GRAD Driving Innovation for Safer Maritime Navigation

# eLoran – From Theory to Operational Capability

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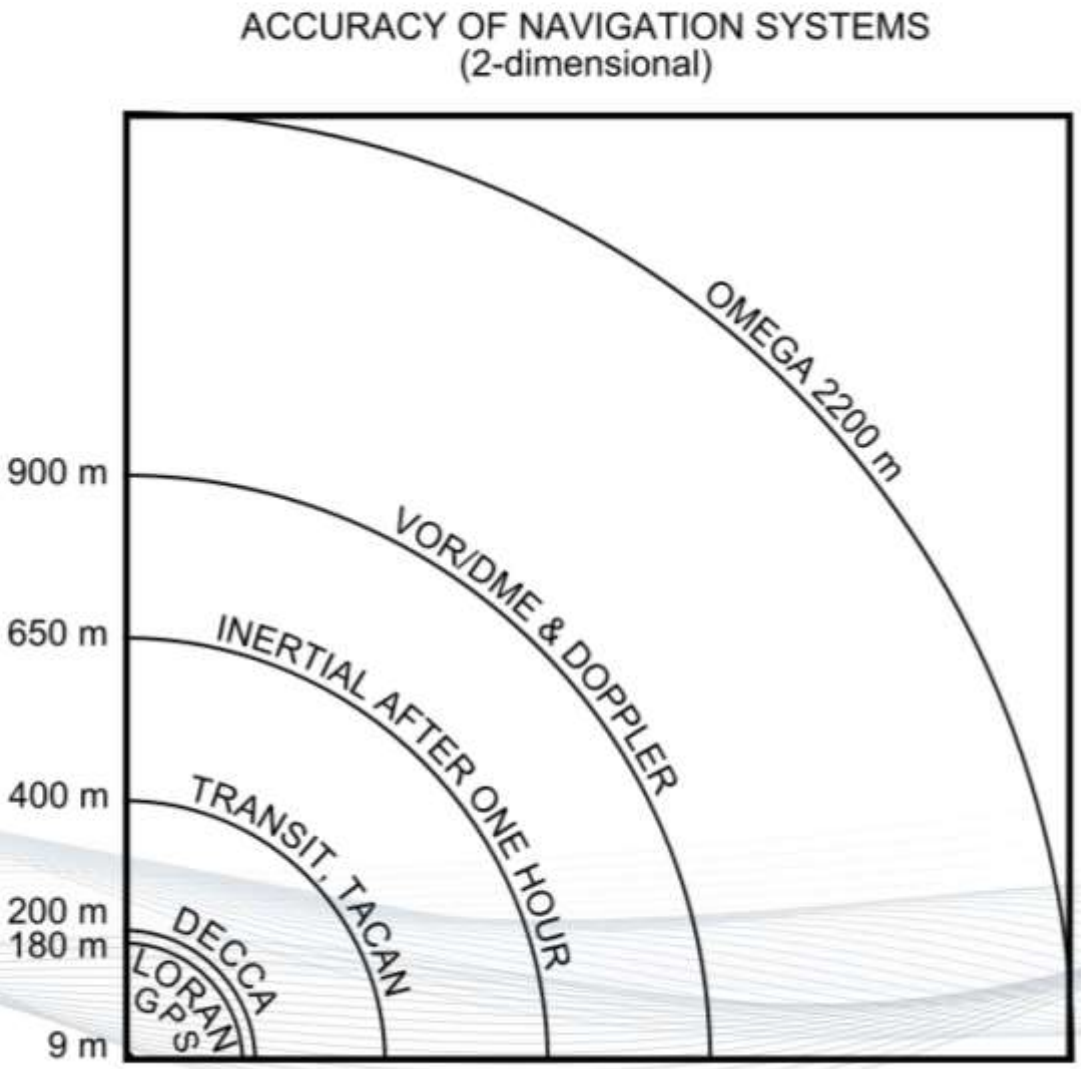
# Over the years



# Yester-year

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Former USCG Loran-C Station Attu, AK

