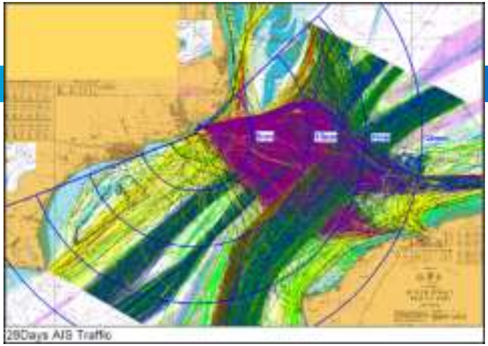
RESILIENT NAVIGATION *and* TIMING FOUNDATION

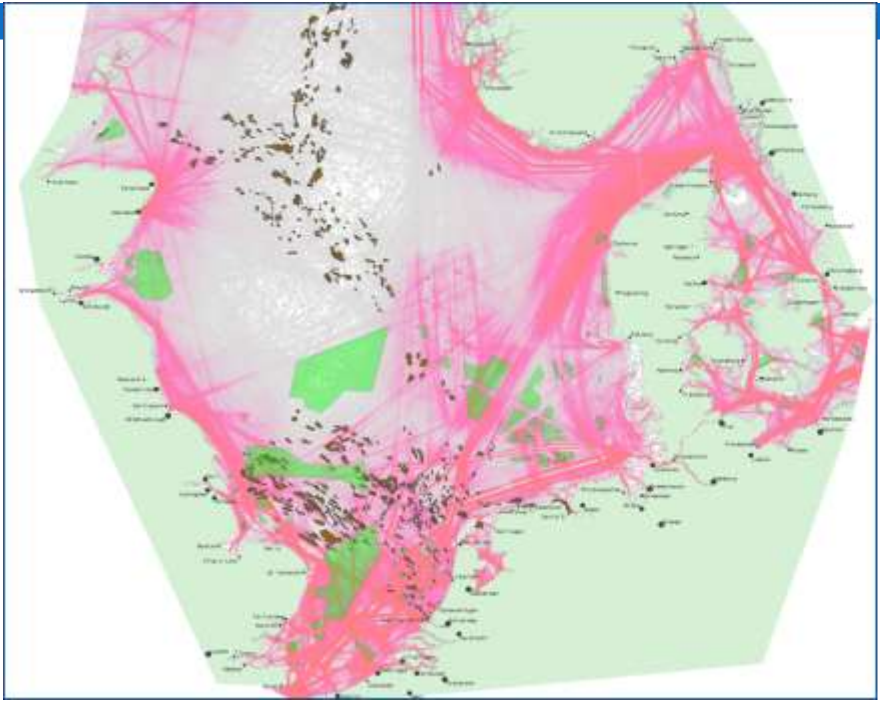
eLoran Results in the UK & US

OCTOBER 2018

Melaha Conference - Cairo

Maritime need for Resilient PNT





Risk of maritime navigation around the UK is growing

GPS vulnerability to interference

Research & Radionavigation
General Lighthouse Authorities
United Kingdom and Ireland

THV Galatea

Jammer of less than 1 milliWatt:

- False positions, and velocities
- Autopilot may turn vessel
- But no alarms!

With a little more jammer power:

- Electronic Chart Displays
- Autopilot
- Automatic Identification System
- Differential GPS
- Satellite voice and data comms
- Maritime distress safety system

