Distance to XMTR: 120 miles
Mean: 22.9 ns
STD: 26.1 ns
Max: 147.0 ns
Min: -90.0 ns

Wildwood, NJ to Washington, DC (USNO)



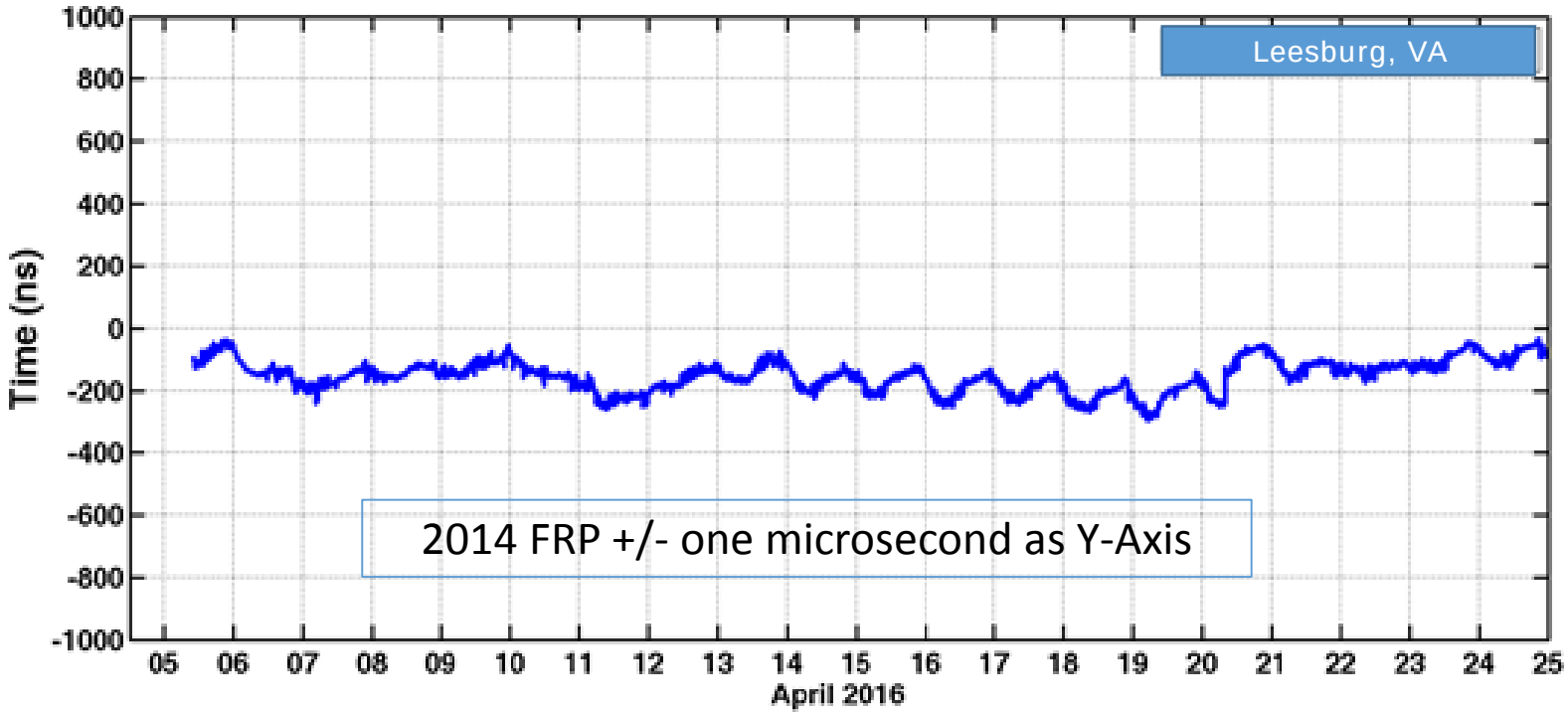
Period: April 2016
Distance to XMTR: 120 miles
Mean: 41.3 ns
STD: 39.4 ns
Max: 147.0 ns
Min: -57.0 ns

Wildwood, NJ to Leesburg, VA



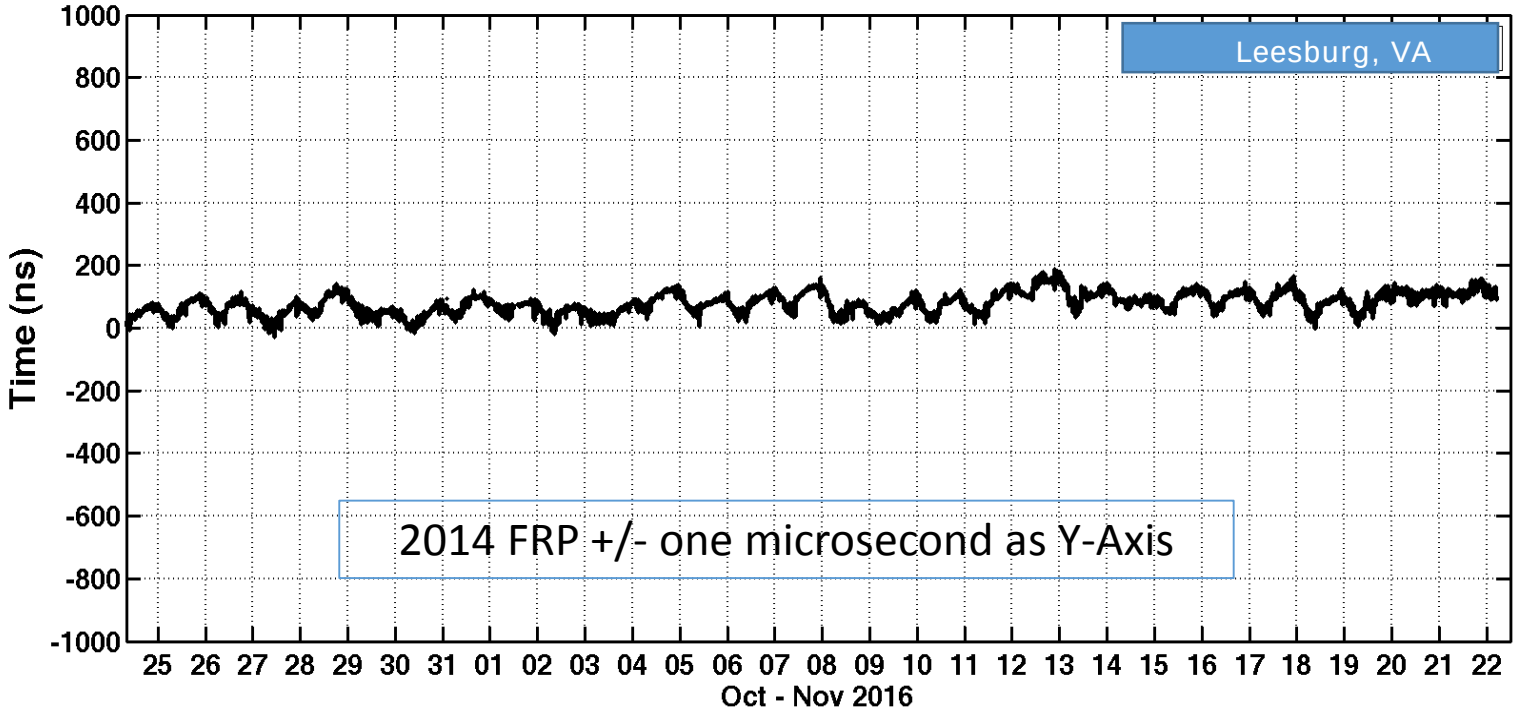
Period: January 2016
Distance to XMTR: 140 miles
Mean: 153.6 ns
STD: 79.9 ns
Max: 358.0 ns
Min: -16.0 ns

