eLORAN – A Viable GNSS Backup

A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

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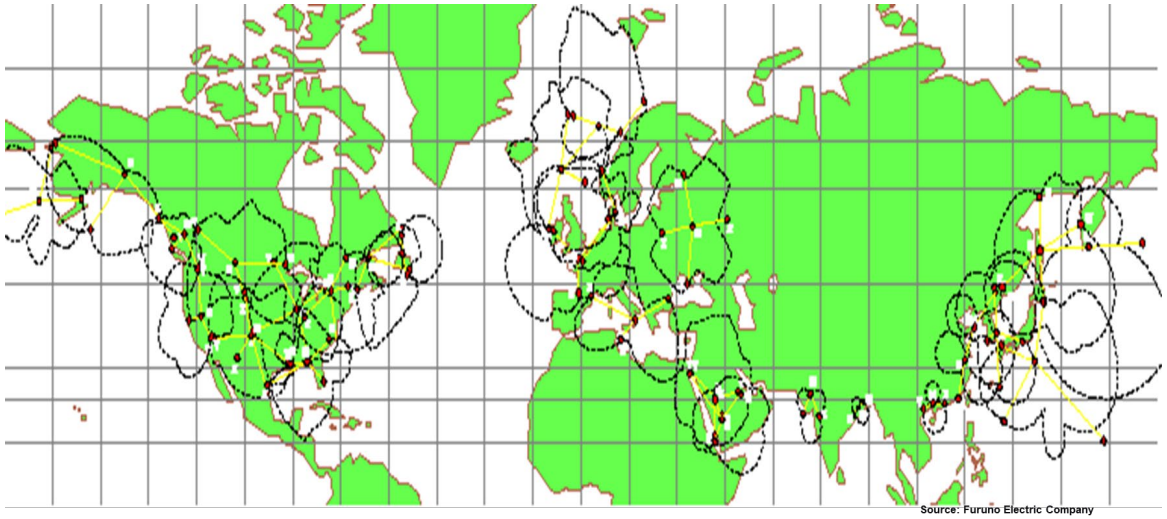
A little history

LORAN-C

Some Background

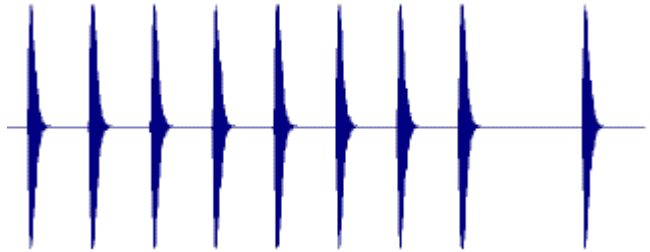
- **Long Range Navigation System – Version C**
  - Operates between 90 KHz and 110 KHz
  - High power (250KW – 1.5MW) peak radiated power
  - Groundwave system
  - Robust frequency standard
  - Excellent availability
- **Developed for maritime navigation in the coastal confluence zone (CCZ)**
- **A supplemental system approved for en-route navigation in the US National Airspace System (NAS)**
- **A Stratum 1 frequency standard**
- **Source of UTC**
  - Master Station provided a time reference to within +/-100 ns of UTC (USNO)

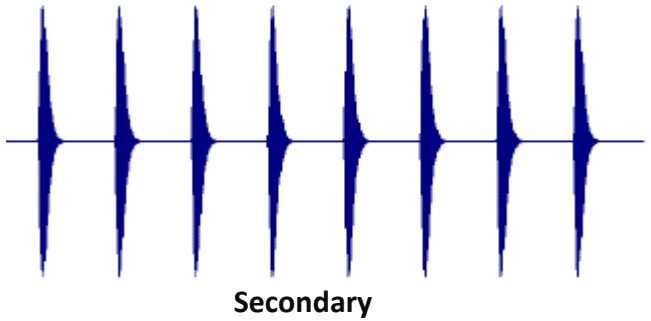
Worldwide Coverage - 2005

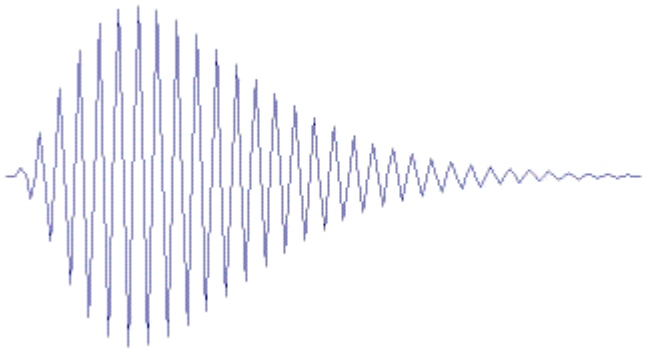


Signal Formats

- **Master broadcasted a series of 9 pulses**
  - The first 8 are 1000 µSec apart, the ninth is 2000 µSec after the 8th
  - 9th pulse was used for identification for manual receivers
- **Secondaries broadcasted a series of 8 pulses**
  - Each 1000 µSec apart
- **The 1000 microsecond spacing is used to provide enough time for the first or second hop skywaves to decay before the next pulse arrives**
- **Loran pulse shape**
  - 99% of output power is between 90-100KHz
  - Leading edge is critical
  - From the start of the pulse to the 62.5 µsec point (peak)







MICROCHIP

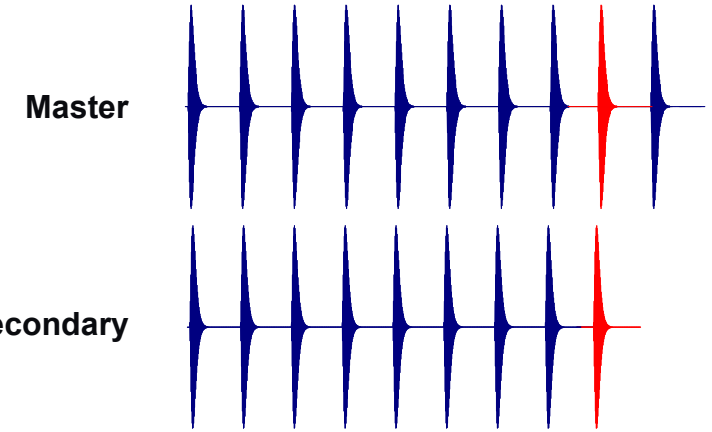
What is New?