plus …

Ship's Radar & Gyrocompass

Problem GPS is everywhere

Synchronized, Precise Time, Frequency, Phase

Precise Positioning & Navigation → Transport/Navigation

→ Financial Systems

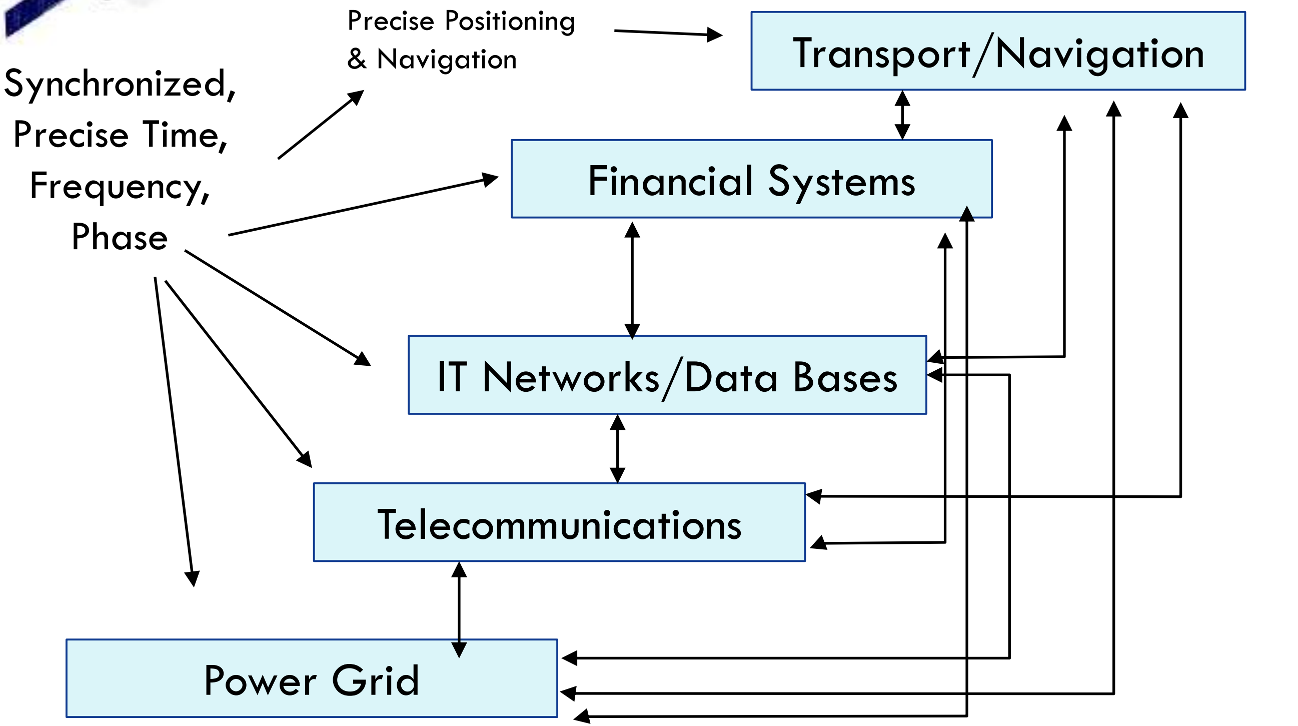
→ IT Networks/Data Bases

→ Telecommunications

→ Power Grid

Problem

GPS is everywhere
"Single Point of Failure" - DHS




Vice President Pence Hosts National Space Council
Dr. Michael Griffin
Admiral James Ellis
https://www.youtube.com/watch?v=9zW2bLJXkRU
1:56:47 / 2:27:57

What to Do?

- Protect – GPS Signals
- Toughen – Users & Equipment
- Augment – w/other signals & sources

What to Do?

- Protect – GPS Signals
  - Interference detection
  - Enforcement

What to Do?

- Toughen – Users & Equipment
    - Anti-jam, anti-spoof
    - Standards, requirements, costs

Radio Equipment Directive – GNSS Receivers

What to Do?

- Augment – w/other signals & sources
  - Five major studies – "eLoran is best/only solution"
  - US Govt Announcement 2008 – "Will build eLoran"
  - US Govt Announcement 2015 – "Will build eLoran"

2018 - $10M for GPS backup Technology Demonstration

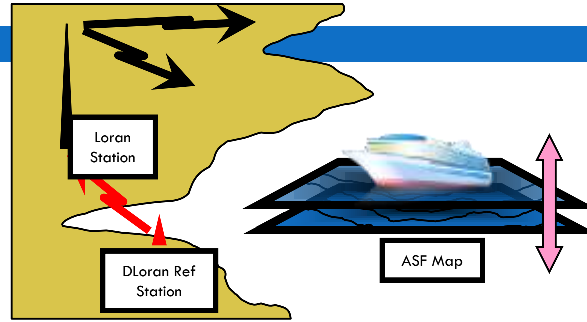
eLoran – low cost, high performance

- Terrestrial, high-power, low-frequency system
- Modern digital technology
- No common mode of failure with GPS
- Plug-and-Play Compatible GPS augmentation
- Accurate positioning
- Precise UTC timing and frequency
- Robust data communications
- Autonomous operation