Wildwood, NJ to Leesburg, VA



Period: April 2016
Distance to XMTR: 140 miles
Mean: -153.0 ns
STD: 49.1 ns
Max: -31.0 ns
Min: -298.0 ns

Wildwood, NJ to Leesburg, VA



Period: October – November 2016

Distance to XMTR: 140 miles

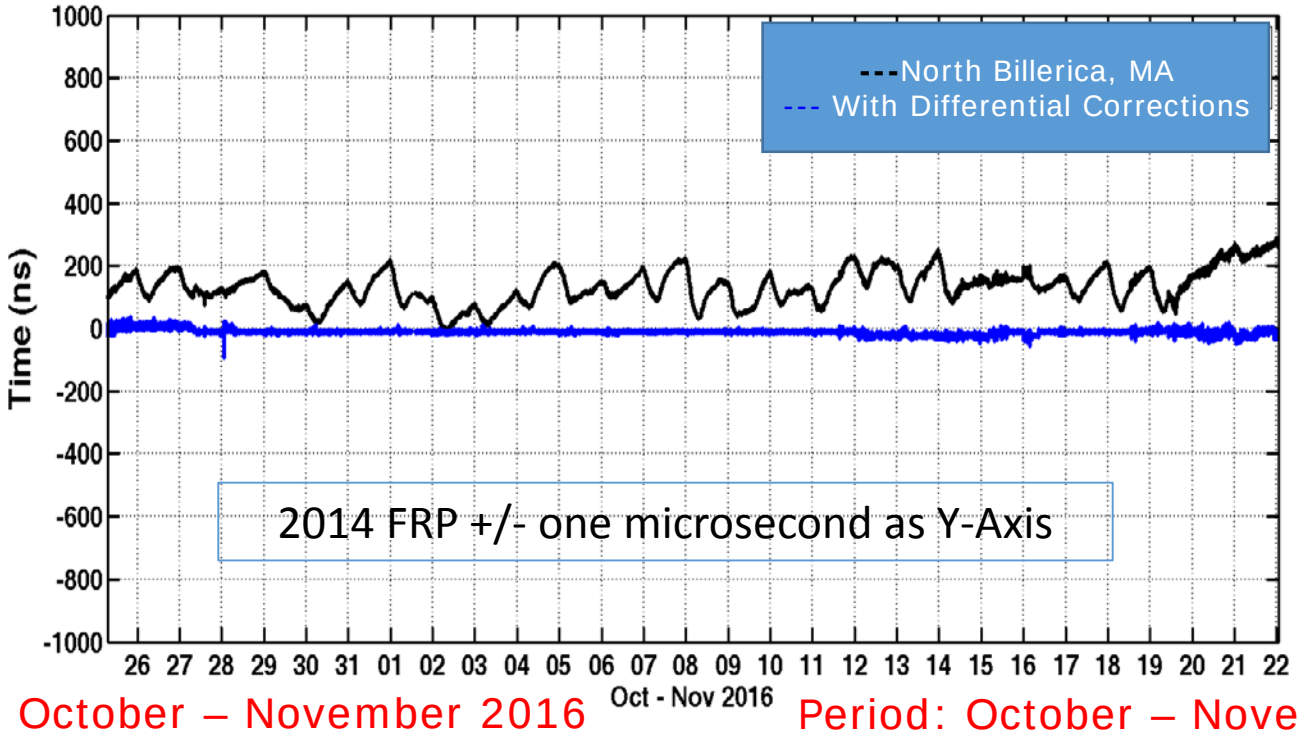
Mean: 79.1

Std : 33.1

Max : 188.0

Min : -29.0

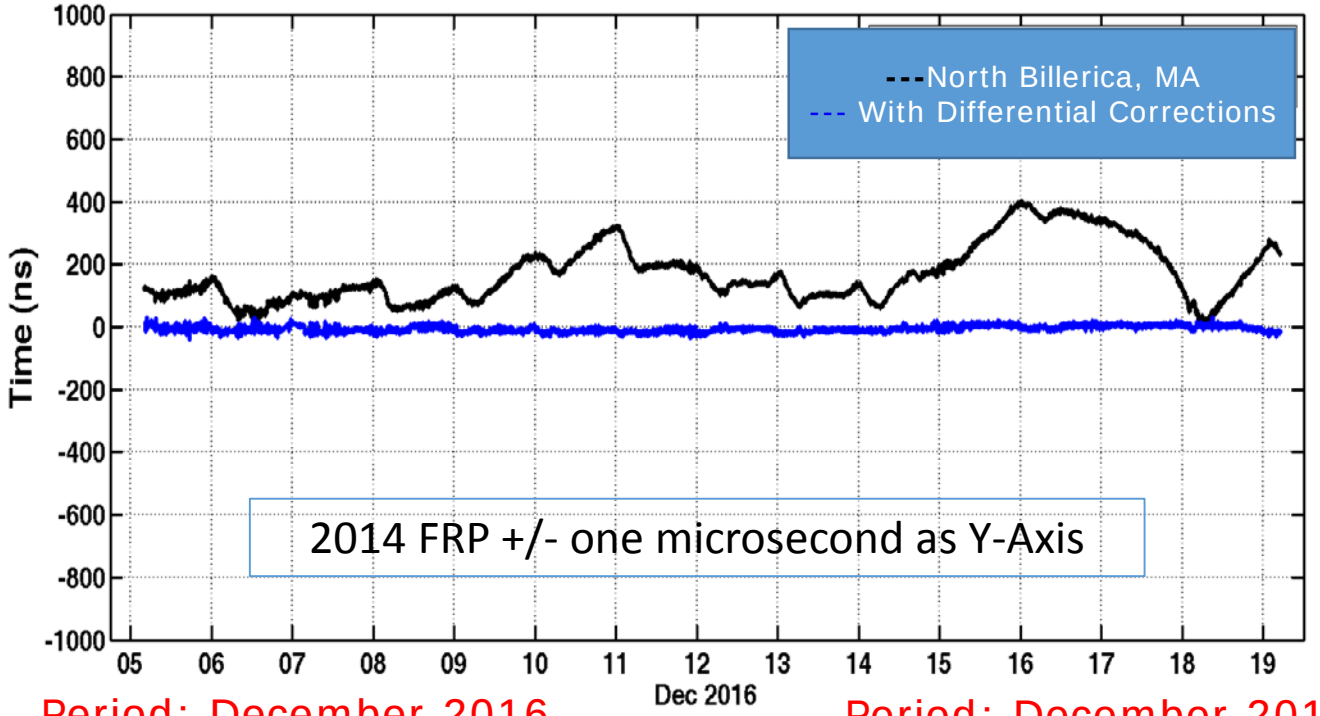
Wildwood, NJ to North Billerica, MA