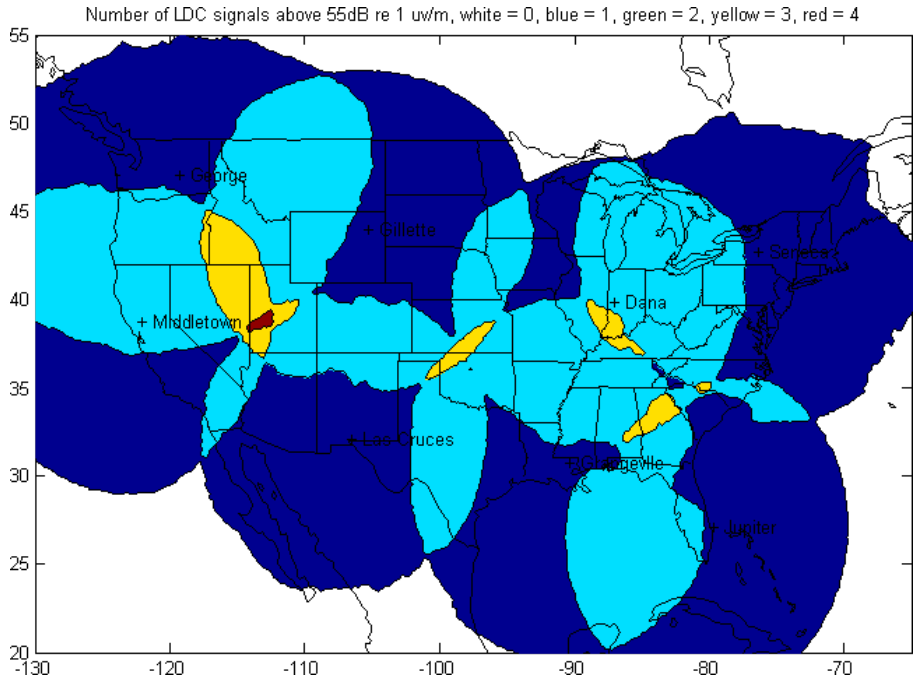
eLORAN Definition Document (V1.0)

- **An internationally standardized (PNT) service**
- **Available for a wide range of applications**
- **Independent, dissimilar, complement to (GNSS)**
- **PNT users will be capable of retaining the safety, security, and economic benefits of GNSS, even when their satellite services are disrupted or when using eLoran in areas where GNSS in not available**
- **eLoran is capable of providing this level of service by meeting the accuracy, availability, integrity, and continuity performance requirements for:**
  - aviation non-precision instrument approaches
  - maritime harbor entrance and approach maneuvers
  - land-mobile vehicle navigation
  - location-based services
  - precise time and frequency users

Loran Data Channel

- **The data channel conveys:**
  - Time of Day & Leap Seconds
  - Differential Corrections
  - Warnings
  - Signal Integrity
- **The data transmitted will include at a minimum:**
  - Station ID, almanac data, differential monitor ID
  - Absolute time with leap-second information
  - Warnings of anomalous radio propagation conditions
  - Authentication of the *eLoran* transmissions
  - Official-use only messages
  - Differential Loran corrections





What is the Plan Today?

Transmitting Stations

- **All broadcasts switch to Time of Transmission (not just Master)**
- **New transmitters**
  - Increase availability
  - Reduce maintenance intervals
  - Improve performance
- **Smaller footprint**
  - Remote operations, remove the staff
  - Eliminate the need for hotel services
  - Containerized vice building(s)

Portable Xmtr: Wildwood, NJ February 2013

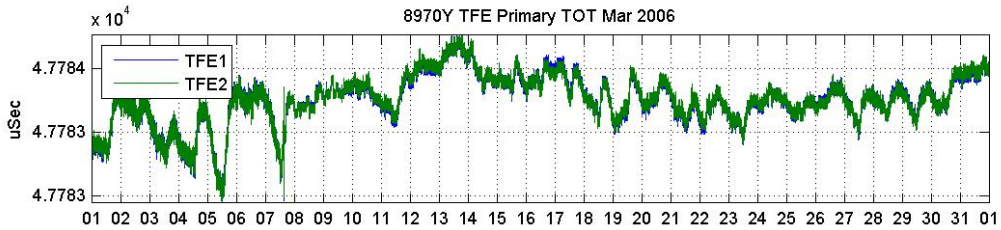
What is the Plan Today?

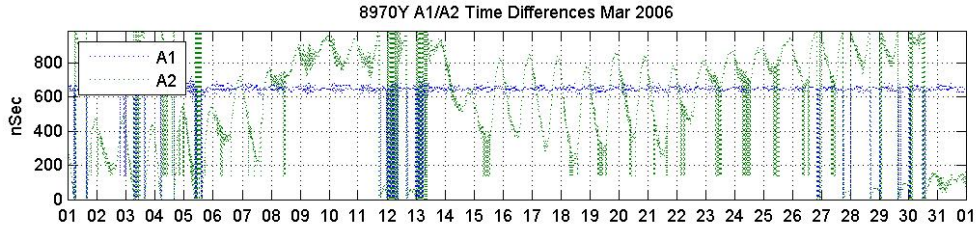
Signal in Space Monitors

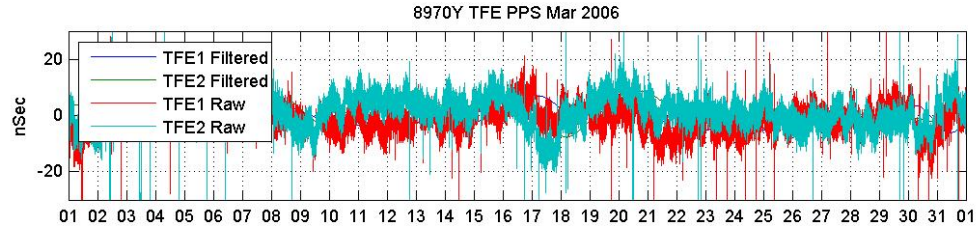
- **Continue to monitor the signal in space**
  - Enough power?
  - Pulse shape?
  - Timing?
  - Message demodulation, did we decode what was sent?
- **Generate differential corrections**
  - Temporal variations and ASF Data
  - Generate differential corrections in real time
  - Send these to the transmitting station for broadcast to the users
  - Demodulate and apply the corrections for integrity
  - Log the generated/decoded messages
- **Propagation anomalies**
  - i.e. Solar activity

LORAN-C Monitor Site, Mayport FL

Time of Transmission: A quick look

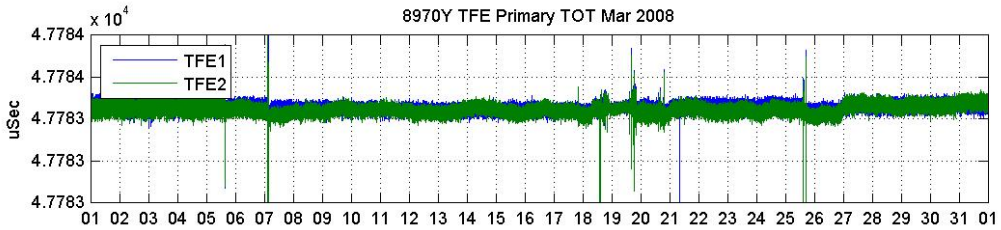


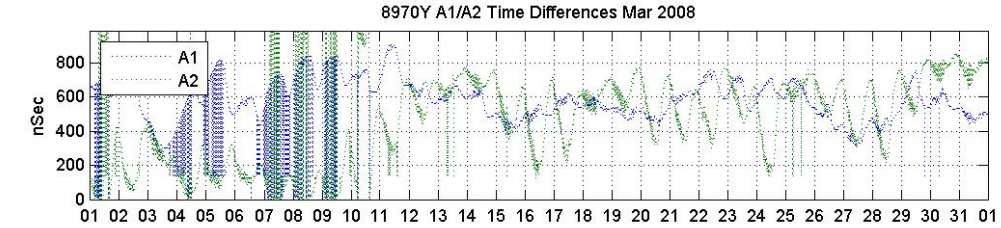


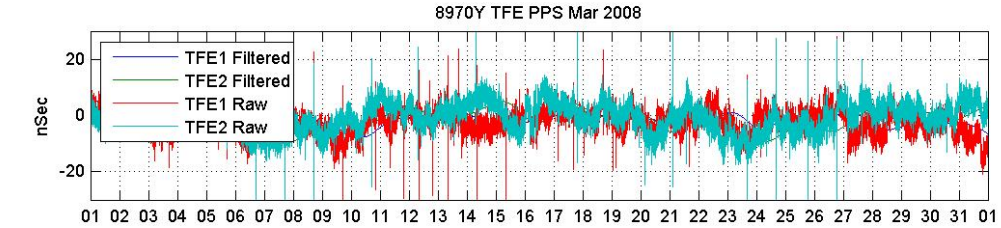


Maintain chain configuration

- Legacy receivers







Redistribute the accuracy curves in the coverage area

- Expect to improve absolute accuracy
- Degrade the repeatable accuracy

What is the Plan Today?