https://www.youtube.com/watch?v=wbJMExW9Rvo

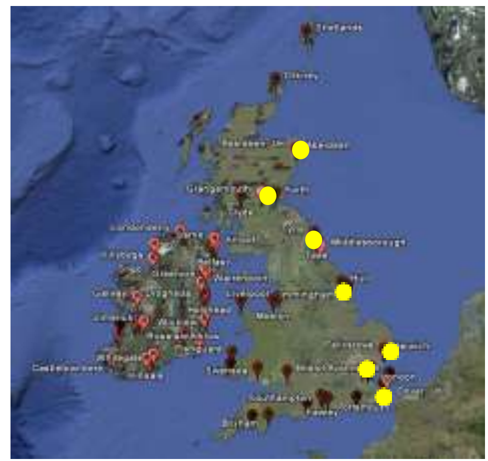
eLoran UK Initial Operational Capability

UK maritime eLoran IOC declared on 31 October 2014



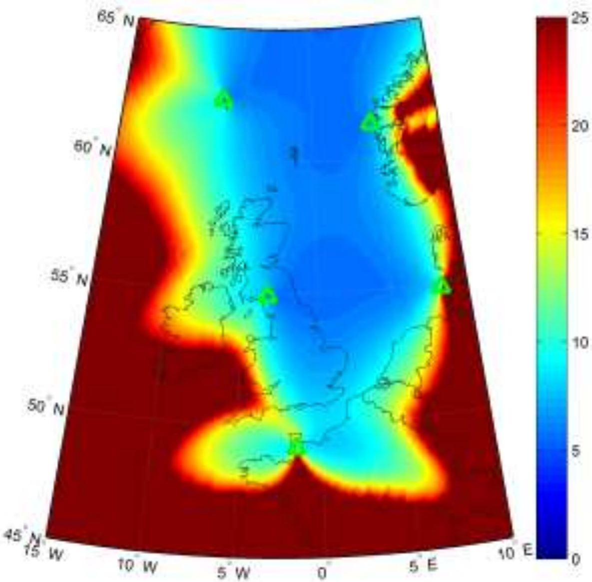
Differential operation

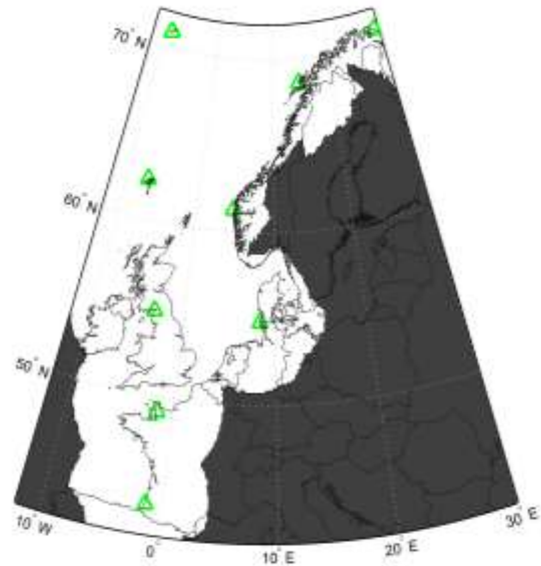
- 7 major UK east coast ports



eLoran IOC coverage

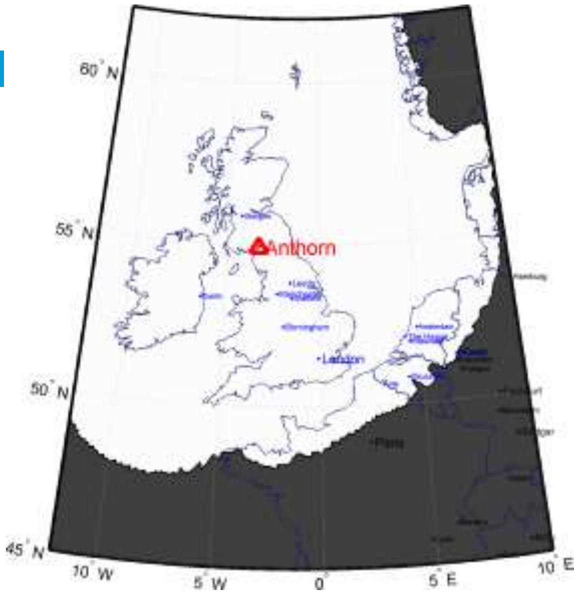
Position accuracy capability (metres)