Picture Credit: Popular Mechanics Magazine

# Loran-C is dead, long live eLoran

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- 1950s Technology
  - Transmitters
  - Receivers
  - System Area Monitors (SAM Control)
  - Time & Frequency Equipment
  - Computers
  - Understanding, modelling and measuring signal propagation
  - Staffing
- Today, comparing eLoran with Loran-C is like
  - Comparing Modernised GPS with Transit Doppler
  - Comparing Inmarsat GX satcom with TELSTAT

# Loran Evolution

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| | Loran-C | Modernised Loran | eLoran |
|---|---|---|---|
| Transmitters | Valve/tube | Solid state | Solid state, messaging and frequency steering |
| Propagation ASFs | Printed/limited | Computed predicted, not necessarily integrated in receiver | Measured or modelled and integrated in receiver |
| DLoran | N/A | N/A | Reference Stations |
| Receivers | Hyperbolic with chains | Time of emission with all-in-view | Time of emission with all-in-view |
| Accuracy | 460m (95%) | 100m (95%) | 10-20m (95%) |
| Notes | 2 Med, 4 Chayka | 9 former NELS | Now |

# What eLoran brings

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| Supported Application | USCG Loran-C | Modernised Loran-C | Prototype eLoran | eLoran |
|---|---|---|---|---|
| Resilient PNT | | | | ✓ |
| Maritime: Ocean | | ✓ | ✓ | ✓ |
| Maritime: Coastal & Harbour | | | ✓ | ✓ |
| Aviation: Non-Precision Approach | | | | ✓ |
| Stratum 1 Frequency | ✓ | ✓ | ✓ | ✓ |
| UTC | | | ✓ | ✓ |
| Precise Timing | | | | ✓ |
| Land Mobile | | | ✓ | ✓ |
| Interference Detection & Mitigation | | | ✓ | ✓ |

# A dissimilar, complementary, multi-modal & independent source of PNT

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| Service | PNT | Multi-Modal | Independent wrt GPS | | |
|---|---|---|---|---|---|
| | | | System | Signal | User |
| GLONASS/ BeiDou/ Galileo | ✓ | ✓ | ✓ | × | × |
| eLoran | ✓ | ✓ | ✓ | ✓ | ✓ |
| DGPS | × | ✓ | × | ✓ | × |
| SBAS | × ✓ | ✓ | × | × | × |
| Radar | × | × | ✓ | ✓ | ✓ |

# Business Case

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- eLoran gave a large positive return over lifetime of system
- Other options gave negative returns
- Only eLoran had been demonstrated to provide security against the vulnerability of GNSS
- Allowing full benefits of e-Navigation

# The Four Horsemen

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- Accuracy
  - Separation between true and computed positions
  - Harbour Approach 10m (95%)
- Integrity
  - Probability Accuracy is within Alert Limit, given the Protection Level is
  - 99.999% (25m Alert Limit)
- Availability
  - Probability the System is online and can meet Accuracy and Integrity
  - 99.8%
- Continuity
  - Given the system is Available, probability it will remain so
  - 99.97% (over 15 minutes)