Command and Control

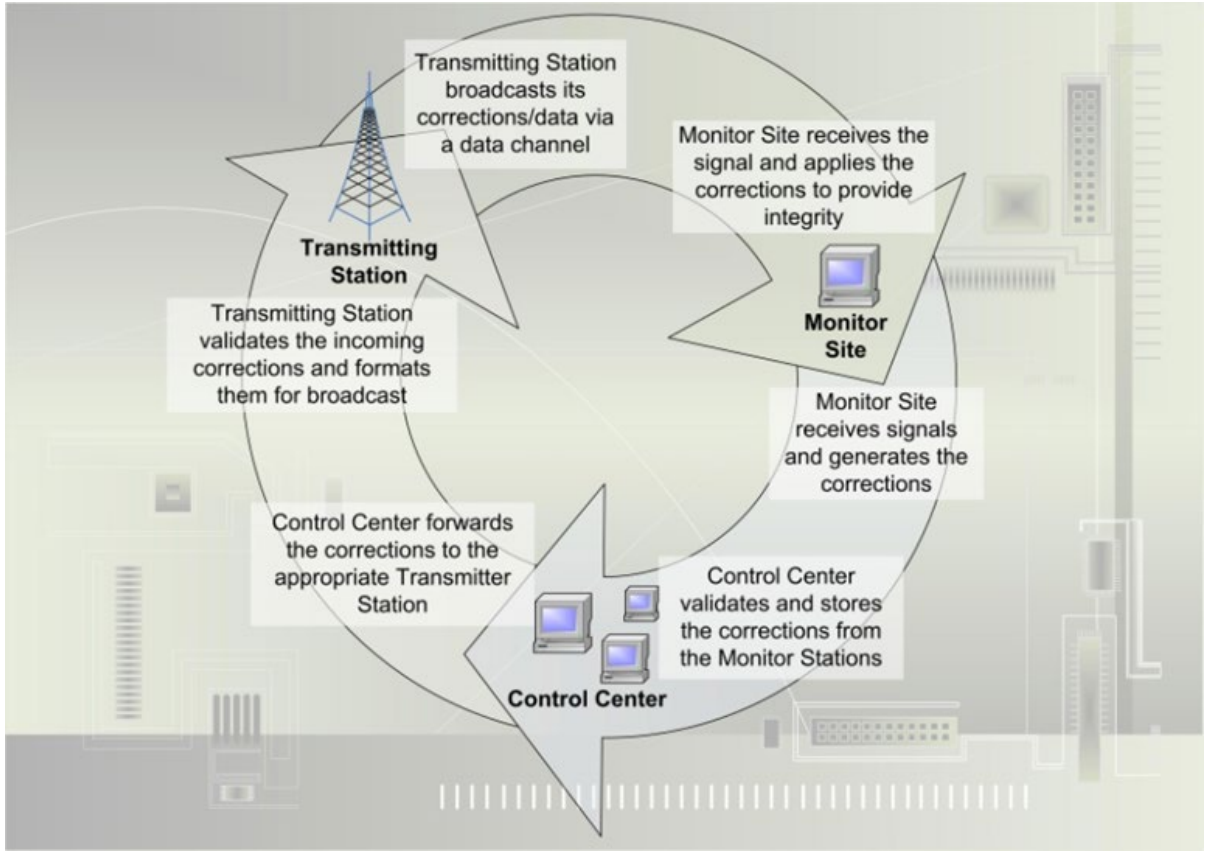
- **Obtains data from each transmitting station on local signal parameters**
- **Obtains data from the remote receivers located throughout the service area to monitor the signal in space.**
- **System Integrity**
  - Station Timing
  - ECD (Pulse Shape)
  - Peak Radiated Power
  - LDC Messages
- **User Interface**
  - Blink
  - LDC Health/Status Messages
  - BNM
  - LNM
  - NOTAMS

USCG Loran Consolidated Control System (LCCS)
Navigation Center Alexandria, VA

What is the Plan Today?

User Equipment

- **OEM Module for integration into hardware**
- **All In View vice Single Chain**
- **ASF database**
- **LDC demodulation for**
  - Corrections
  - Almanac
  - Health and Status



