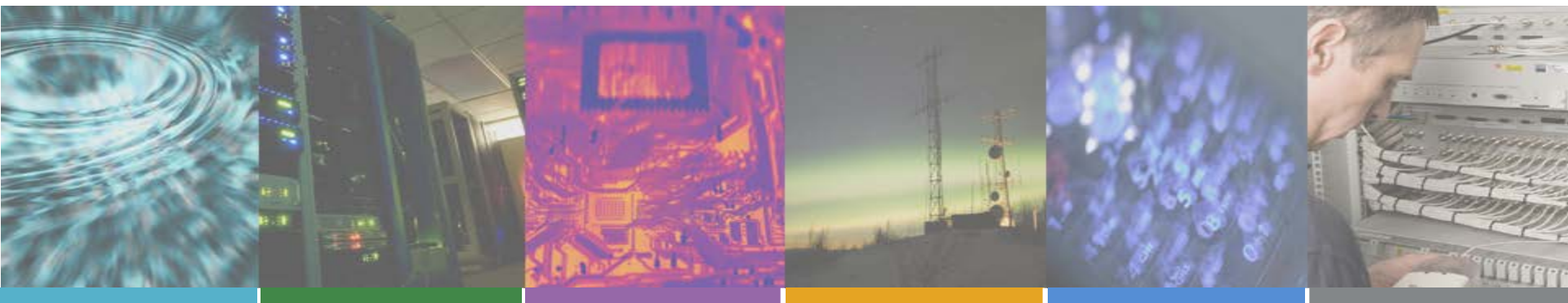


eLoran Trials in and around the UK for Time and Position



Prof. Charles Curry BEng, CEng, FIET
Chronos Technology Ltd

WSTS, San Jose, Thursday 12th March – Session 7

Presentation Contents

- eLoran International Situation
- Background Research
- Timing Research & Loran Data Channel
- Major UK eLoran Trial
- Conclusions

International Loran Situation

- UK – Active
- France & Norway – Continuity Discussions
- USA – Switched Off, Some CRADA Activity
- Russia, Korea, China - Active
- India, Saudi Arabia – Contemplating Upgrades



Recent Developments

- Korea
 - Award of Contract for new & refurbished transmitter sites
 - Inspired by North Korean jamming – next slides
- USA DoD
 - RFI for US army for 50,000 eLoran receivers
 - Inspired by vulnerability of GPS (GNSS) only
- IOC for UK eLoran for Navigation
 - Differential eLoran stations now operational
 - 10m accuracy for harbour entrance along East coast

Impact of Jamming in Korea



Intentional High-Power GPS Jamming

[The Central Radio Management Office, South Korea]

Dates	Aug 23-26, 2010 (4 days)	Mar 4-14, 2011 (11 days)	Apr 28 – May 13, 2012 (16 days)
Jammer locations	Gaesong	Gaesong, Mt. Gumgang	Gaesong
Affected areas	Gimpo, Paju, etc.	Gimpo, Paju, Gangwon, etc.	Gimpo, Paju, etc.
GPS disruptions	181 cell towers, 15 airplanes, 1 battle ship	145 cell towers, 106 airplanes, 10 ships	1,016 airplanes, 254 ships