# eLoran Initial Operational Capability

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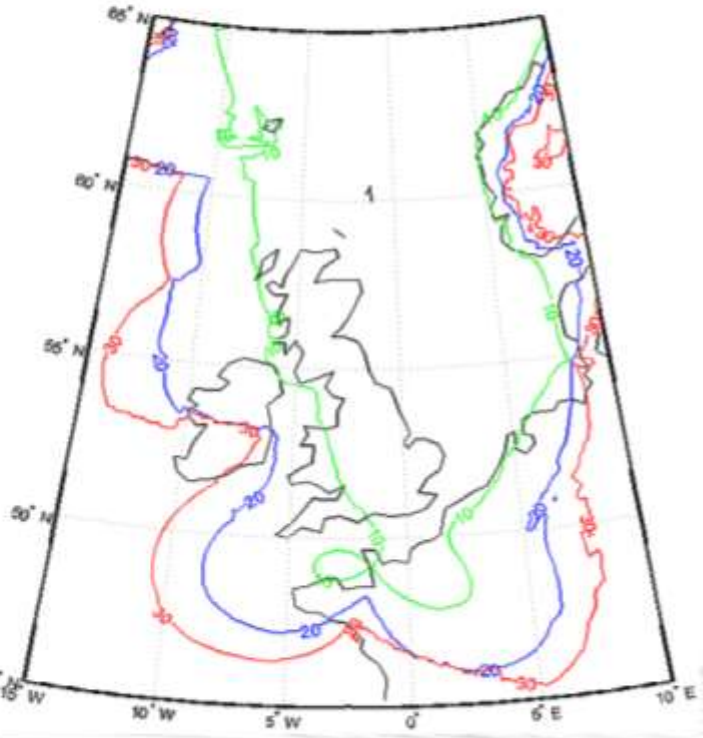
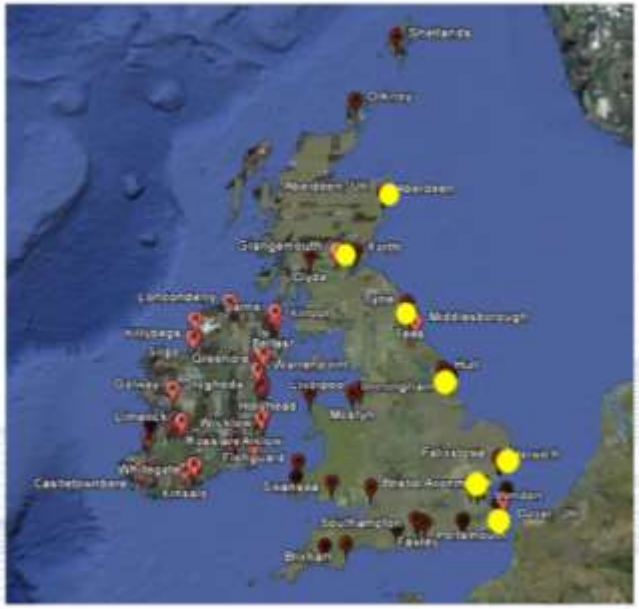
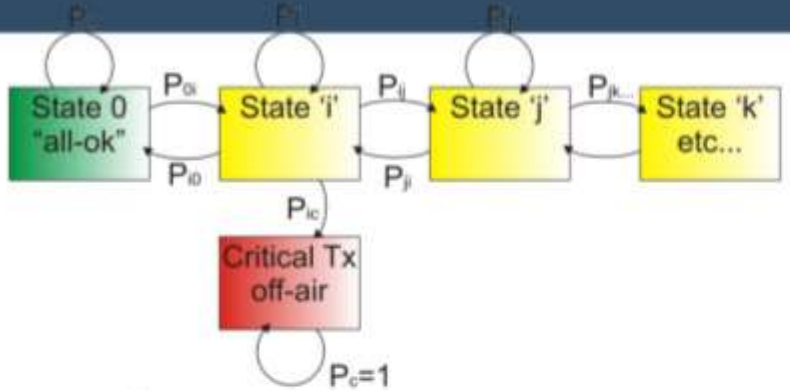
- 7 major east coast ports
- formally declared 31 October 2014

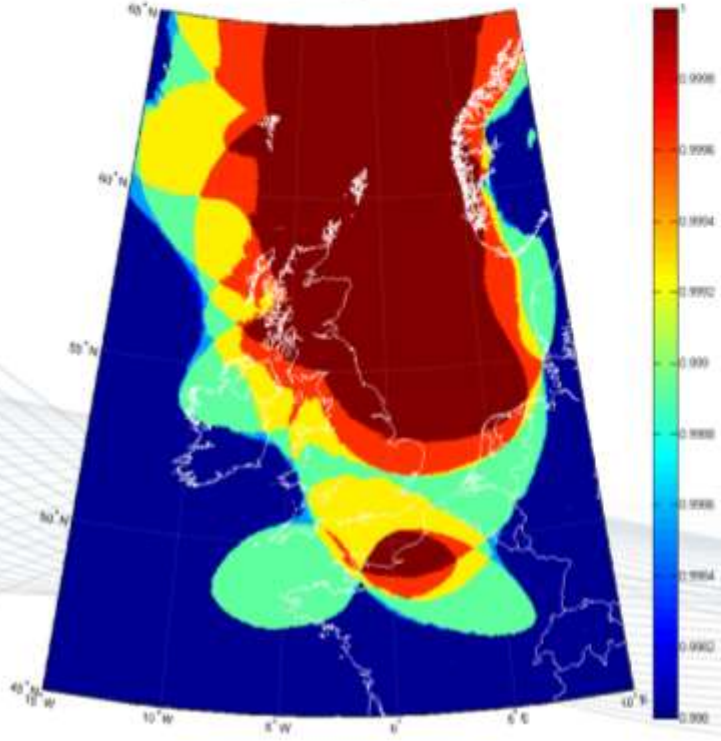







# Continuity



- Given System is fault-free, what is probability it will continue for next 15 minutes?
- State-Trapping Markov Chain
- Map the System Continuity
  - Dependent on number of Transmitters