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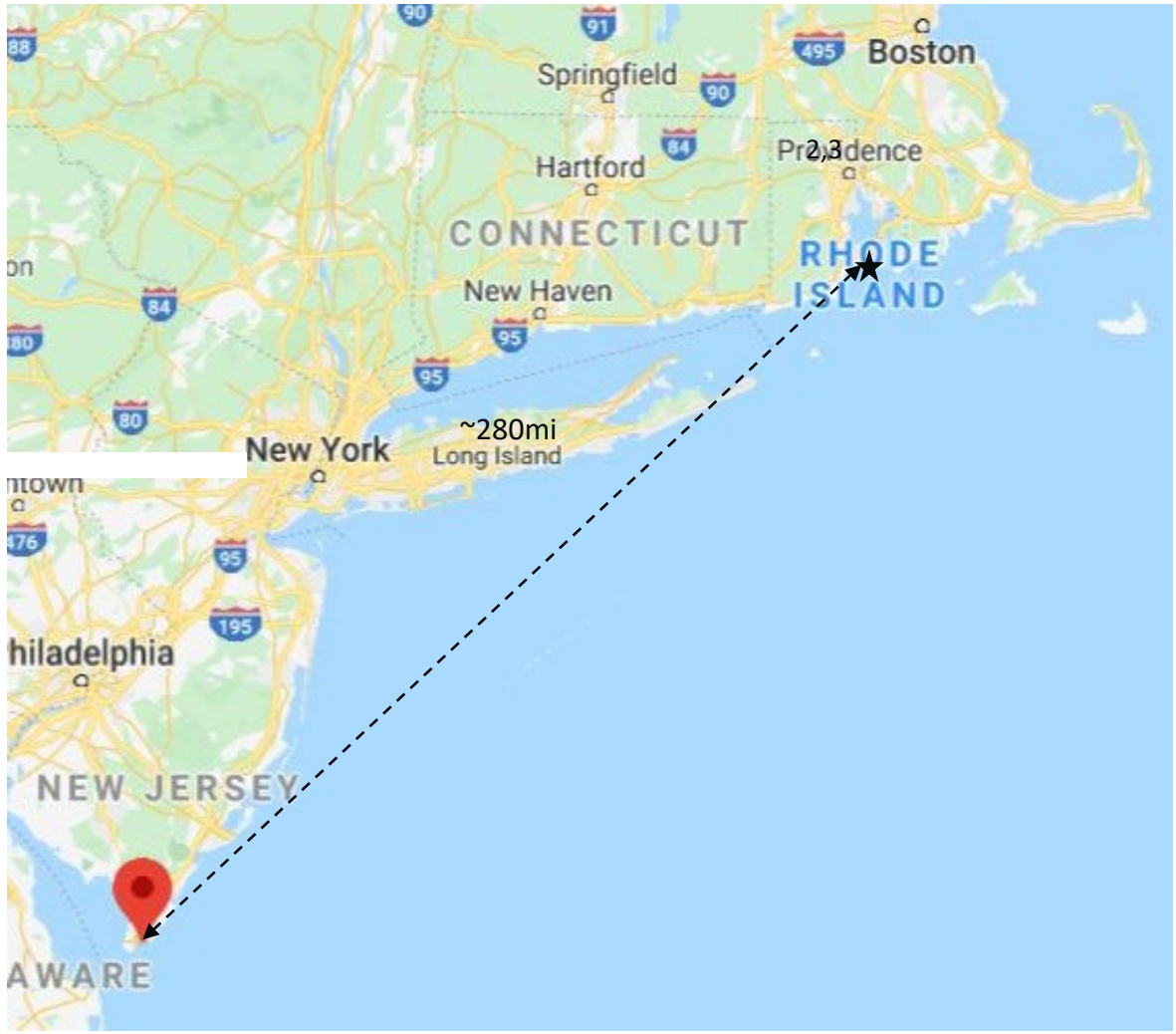
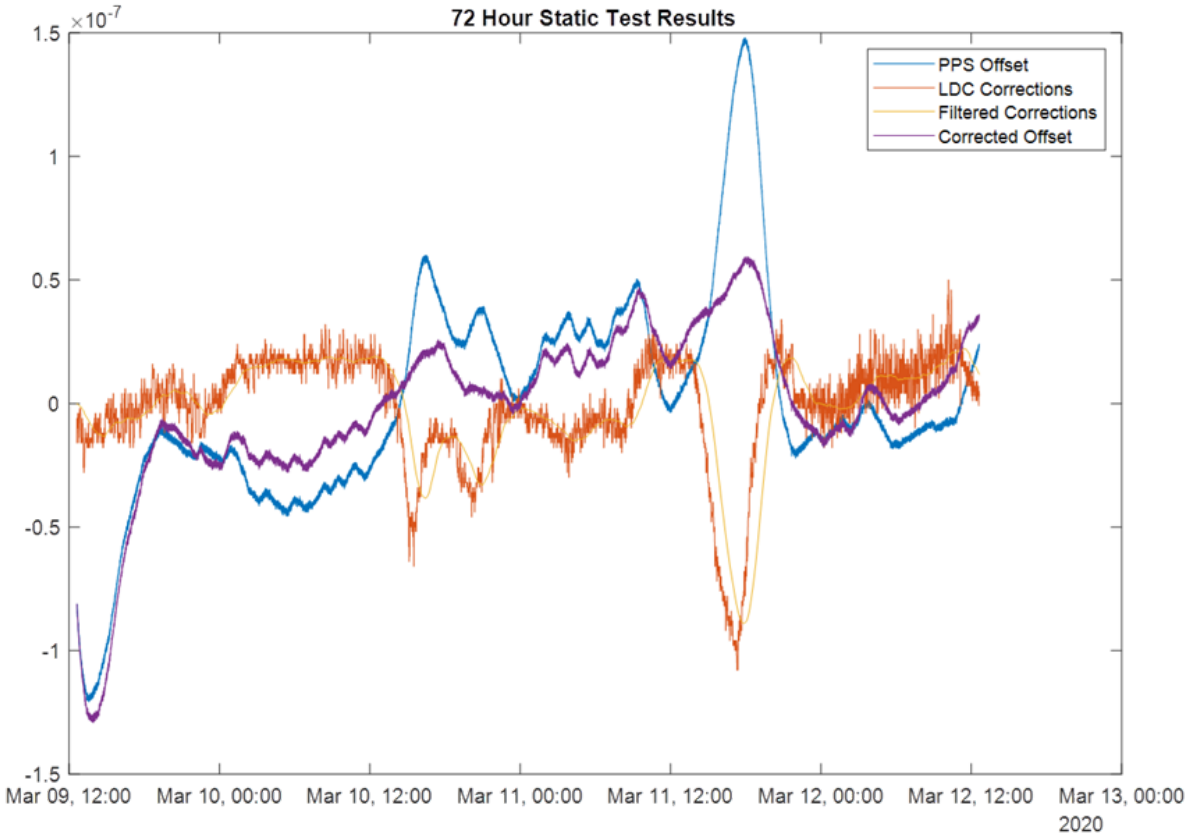
Recent Testing