Prof. Jiwon Seo -Yonsei University, South Korea

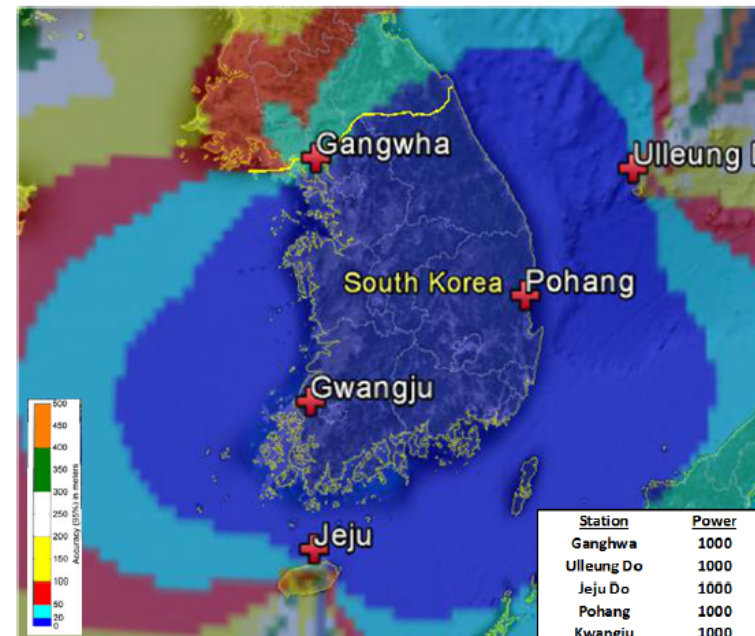
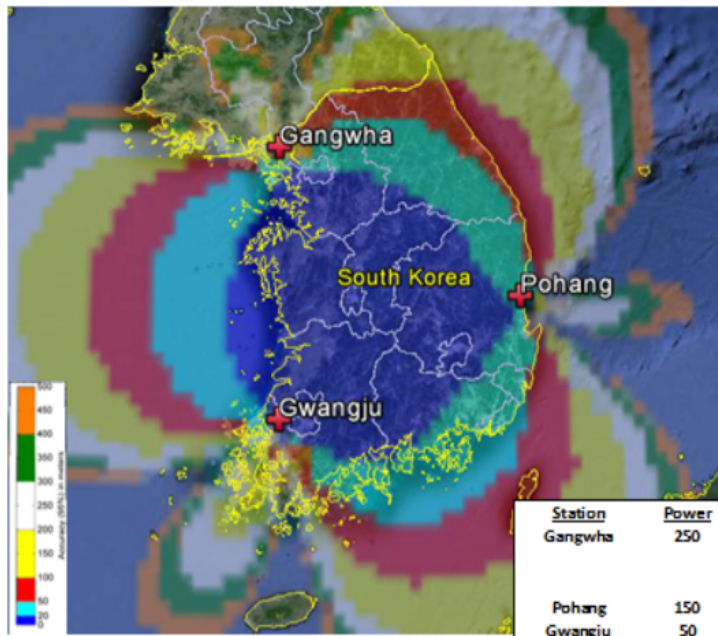
Resilient PNT Forum II, Dana Point, California

January 26, 2015



Revised Korean eLoran Program

- Two-phase approach
 - First phase: Implement maritime eLoran for the West Sea of Korea with 3 transmitters and 2 differential stations
 - Second phase: If demonstrated performance is satisfactory, more transmitters and differential stations may be deployed to cover other areas



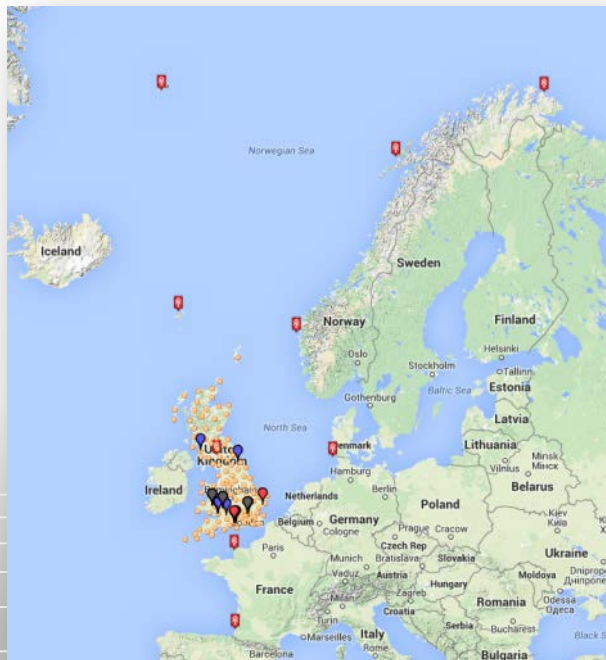
RN WECDIS

- WECDIS – Warship Electronic Chart Display & Information System – (Time & Position)
- Lockheed Martin awarded RN WECDIS – 2003
- Interfaces to 50+ Ships' Systems
- 90+ Ships and Submarines
- 2014 - Lockheed Martin & Chronos
- Provision of dual mode GPS/eLoran
- Safe Accurate Navigation in GNSS denied environment
- New era for Fleet Navigation for RN Warships and Submarines