With and Without Differential Corrections



Period: October – November 2016
Distance to XMTR: 310 miles
Without Differential corrections
Mean: 134.1
Std : 54.6
Max : 292.0
Min : -12.0

Period: October – November 2016
Distance to XMTR: 310 miles
With Differential corrections
Mean: -10.5
Std : 8.1
Max : 38.0
Min : -95.0

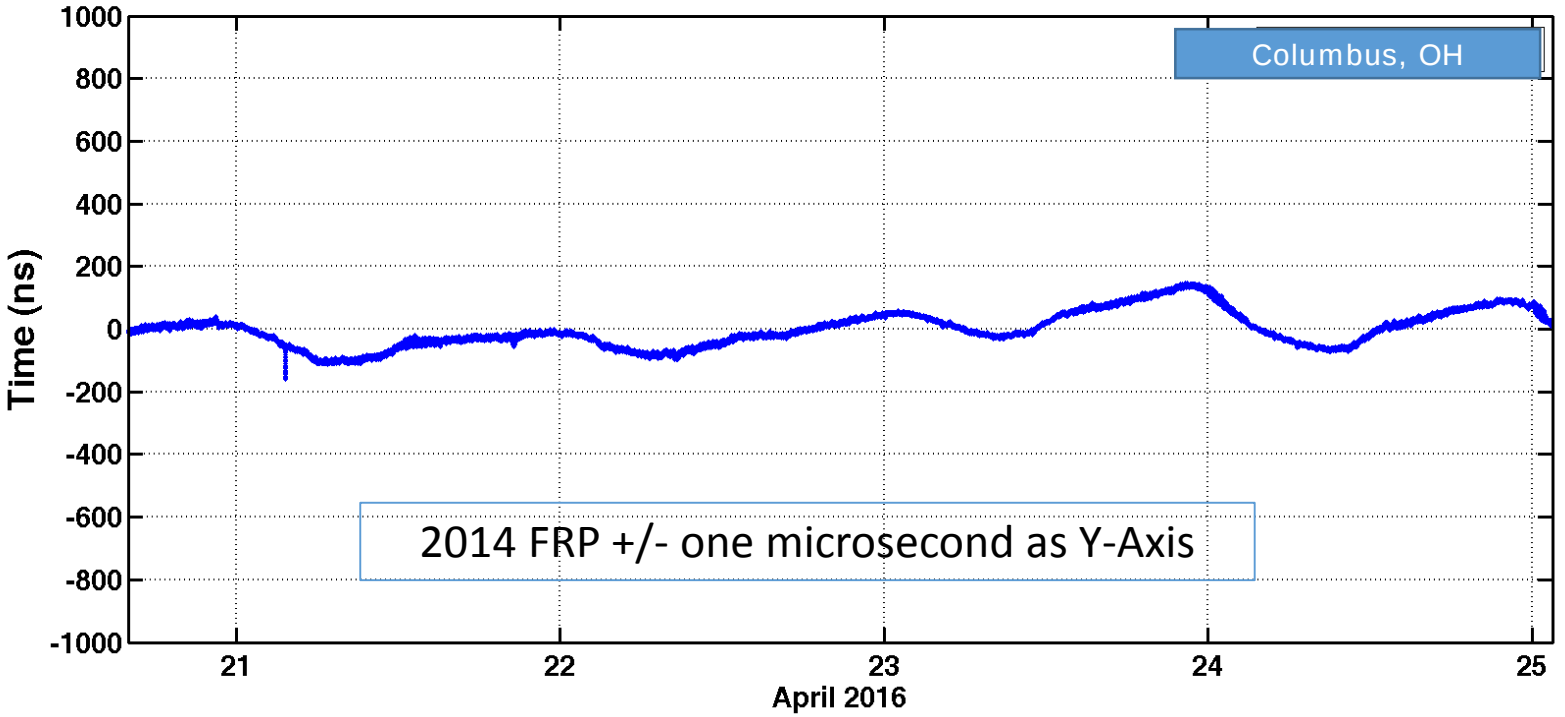
Wildwood, NJ to North Billerica, MA
With and Without Differential Corrections