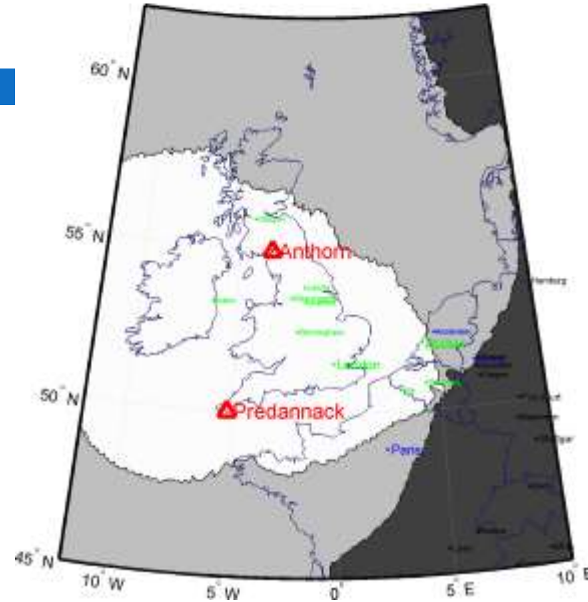
Indoor coverage of eLoran 500ns timing accuracy

UK-only Timing & Data Capability



UTC Timing from UK Anthorn Transmitter alone: 500ns, indoors

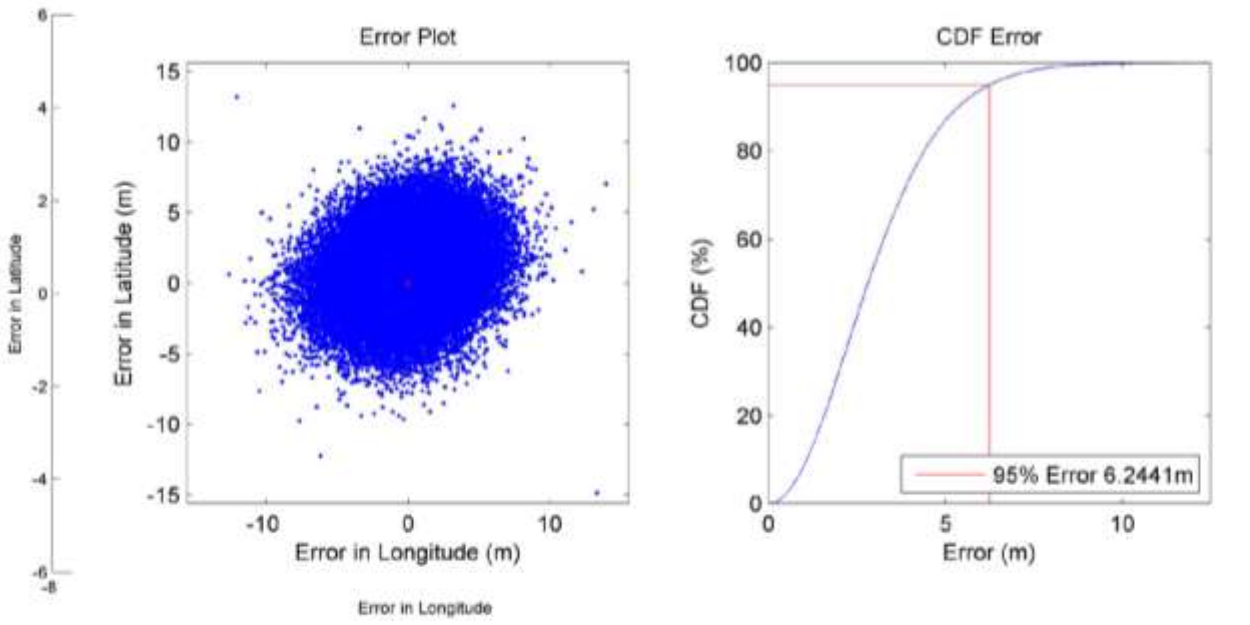
Single Tx Timing & Data capability



With a 2nd UK permanent transmitter (100kW) installed in Cornwall

Robust UTC Timing & Data capability

Humber Site – Location accuracy



Summary, all Locations

Differential eLoran Station	Predicted Horiz. Accuracy (95%)	Measured Horiz. Accuracy (95%)	Difference vs Model
Harwich	8.90 m	6.59 m	25.9 % better
Dover	10.20 m	6.87 m	32.6% better
Sheerness	9.30 m	7.78 m	16.3% better
Middlesbrough	5.80 m	No data yet	tbd
Leith	8.40 m	7.14m	15.0% better
Aberdeen*	7.20 m	7.33m	1.8% worse
Humber*	6.40 m	6.24 m	2.5% better