# Availability

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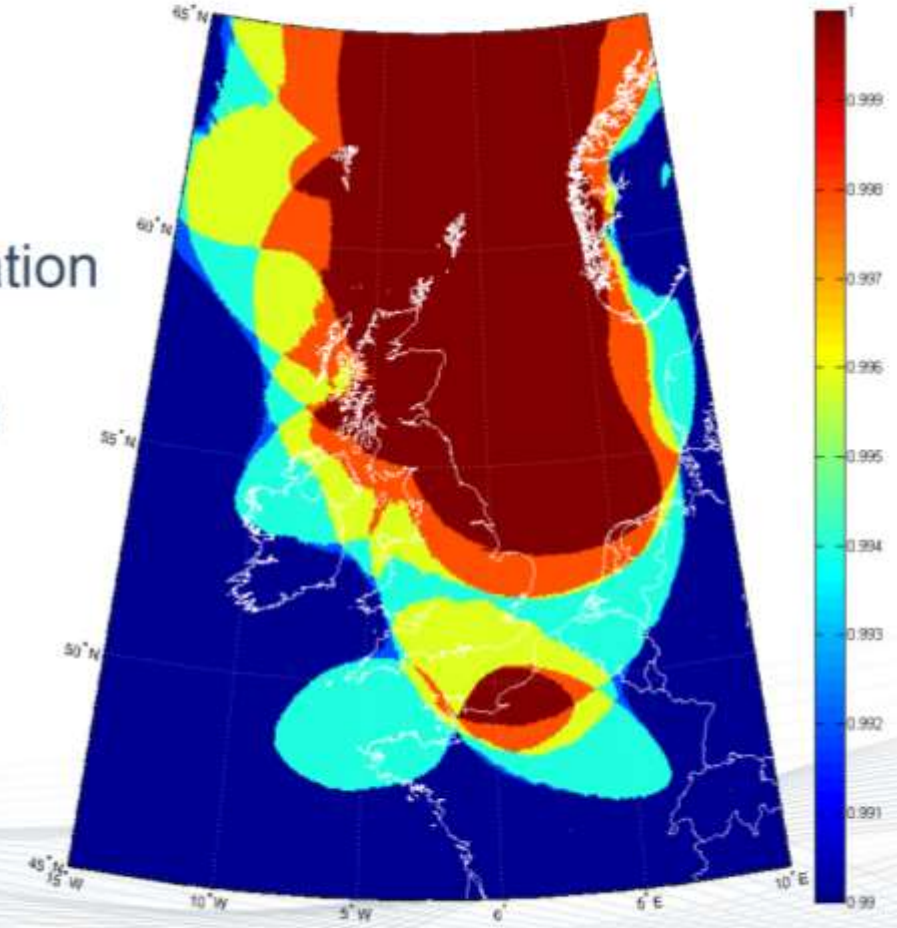
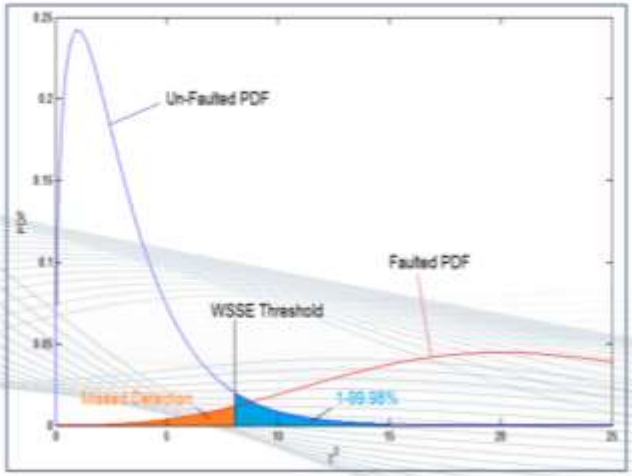