Period: December 2016
Distance to XMTR: 310 miles
Without Differential corrections
Mean: 171.7
Std : 92.8
Max : 404.0
Min : 12.0

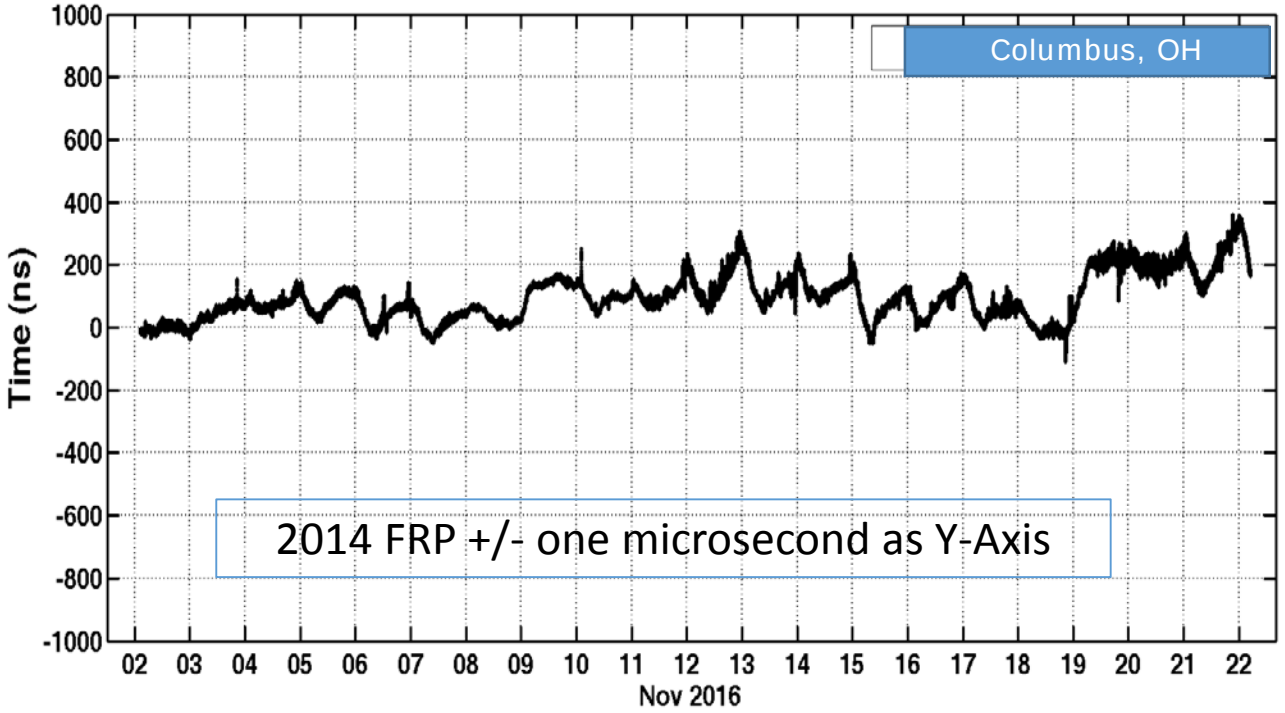
Period: December 2016
Distance to XMTR: 310 miles
With Differential corrections
Mean: -5.1
Std : 9.7
Max : 32.0
Min : -40.0

Wildwood, NJ to Columbus, OH



Period: April 2016
Distance to XMTR: 440 miles
Mean: 170.4 ns
STD: 56.4 ns
Max: 148.6 ns
Min: -159.4 ns