* At Aberdeen and Humber the antennas are located on the wall of a building and thus have less elevation than the other sites. It should also be noted that the model was based on previous performance attained using an H-field antenna

eLoran Initial Operational Capability in the United Kingdom – First results

Gerard Offermans, Erik Johannessen, Stephen Bartlett, Charles Schue, Andrei Grebnev, *UrsaNav, Inc.*
Martin Bransby, Paul Williams, Chris Hargreaves, *General Lighthouse Authorities of the UK and Ireland*

BIOGRAPHIES

Dr. Gerard Offermans is Senior Research Scientist of the UrsaNav LFBU engaged in various R&D project work and product development. He supports customers and operations in the European, Middle East, and Africa (EMEA) region from UrsaNav's office in Belgium. Dr. Offermans is one of the co-developers of the Eurofix data channel concept deployed at Loran installations worldwide. Dr. Offermans received his PhD, with honors, and Master's Degree in Electrical Engineering from the Delft University of Technology.

Erik Johannessen is Vice President of LF Business Development at UrsaNav. He is responsible for leading the Low Frequency Business Unit (LFBU) in business development, and also provides technical and operational expertise with LF Business Unit systems, services, and products.

Steve Bartlett is Vice President of Operations for the UrsaNav LFBU. He is responsible for all aspects of business operations including manufacturing, engineering, quality control, program management, and project delivery. Steve served as an active duty officer in the U.S. Coast Guard and retired from the U.S. Coast Guard Reserve. He earned his BS in Electrical Engineering from Northeastern University and an MS in Electrical Engineering from North Carolina State University.

Charles Schue is co-owner and President of UrsaNav, Inc. He champions providing Low Frequency Alternative Positioning, Navigation, Time and Frequency, and Data solutions for "sky-challenged" users. He served in the U.S. Coast Guard, where his expertise included radio navigation systems, and was the first Commanding Officer of the Coast Guard's Loran Support Unit. He holds Masters Degrees in Electrical Engineering, Engineering Management, and Business Administration. He is a Fellow of the Royal Institute of Navigation.

Andrei Grebnev is Principal Engineer at UrsaNav, Inc. and is responsible for the design of new products for LF systems and eLoran user equipment technology. He received BS and MS degrees in Radioelectronics Engineering from Moscow Aviation Institute. He worked at the same Institute as Senior Research Engineer and later as Chief of Receivers Laboratory. Mr. Grebnev holds patents pertaining to the use of magnetic loop antennas for Loran and has authored several papers on the subject.

Martin Bransby is the Manager of the Research and Radionavigation Directorate of the General Lighthouse Authorities of the UK and Ireland. He is responsible for the delivery of its project portfolio in research and development in such technical areas as AIS, eLoran, e-Navigation, GNSS and Lights. He is a Fellow of the Royal Institute of Navigation, and holds memberships of the Institute of Engineering & Technology and the US Institute of Navigation. He is also a member of the International Marine Aids to Navigation and Lighthouse Authorities' (IALA) Aids to Navigation Management Committee.

Dr. Paul Williams is a Principal Development Engineer with the Research and Radionavigation Directorate of The General Lighthouse Authorities of the UK and Ireland, based at Trinity House in Harwich, England. He is currently the technical lead of the GLA's eLoran Work Programme. The work involves planning the GLA's maritime eLoran trials and work on a wide range of eLoran related projects. He holds BSc and PhD degrees in Electronic Engineering from the University of Wales, is a Chartered Engineer, a Fellow of the Royal Institute of Navigation, and is chairman of the Radio Technical Commission for Maritime Services Special Committee 127 on Standards for Enhanced Loran (eLoran) Systems.

Chris Hargreaves is a Research and Development Engineer with the Research and Radionavigation Directorate of The General Lighthouse Authorities of the UK and Ireland, based at Trinity House in Harwich, England. His work is focused on the GLA's eLoran project in particular measurement trials, software development and data analysis. He holds an MSci degree in Mathematics and Physics from the University of Durham, and an MSc in Navigation Technology at the University of Nottingham and is a member of the Institute of Navigation and the Royal Institute of Navigation.