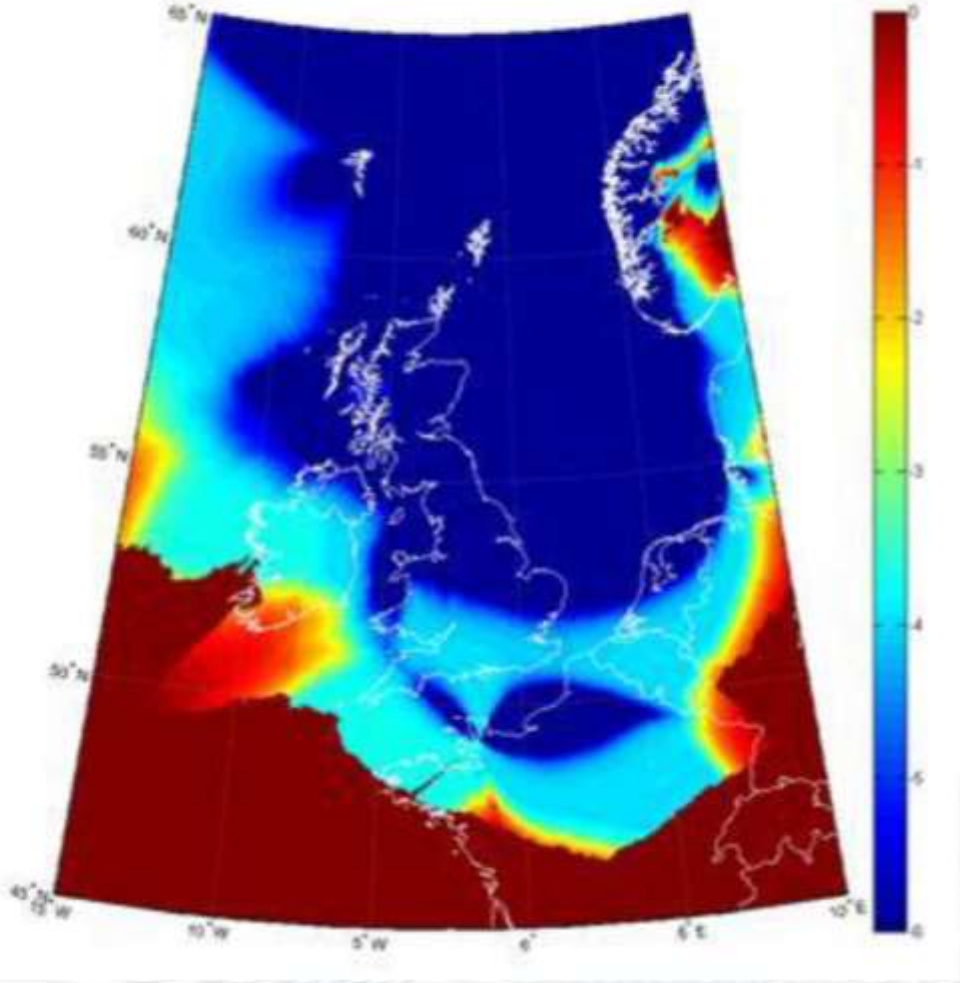
- Same Markov-Chain for calculation
  - Sum the ‘OK’ states
  - Transmitter off-airs are the largest culprit (maintenance)