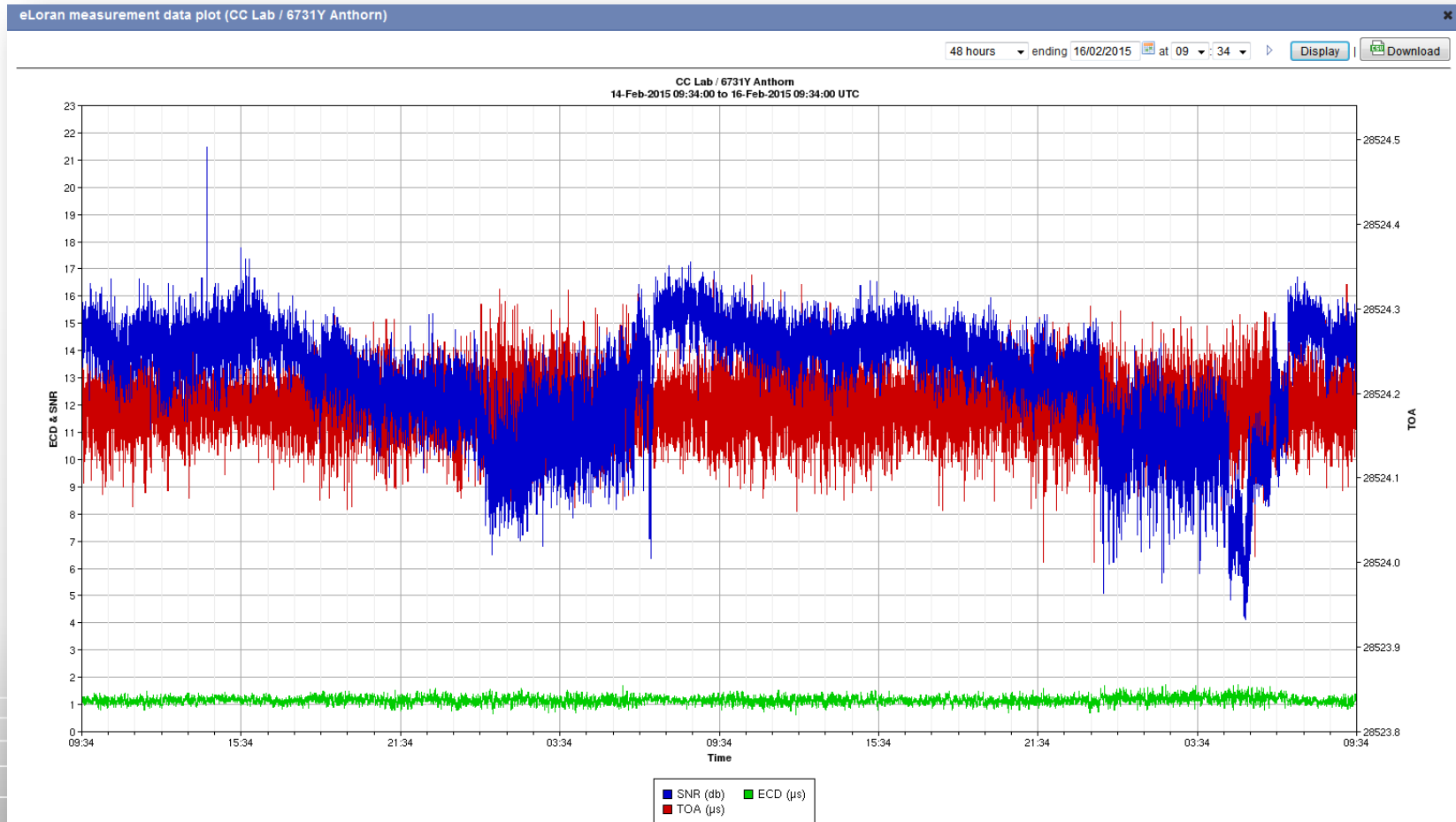
Background Research

- GAARDIAN and SENTINEL
 - Innovate UK Supported Research
- Researching eLoran reception since 2008