DOT Demo 2020

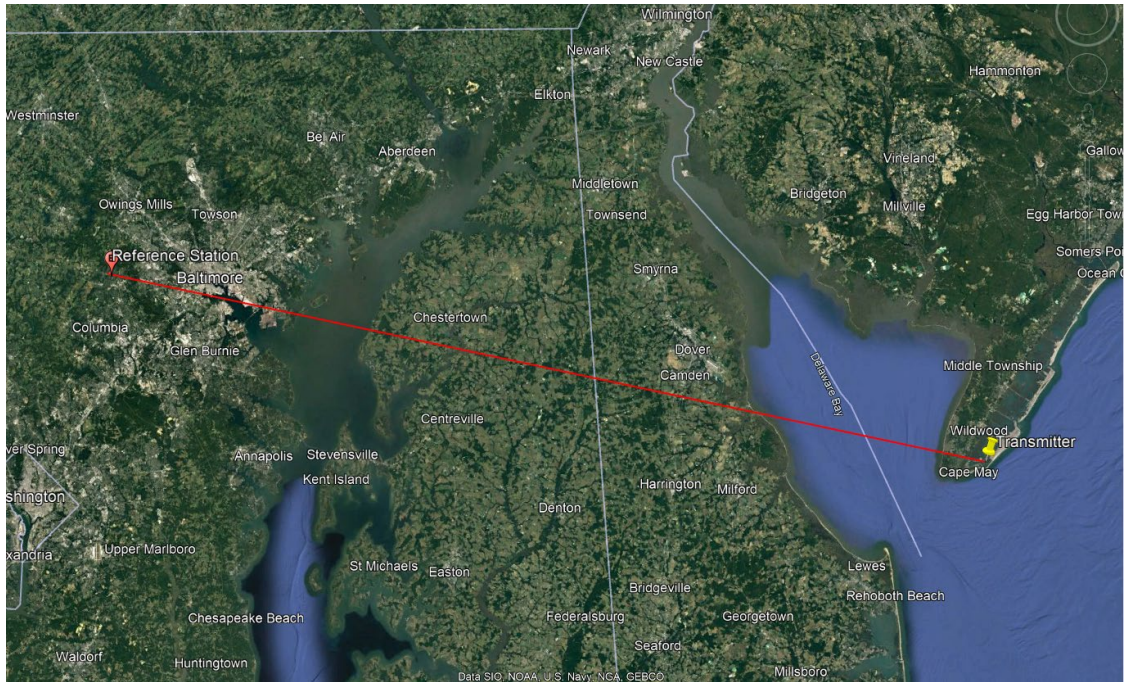


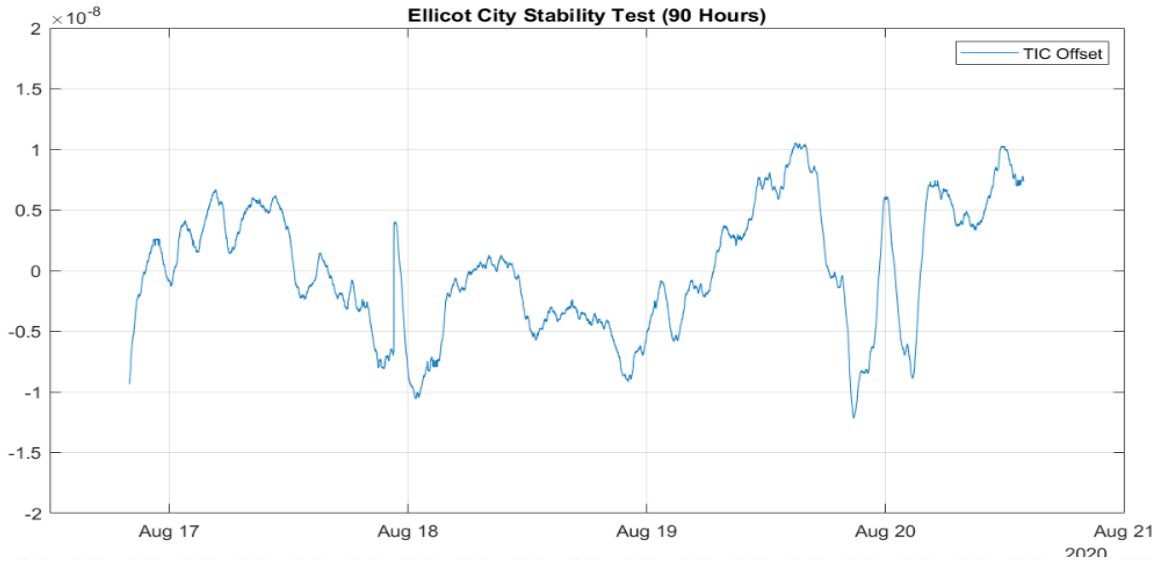


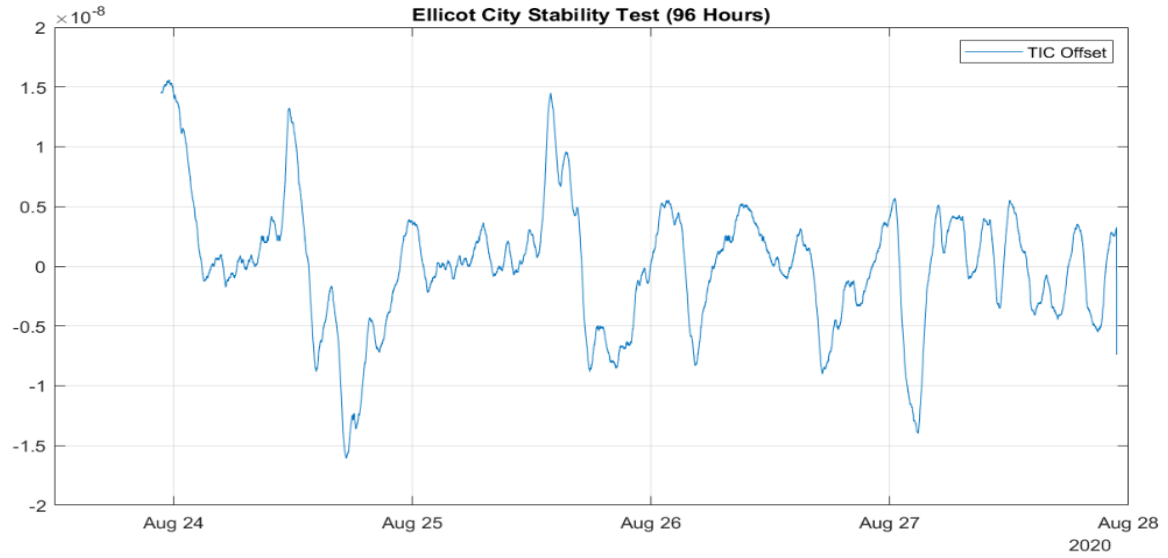
Sites

1: Transmitter: Wildwood, NJ
2: Ref. Station: JBCC, MA
3: UE Static: JBCC, MA

Testing – Baltimore MD - 2020





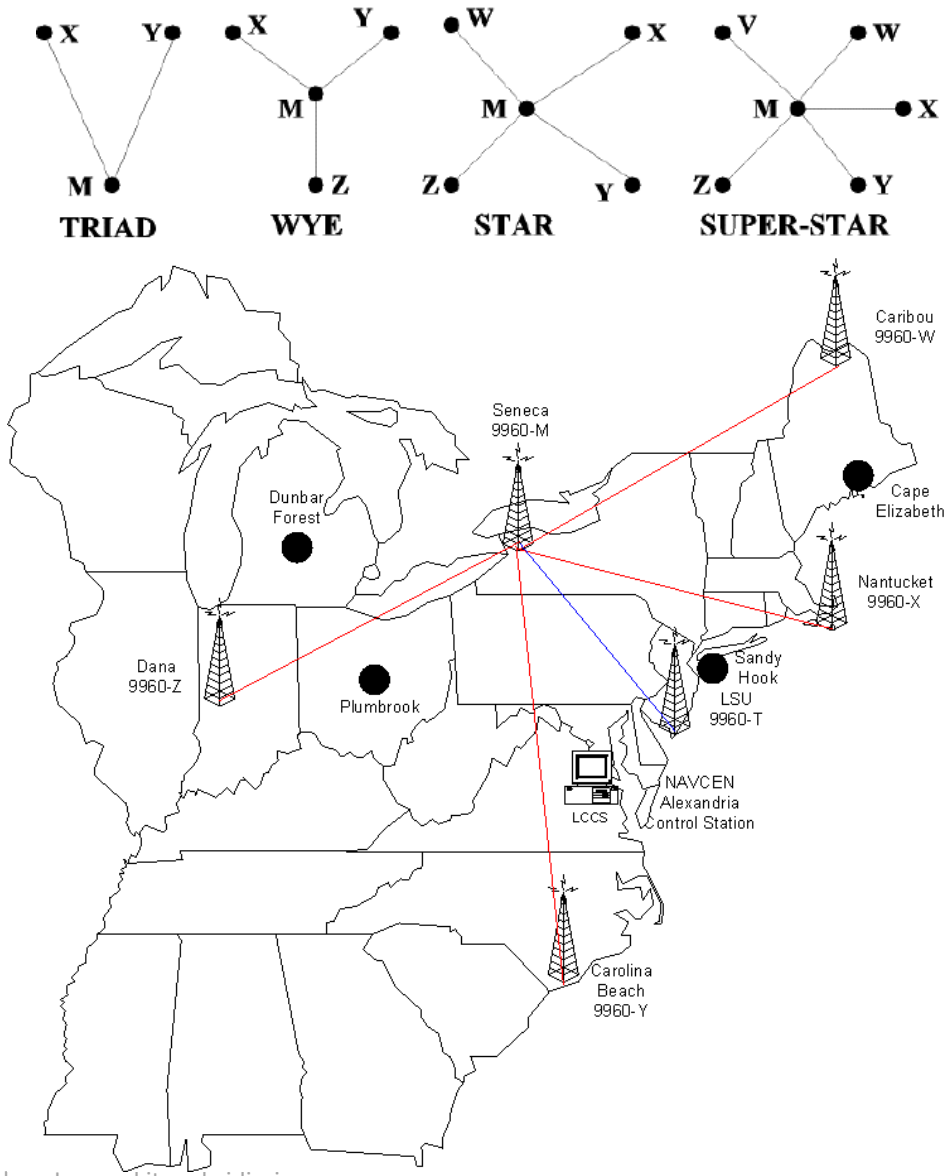


- **50KW Transmitter**
- **95NM Baseline**
- **Reference Station and Integrity Monitor**
  - Generate Corrections
  - Broadcast in real-time
  - Apply the corrections
  - Measure eLORAN PPS –VS - GPS

Thank you.

Chain Operations

- **A LORAN-C Chain consisted of:**
  - One Master station (M)
  - Up to five secondary stations
    - V, W, X, Y, Z
  - A Control Station
  - 2-4 Monitor Receiver Sites



Modernization Efforts ~1997-2004

Issue	Mitigation
Old timing sources	Replaced all the cesium clocks in the system 5061A to 5071A