# Integrity

- RAIM
  - Residuals-based RAIM
  - Calculate Probability of Missed Detection ($P_{MD}$)
- Map the System Integrity
  - 1 minus the $P_{MD}$



# The "T" bit

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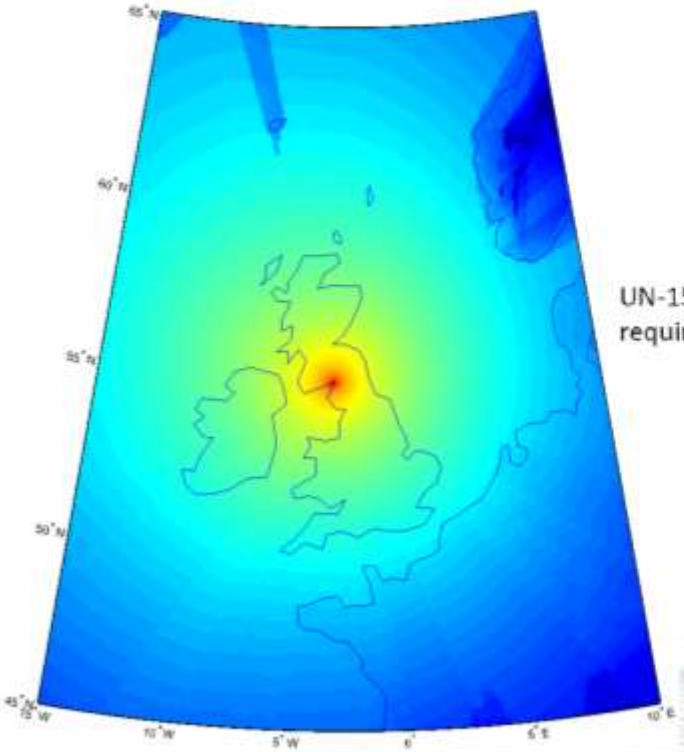
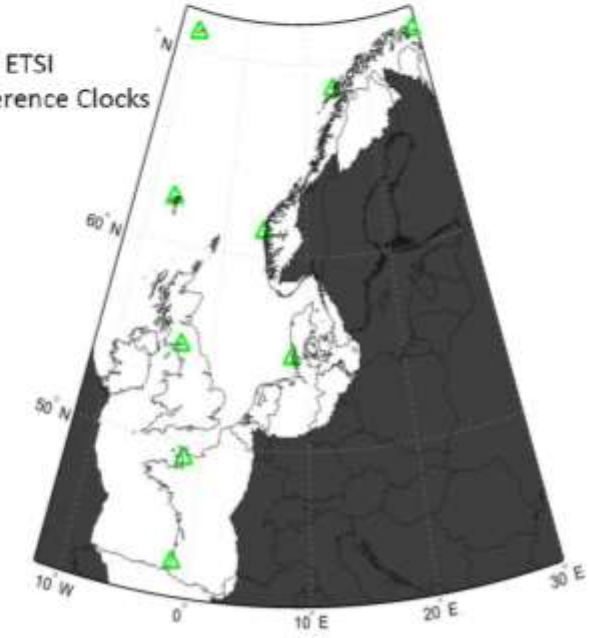
## The GLA prototype eLoran system provides precise telecommunications timing across the UK and Ireland

**… plus secure data**



UrsaNav UN-150 eLoran Timing Receiver

UN-150 eLoran timing receiver meets the stringent ETSI requirements for telecommunications Primary Reference Clocks



# Now

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GLA eLoran station at Anthorn, UK

- Smaller SWAP
- Less expensive
- Zero manpower
- 3 container solution

# The future

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eLoran-In-A-Box "ELB" Concept

# In the United States

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| | Study | Announcement |
|---|---|---|
| 2001 | Volpe Transportation Sys Center | |
| 2004 | ***Presidential Directive NSPD-39: 'We will acquire a backup capability for GPS'*** | |
| 2007 | Institute for Defense Analysis | |
| 2008 | ***DHS Press Release: 'We will create eLoran to backup/protect GPS'*** | |
| 2009 | Volpe Transportation Sys Center | |
| 2010 | US Decides to switch off Loran-C | |
| 2011 | DHS National Risk Estimate | |
| 2012-17 | DHS Wireless Timing CRADA (eLoran) | |
| 2014 | DoD-DoT-DHS Tiger Team | |
| 2015 | ***PNT Excom Letter to Congress: 'We will build eLoran timing, then PNT system'*** | |
| 2016 | Volpe Transportation Sys Center | |
| 2018 | DoD-DoT-DHS NDAA Report to Congress – delayed till summer/autumn | |