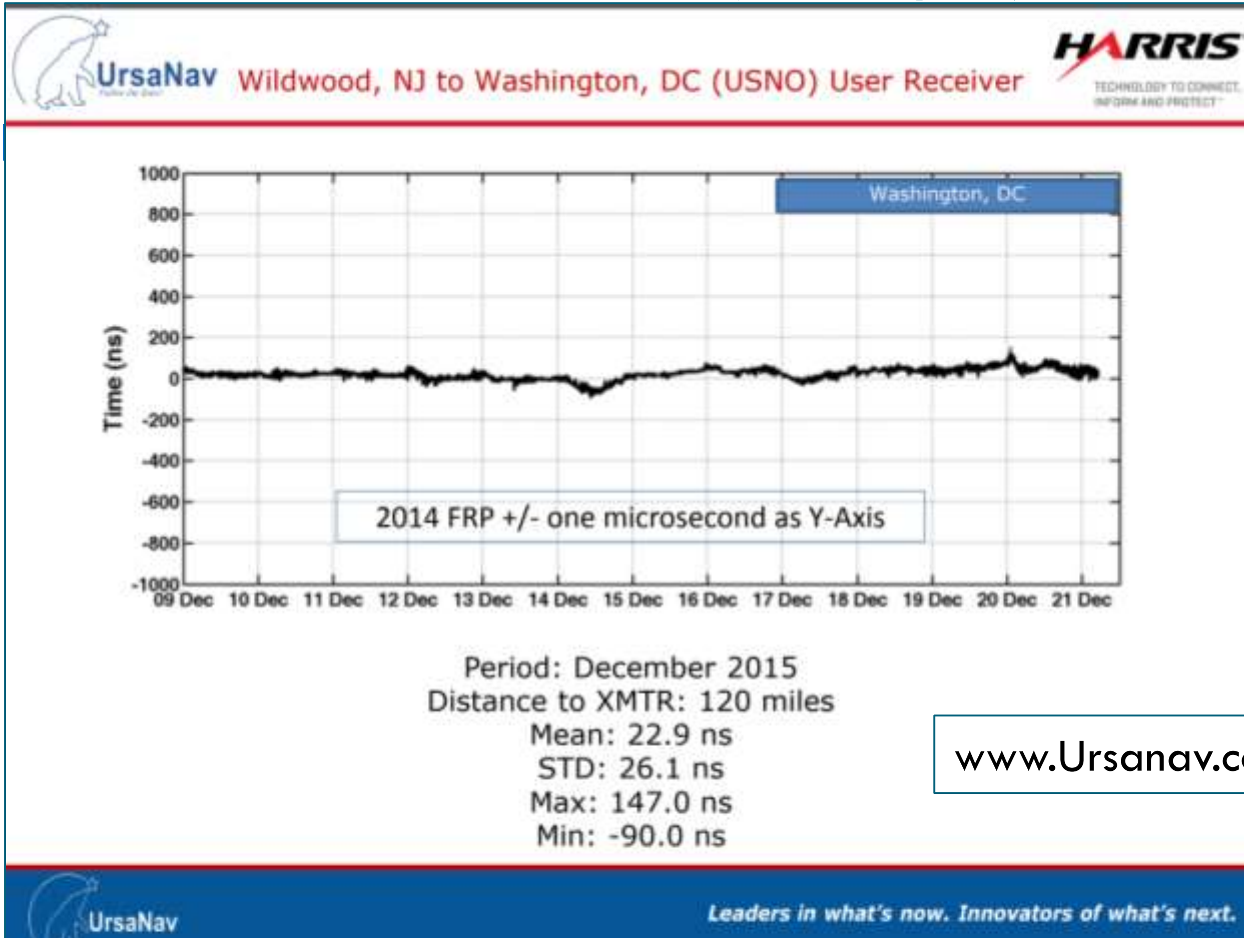
ABSTRACT

There is an increasing awareness in the Maritime world that no single system can provide Position, Navigation, and Time (PNT) resiliently under all circumstances. At this moment GPS (with augmentations) is used on most commercial vessels, and in many cases integrated into systems we did not expect would need or use GPS derived