Old timing equipment	New Time and Frequency Equipment (TFE) suites
Momentary Off Airs	Replace Tube transmitters (TTX) w/Solid State Transmitters (SSX), SSX Upgrades., UPS Systems, Emergency Generators
Simple propagation model	New ASF tables/algorithms, improved models.
No real-time corrections	LORAPP (Differential Loran)
Precipitation Static	H-Field Antenna
Atmospheric Noise/Lightning	H-Field, Antenna, CCIR Models, All in View (AIV) receiver, improved protection
Chain/Station Availability	All in View Receivers
Presumed Integrity/ABS	Included in TFE. System refinements.
Receiver acquisition time	New DSP technology, reduction in the # of momentary O/As., AIV/Integrated Receiver
Solar Activity	Early Skywave Monitors

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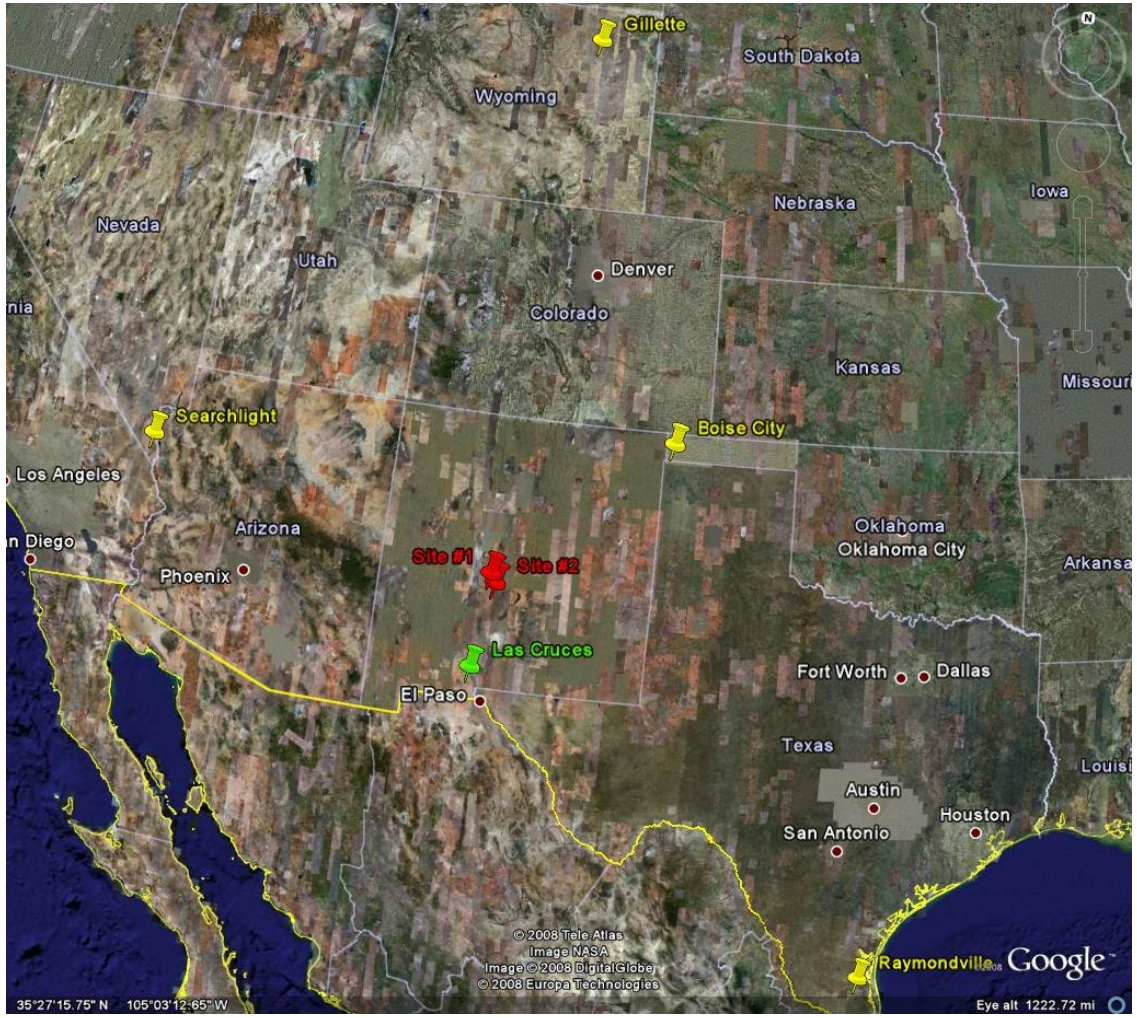
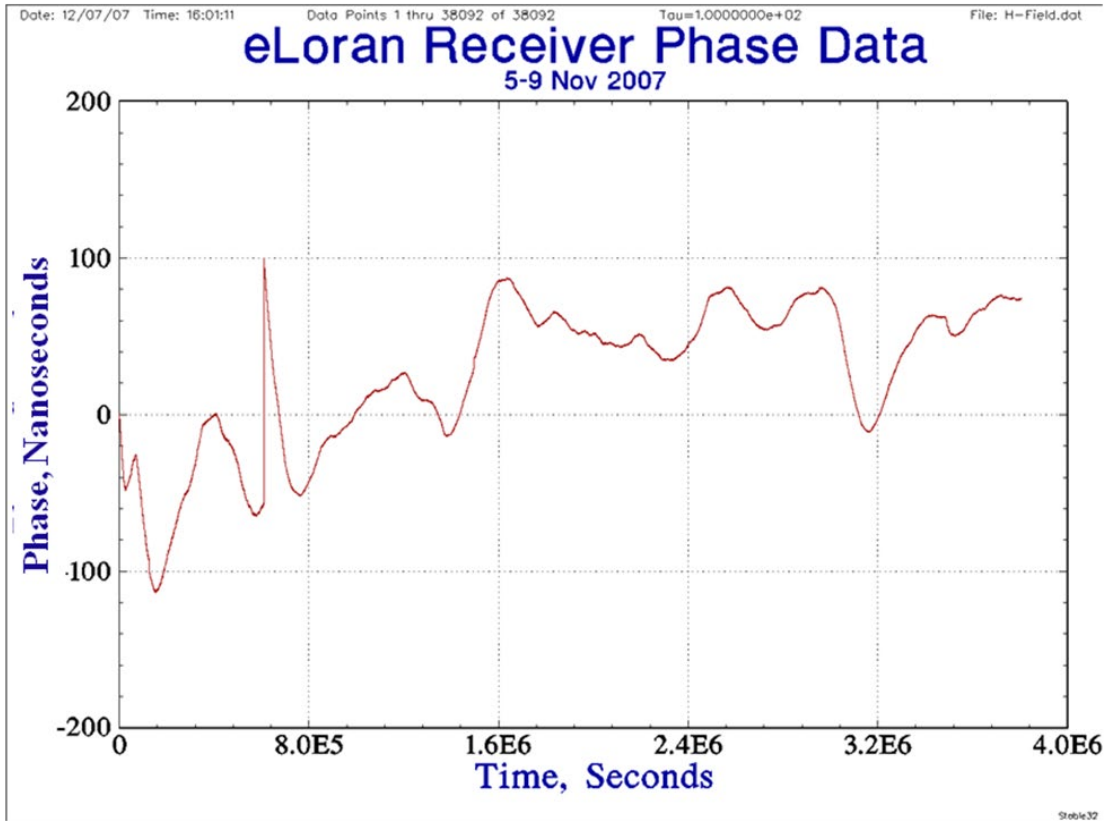
Minimize the Impacts on Legacy Users