# CRADA

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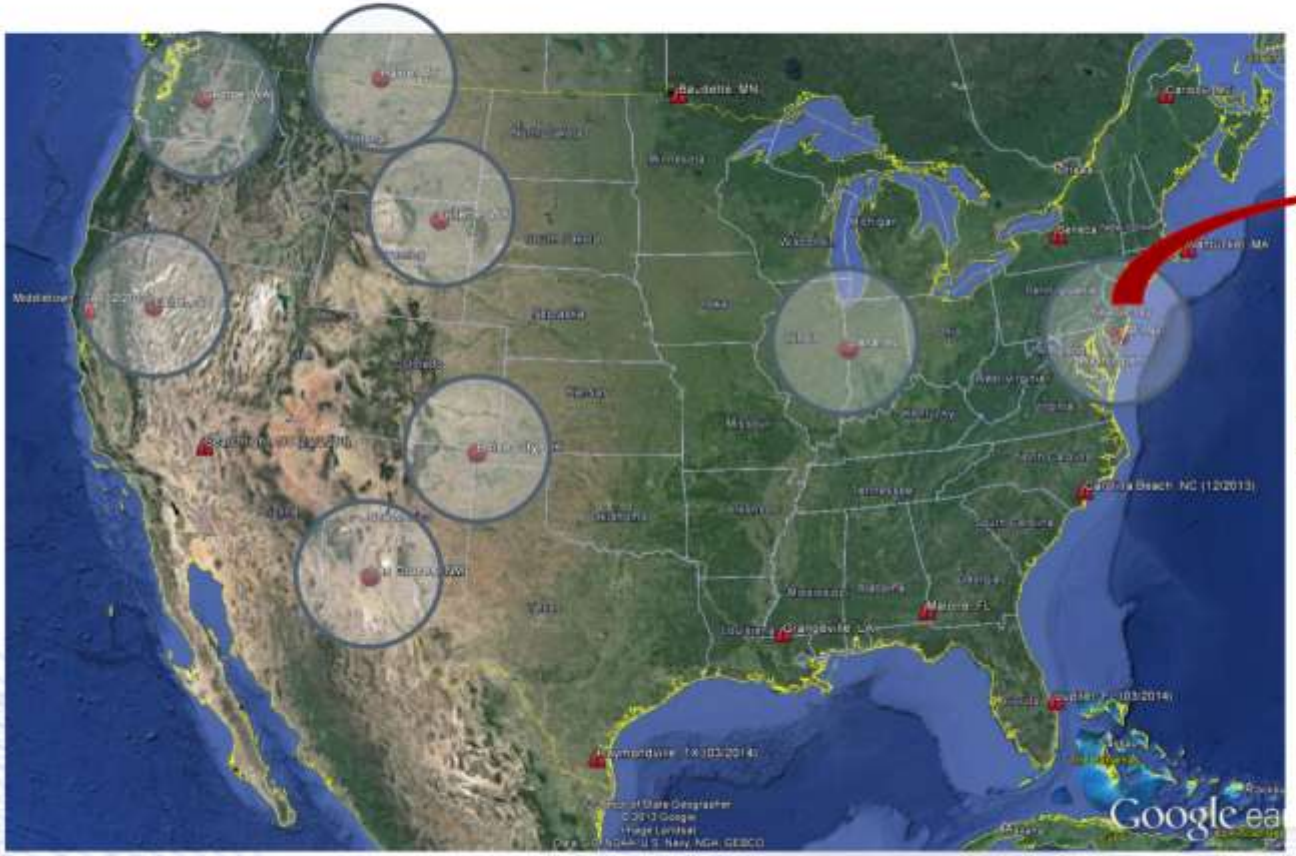
Ongoing Efforts




UrsaNav
Follow the Stars!

Eight (e)Loran sites that were available for operation under CRADAs with DHS and USCG.

Most often used is former USCG Loran Support Unit site in Wildwood, NJ.

Note: Circles help pinpoint site.
They do NOT indicate coverage!