ION Paper

50ns achieved outside

Work in the United States (example)



www.Ursanav.com

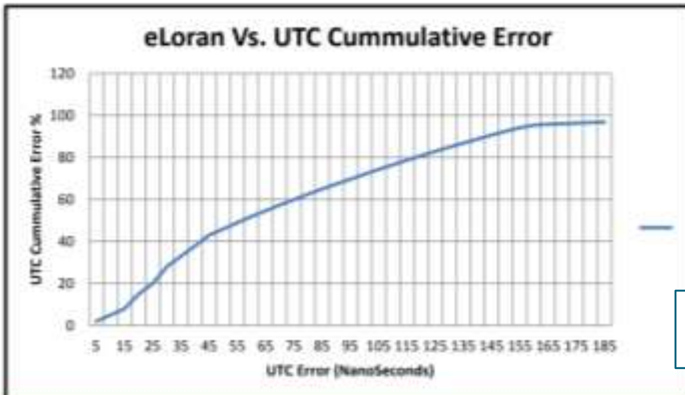
Work in the United States - Summary

UrsaNav

HARRIS

eLoran CRADA Executive 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 156 Nanoseconds of UTC



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Leaders in what's now. Innovators of what's next.

Work in the United States - Summary

UrsaNav — eLoran CRADA Executive Summary — HARRIS

- *With* differential corrections applied 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 January 2017
- eLoran in Smart Grid application Proofs-of-Concept are planned for Feb/March 2017

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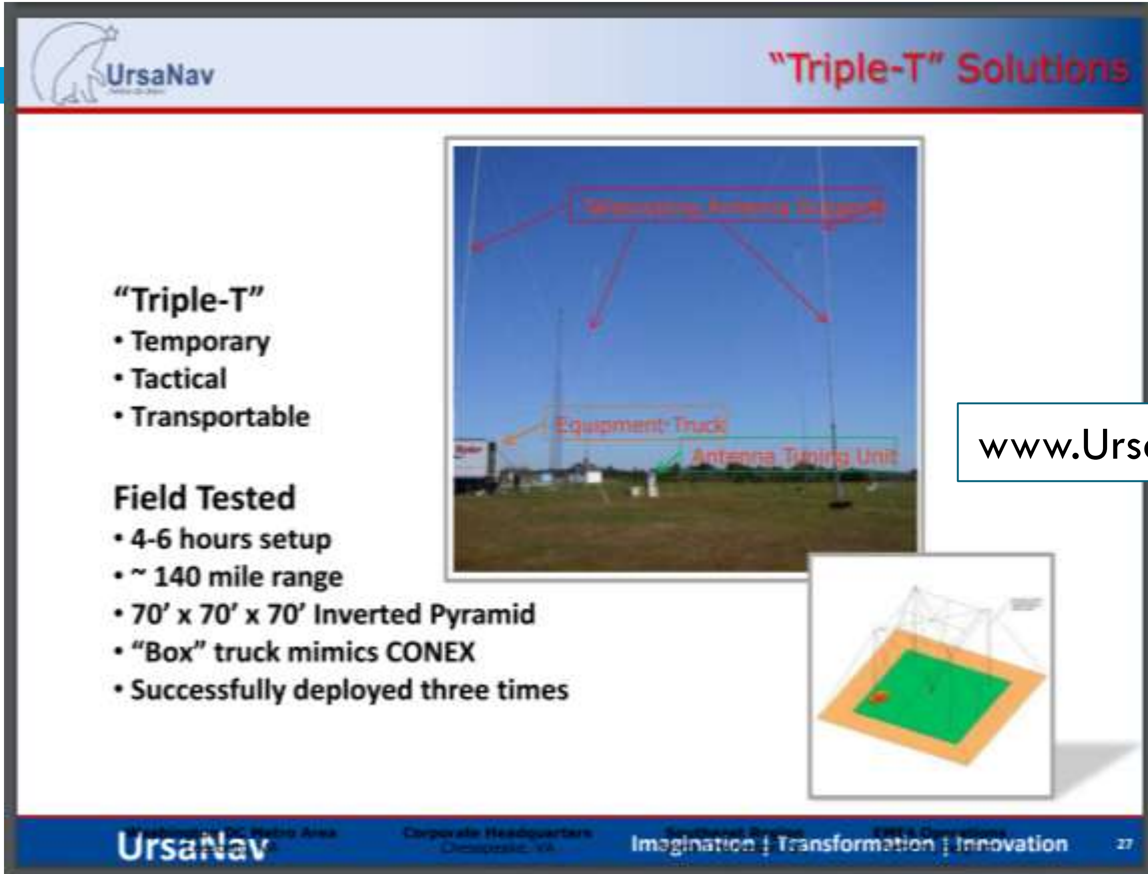
Portable Capability