- **In order to minimize these impacts the USCG:**
  - Kept the Master Stations synchronized to UTC-USNO
  - Retained the Blink criteria:
    - The timing tolerance remains at +/- 100nSec for Maritime users and +/- 500nSec for Aviation users (ABS)
    - The ECD (pulse shape) tolerances remain unchanged
    - The stations will continue to blink when their output power falls below 70.7%
  - Blink all secondary stations when the Master station is out of tolerance (except for confirmed off air/AUTM periods).
  - Detect propagation conditions/solar events that may impact the user's ability to lock on and properly track the signal
  - Continue to solicit for user objections for scheduled signal outages
  - Notify the users of all scheduled and unscheduled signal outages

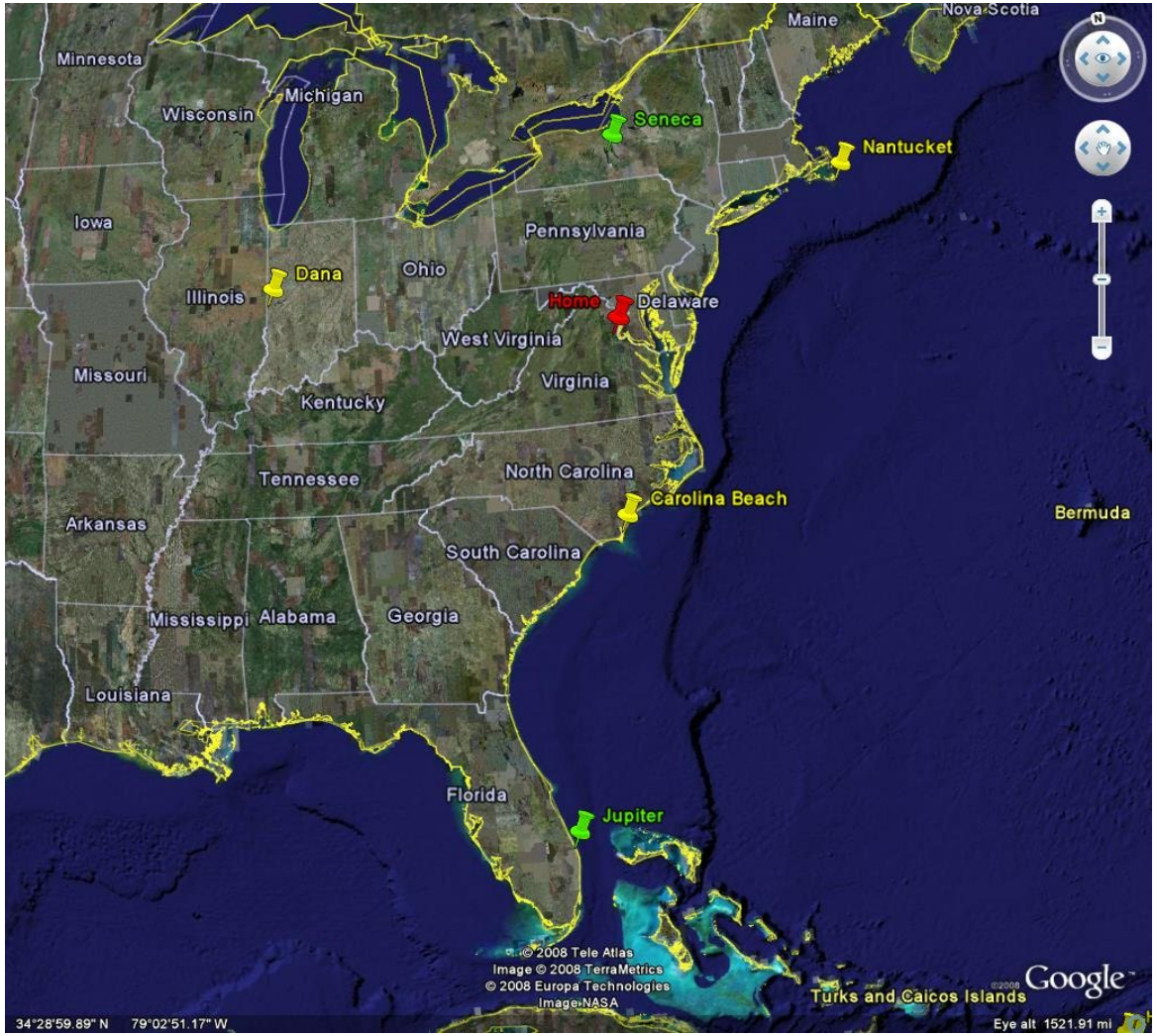
Fall 2007: Outdoor E-Field Antenna



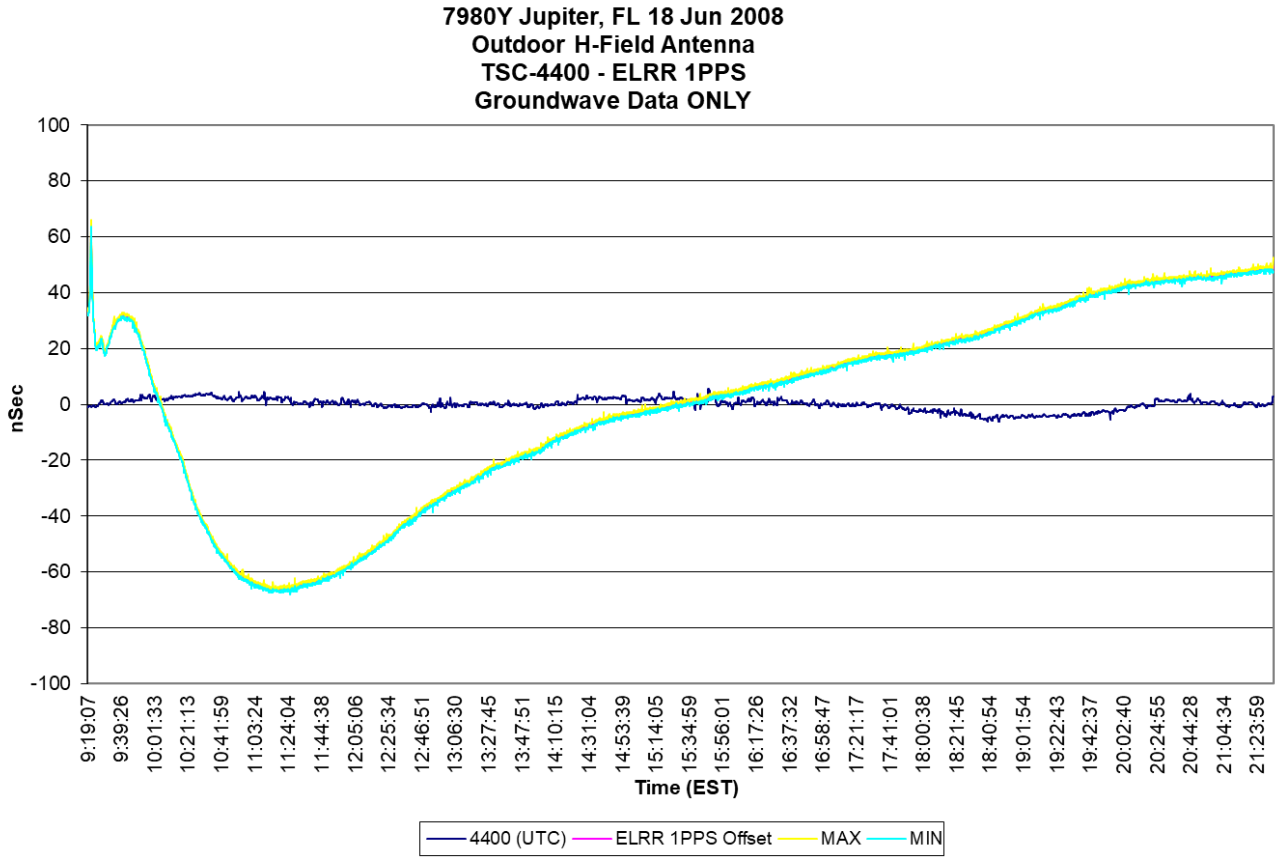


- ELRR located on WSMR
- Demodulating
  - Las Cruces, NM

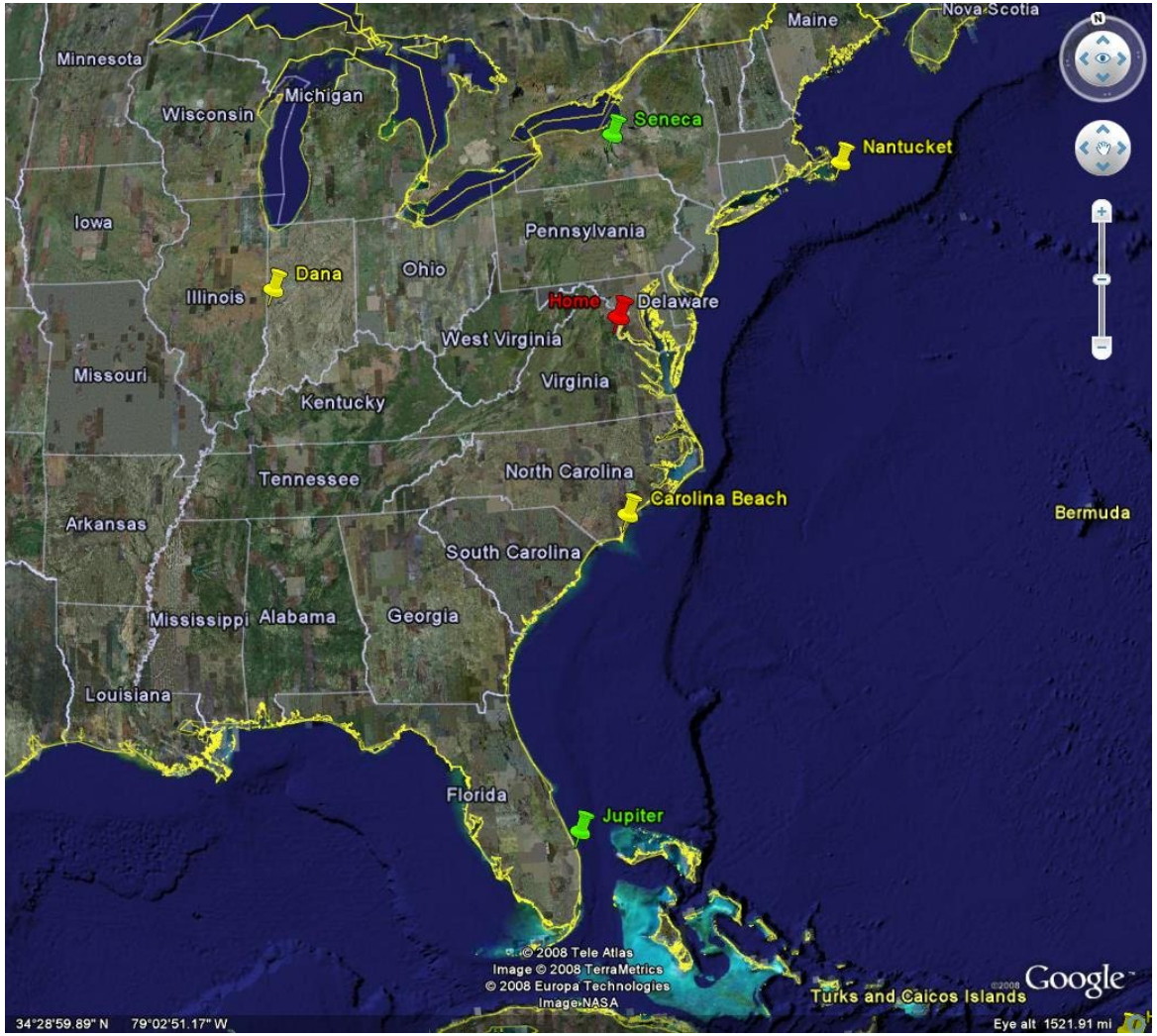
Summer 2008 Outdoor H-Field Antenna



- RX located in Stafford, VA
- 7980-Y Jupiter, FL



Summer 2008 Indoor H-Field Antenna



- **RX located in Stafford, VA**
- **8970-X Seneca NY**