# US Timing Performance

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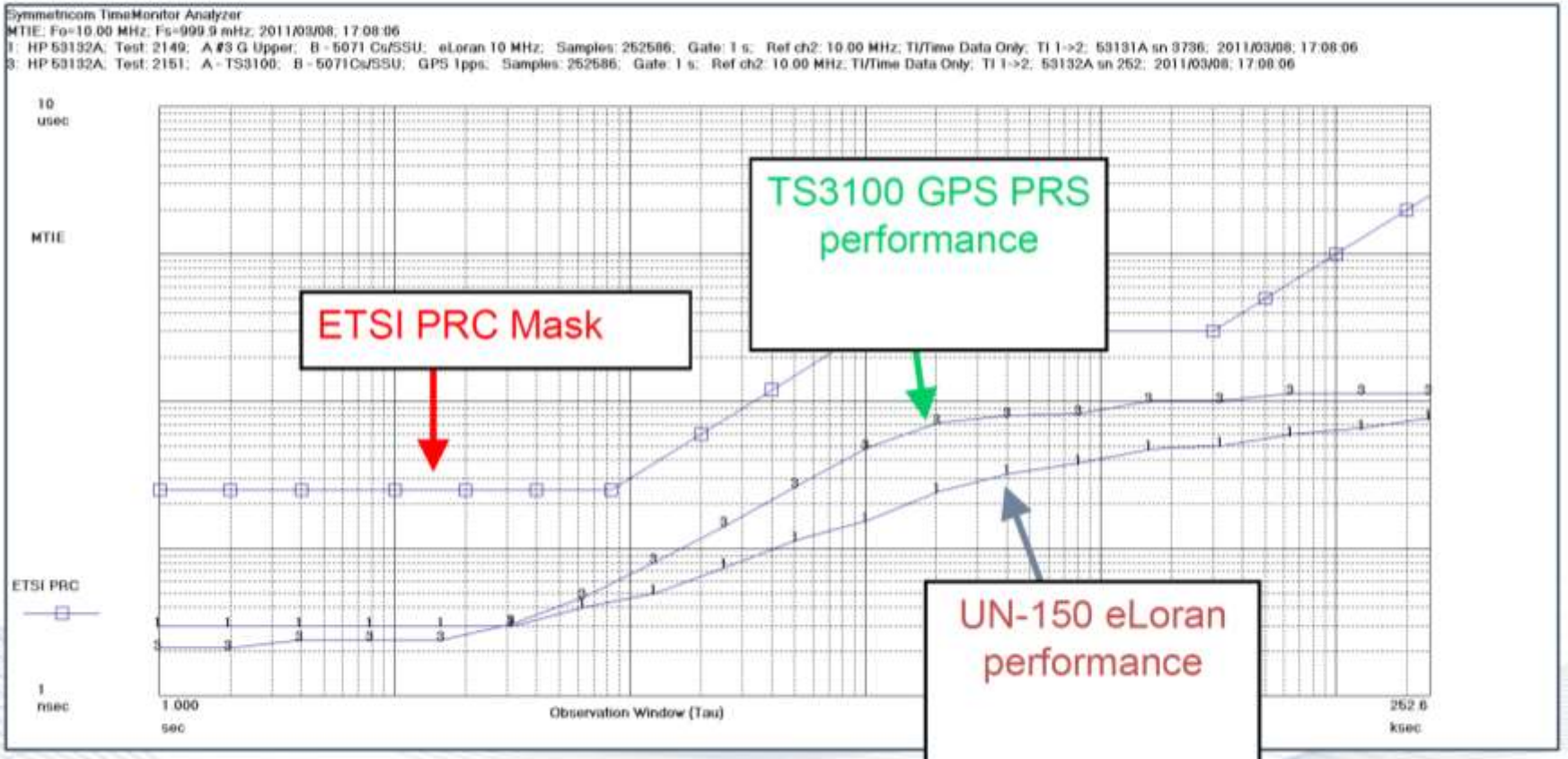
April 19, 2016
**Indoors at NYSE**
Distance to XMTR: **130** miles
Scale: +/- 50 ns
STD: 7.1 ns
Mean: -16.1 ns

# Timing




Testing by National Physical Laboratory & Chronos Technology Ltd.
[ETSI: European Telecommunications Standards Institute]

# So what?

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- Enhanced Loran is an internationally-standardized positioning, navigation, and timing (PNT) service for use by many modes of transport and in other applications
- eLoran meets the accuracy, availability, integrity, and continuity performance requirements for aviation non-precision instrument approaches, maritime harbour entrance and approach manoeuvres, land-mobile vehicle navigation, and location-based services, and is a precise source of time and frequency for applications such as telecommunications
- eLoran is an independent, dissimilar, complement to Global Navigation Satellite Systems (GNSS). It allows GNSS users to retain the safety, security, and economic benefits of GNSS, even when their satellite services are disrupted
- It's been proven, it's operational here and now, and ready to go further…


Image credit: Tim Harvey
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Thank You