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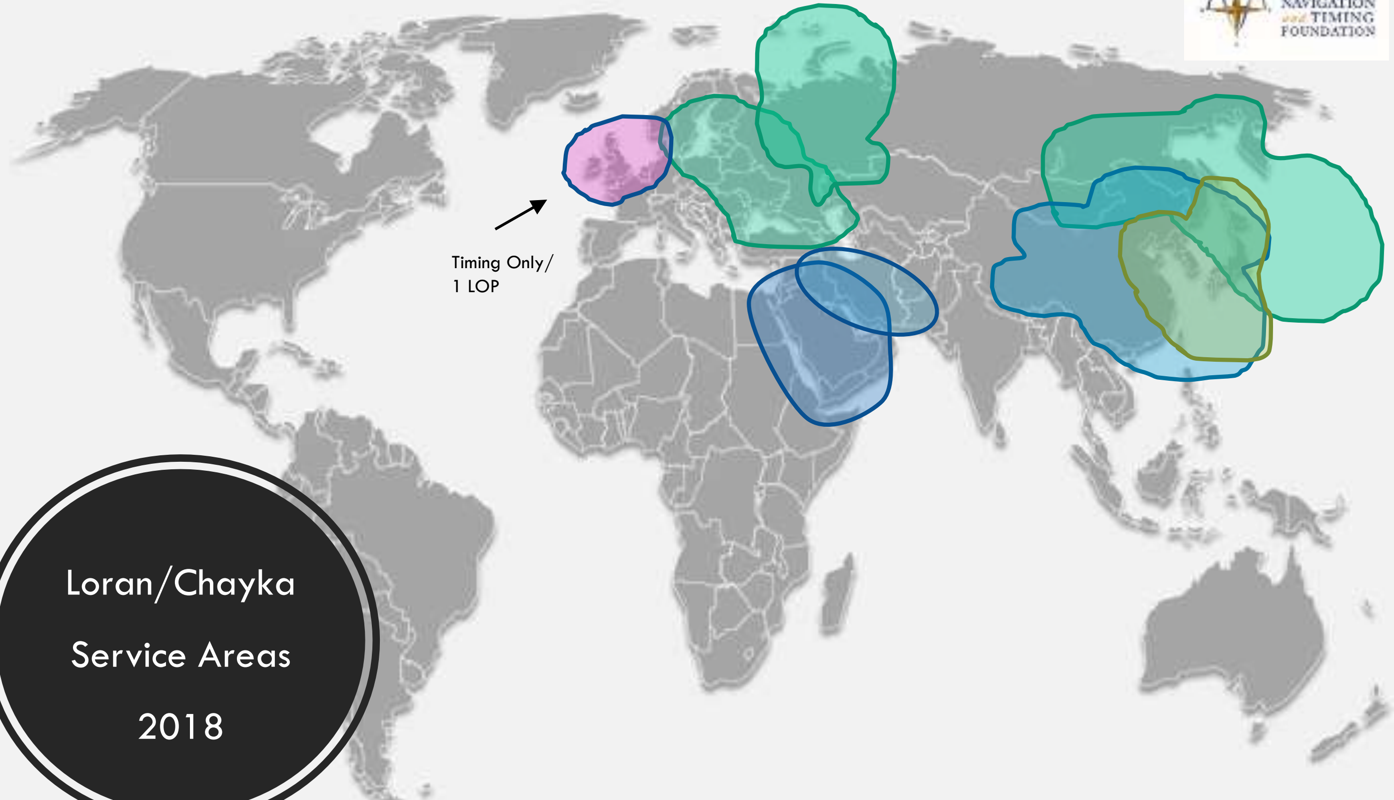
RESILIENT NAVIGATION and TIMING FOUNDATION

Loran/Chayka Service Areas 2018



Service Areas Approximate. Consult national authorities in UK, Saudi Arabia, Russian Federation, China, & South Korea for more information

RESILIENT NAVIGATION and TIMING FOUNDATION

جميع أطفال الله بحاجة إلى ملاحة جيدة وتوقيت!

The Resilient Navigation and Timing Foundation is a 501(c)3 scientific and educational charity registered in Virginia