Wildwood, NJ to Columbus, OH



Period: November 2016

Distance to XMTR: 440 miles

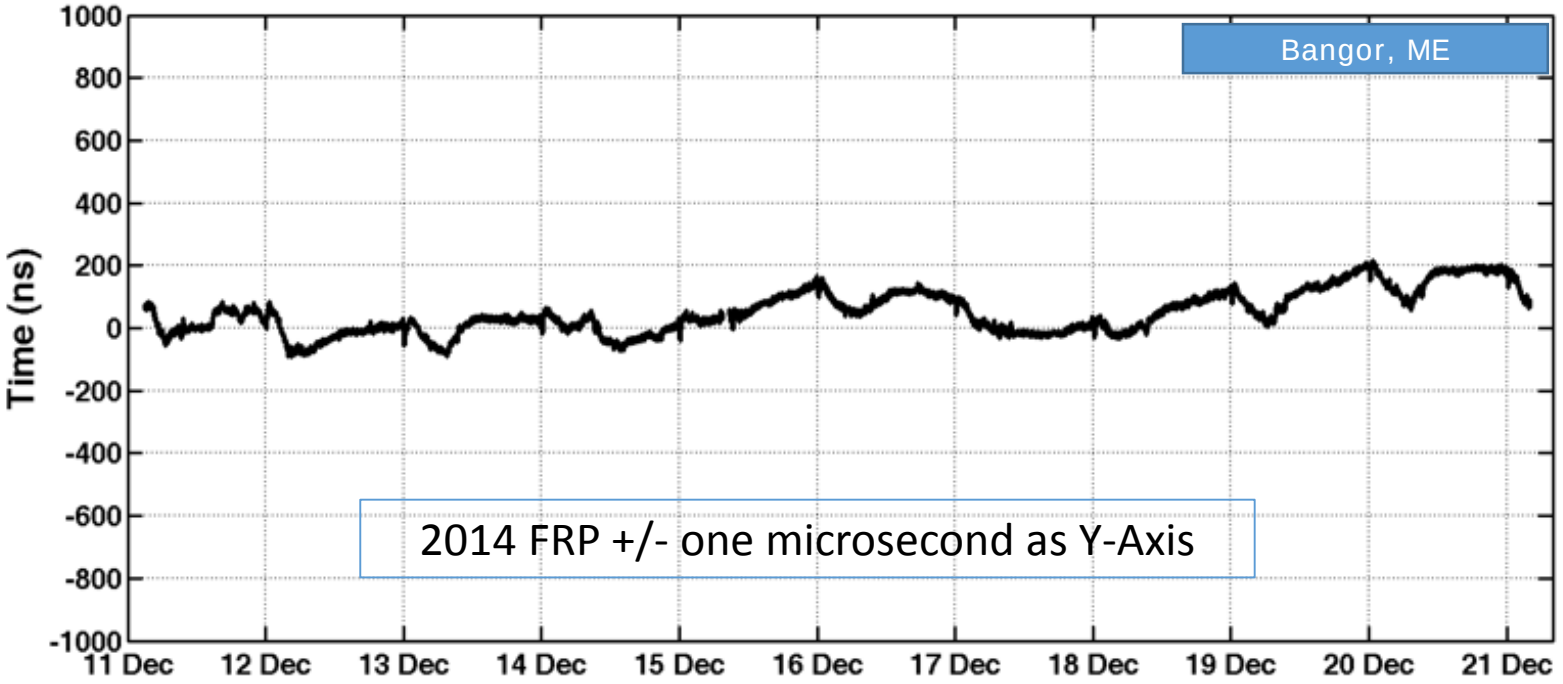
Mean: 93.8

Std : 74.1

Max : 361.0

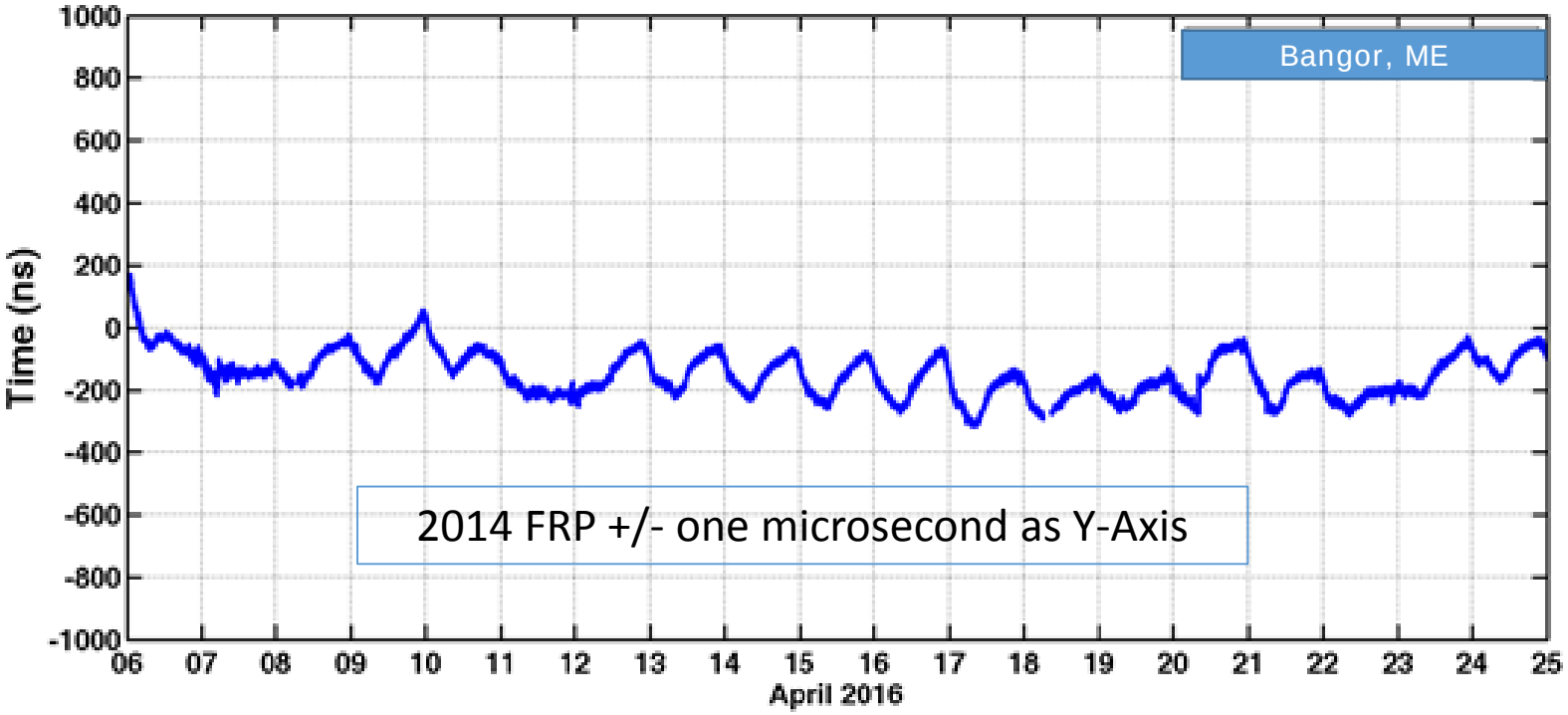
Min : -109.0

Wildwood, NJ to Bangor, ME



Period: December 2015
Distance to XMTR: 500 miles
Mean: 49.7 ns
STD: 68.6 ns
Max: 216.0 ns
Min: -91.0 ns

Wildwood, NJ to Bangor, ME



Period: April 2016

Distance to XMTR: 500 miles

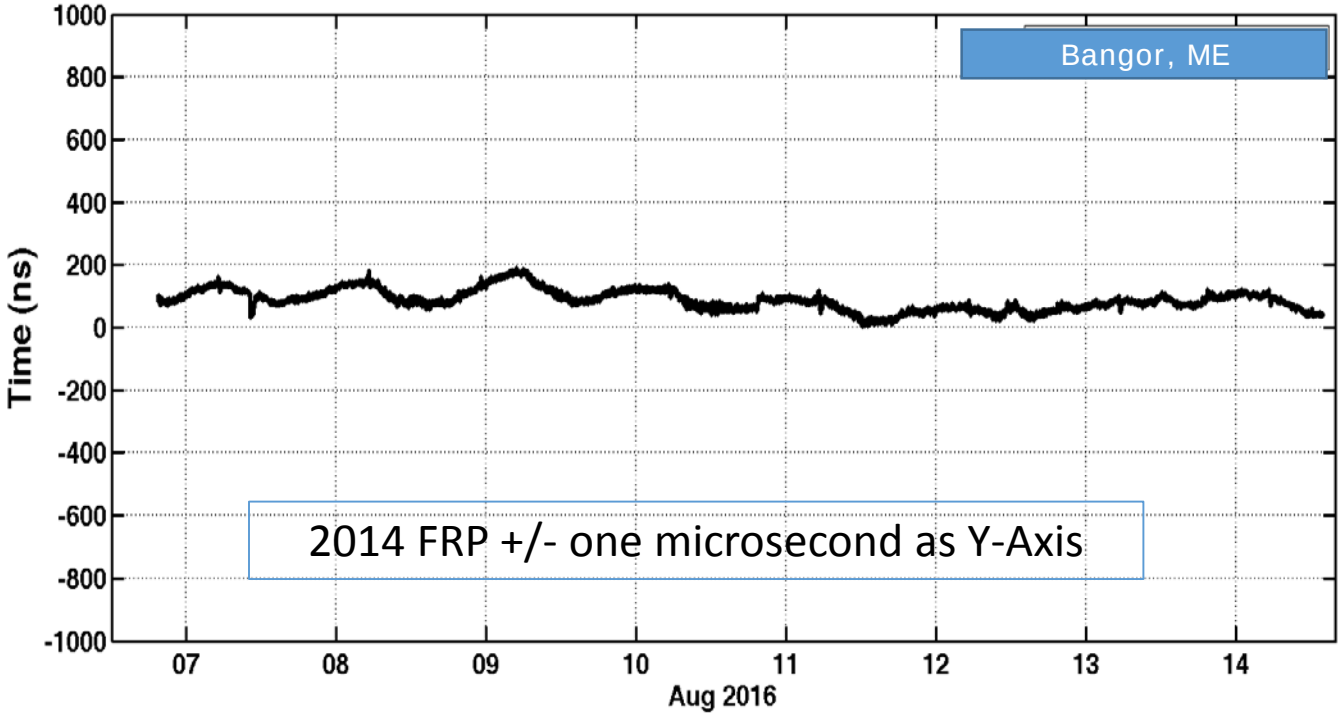
Mean: -149.1 ns

STD: 69.7 ns

Max: 171.0 ns

Min: -318.0 ns

Wildwood, NJ to Bangor, ME



Period: August 2016

Distance to XMTR: 500 miles

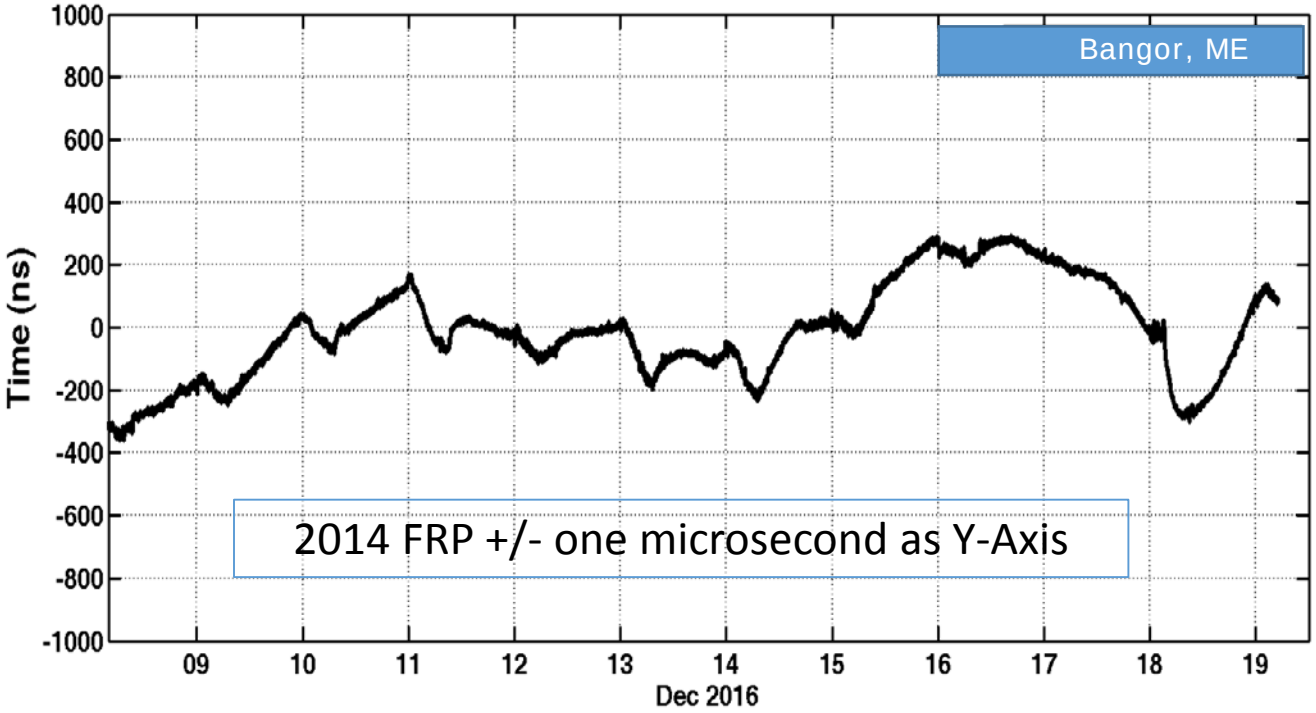
Mean: 87.6

Std : 32.9

Max : 191.0

Min : 2.0

Wildwood, NJ to Bangor, ME



Period: December 2016

Distance to XMTR: 500 miles

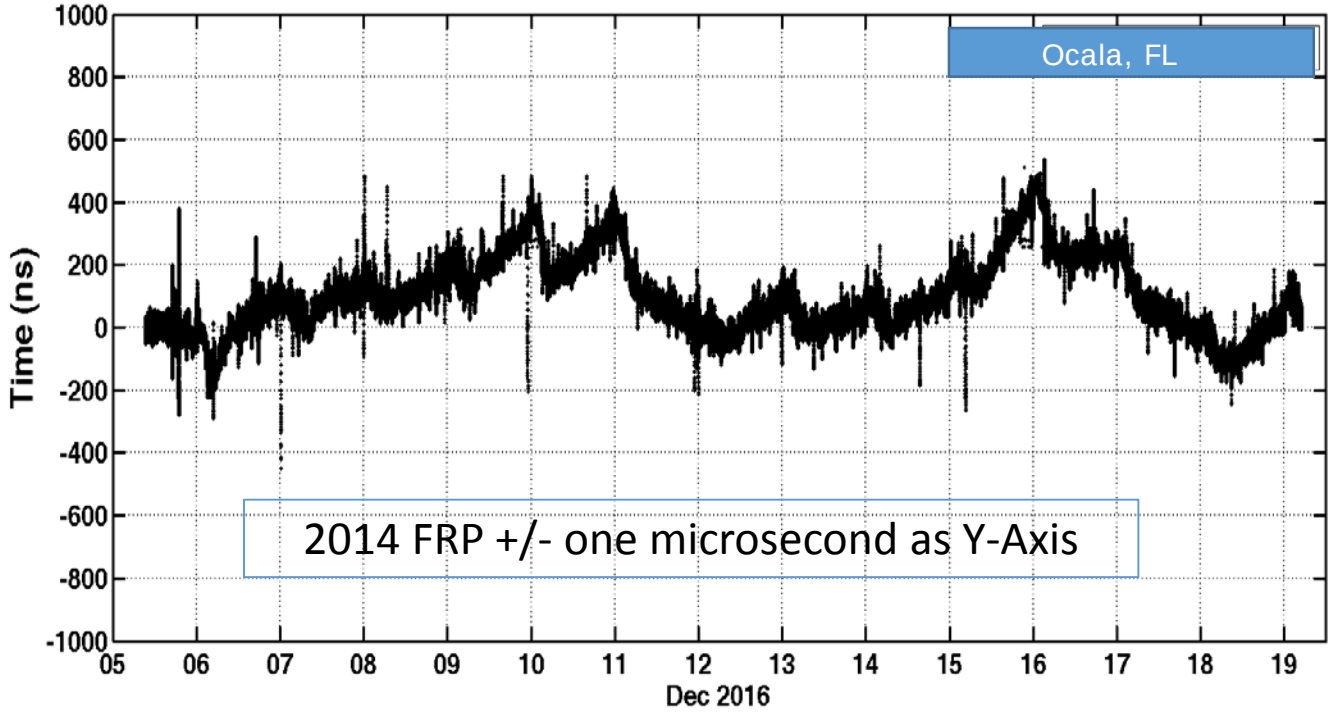
Mean: -9.1

Std : 154.2

Max : 294.0

Min : -361.0

Wildwood, NJ to Ocala, FL User Receiver



Period: December 2016

Distance to XMTR: 790 miles

Mean: 93.0

Std : 114.7

Max : 536.0

Min : -448.0

eLoran CRADA Summary

- ***Without*** differential corrections or augmentations, eLoran results have easily demonstrated the ability to meet the (+/-) one microsecond timing synchronization requirement proposed in the 2014 Federal Radionavigation Plan (FRP)
- ***Without*** differential corrections or augmentations, eLoran results within a 500 mile range of the test transmitter location have demonstrated (+/-) 500 nanoseconds synchronization to UTC
- ***Without*** differential corrections or augmentations, 95% of all data collected was within 200 Nanoseconds of UTC
- ***With*** differential corrections at certain locations in the vicinity of a Differential eLoran Reference Station, eLoran demonstrated time synchronization to UTC well within 100 nanoseconds
- eLoran was proven in field trials to be a successful backup to GPS timing in a Wide Area Multilateration (WAM) aviation application, providing equivalent performance to GPS
- Additional aviation testing is ongoing, with plans underway to demonstrate precise time synchronization, Loran Data Channel (LDC) communication, and compass (heading) applications in Unmanned Aerial Vehicles and General Aviation aircraft in 2017
- eLoran in Smart Grid application Proofs-of-Concept are planned for later in 2017

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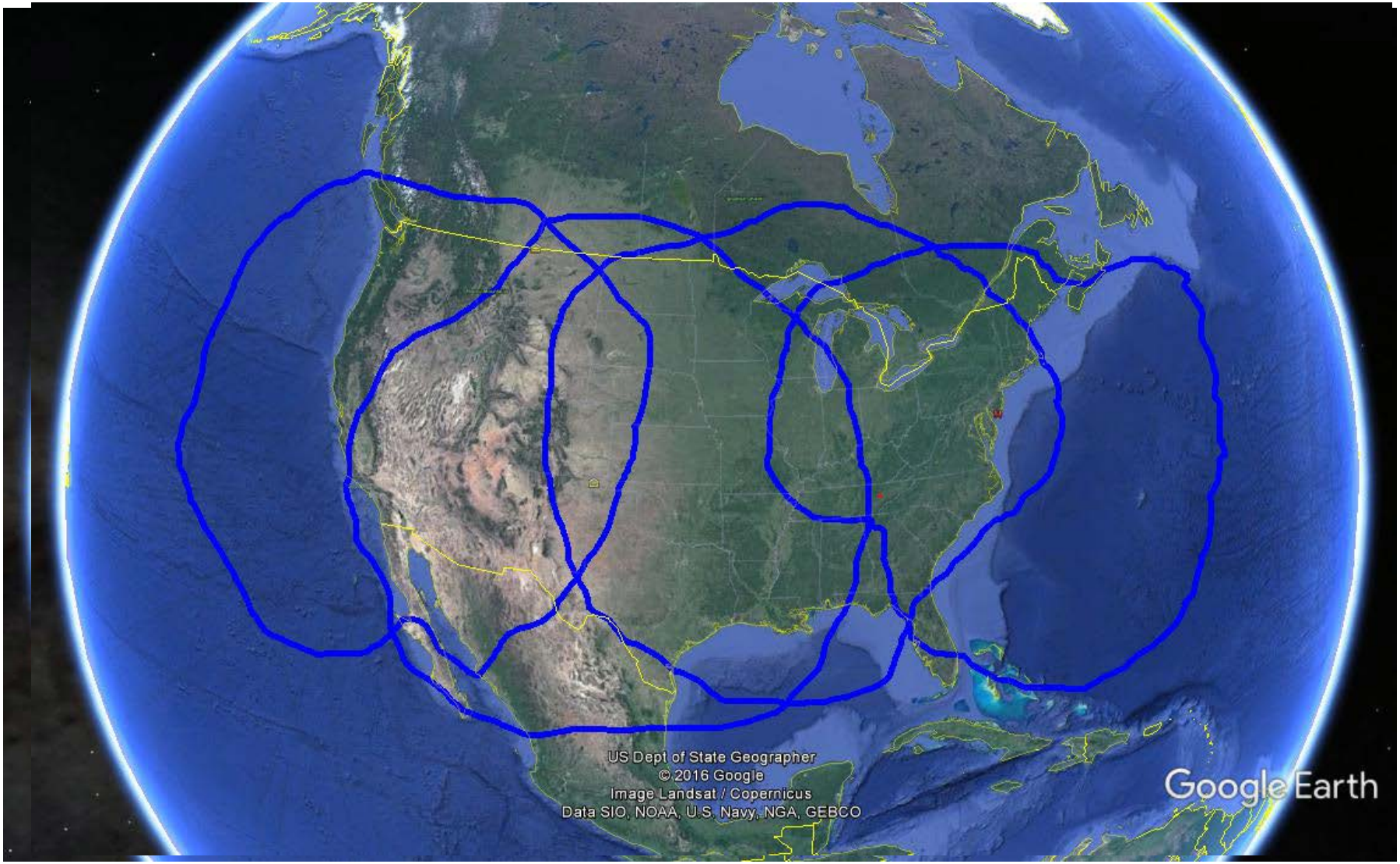
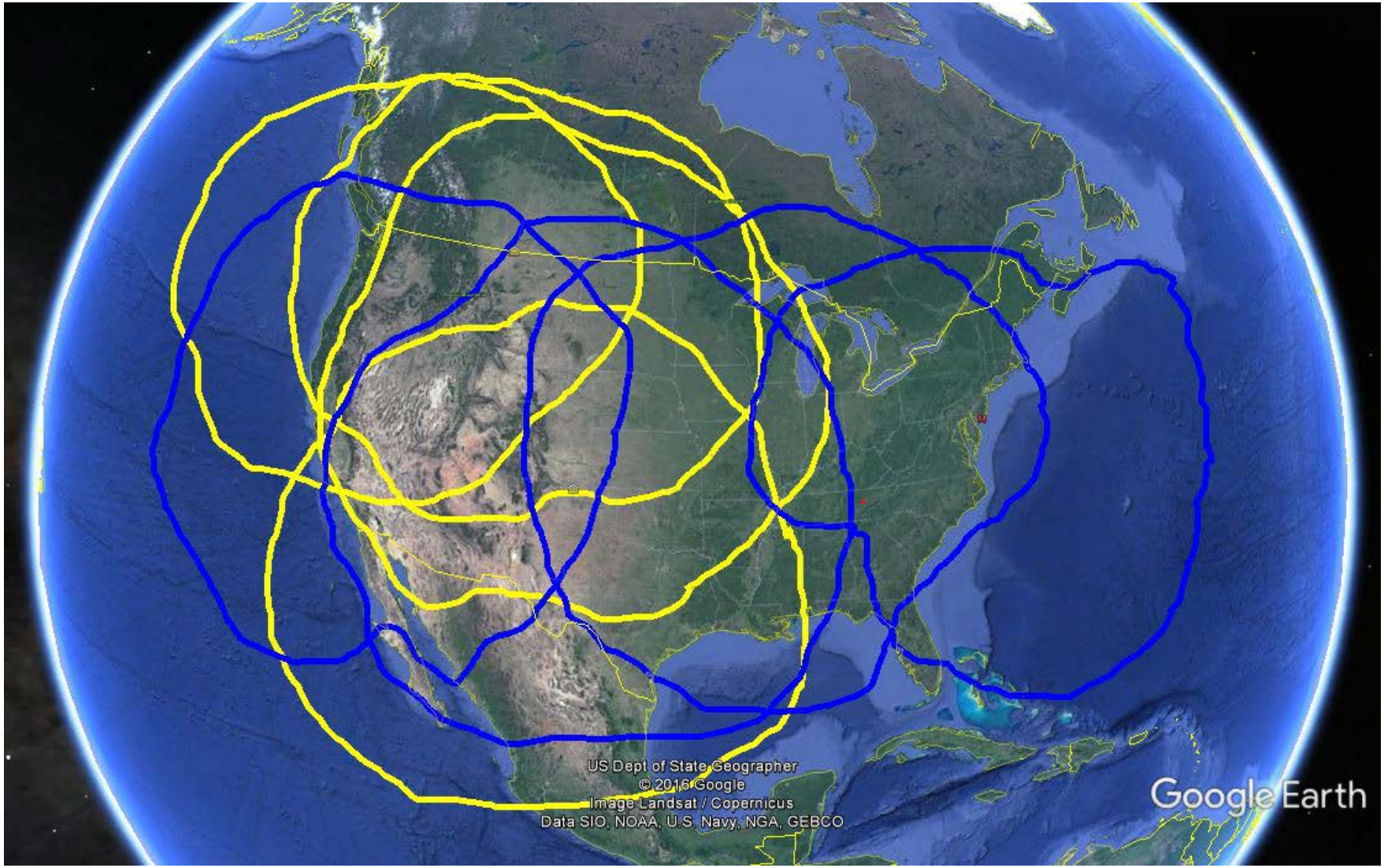
  - Potential <100ns Coverage

Potential 1 µs Coverage – 4 Station



Potential 1 µs Coverage – 8 Station



Representative 100 ns Coverage

Notional Location of Differential eLoran Reference Station Site

Contact Us for Collaborative Efforts!

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