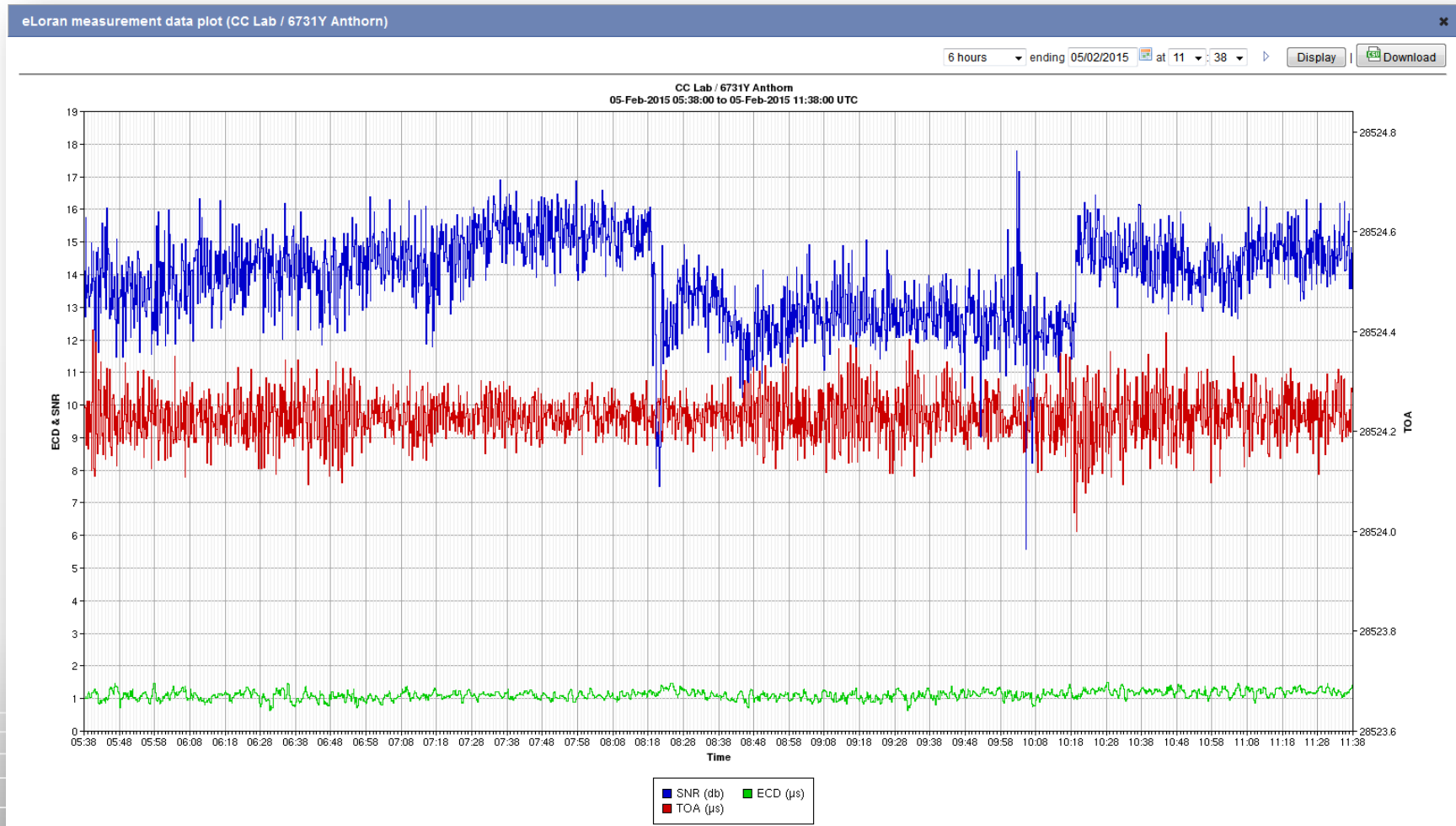


Probe	GPS	eLoran	1PPS	UoB
FFT	GLA	FFT_UoB		
Status: OK Actions				
Fix status				
Type:	Autonomous mode			
Time:	2015-02-16 09:36:01			
Stations				
Name	SNR	RA / EC	TOA	
ECN				
6731Y Anthorn	1.14	13.89	28524.23	0.00 / -
6731Z Sylt	0.60	6.64	44831.97	0.00 / -
6731M Lessay	1.24	20.32	1113.73	70.44 / 99.97
7499Y Vaerlandet	1.98	-0.92	33387.82	0.01 / 1.15
6731X Soustons	0.26	3.35	16104.05	0.00 / 3.23
9007X Boe				0.00 / -
9007W JanMayen				0.00 / -
7001Y Berlevag				- / -
9007M Ejde	6.90	-4.77	4064.83	0.01 / -
7499M Sylt	0.31	5.35	2732.06	0.00 / -
7499X Lessay	1.04	20.13	15213.76	0.00 / -
9007Y Vaerlandet	-0.16	-0.93	44988.10	0.00 / -
7001M Boe				0.00 / -
7001X JanMayen				0.00 / -

SNR, ECD, & TOA



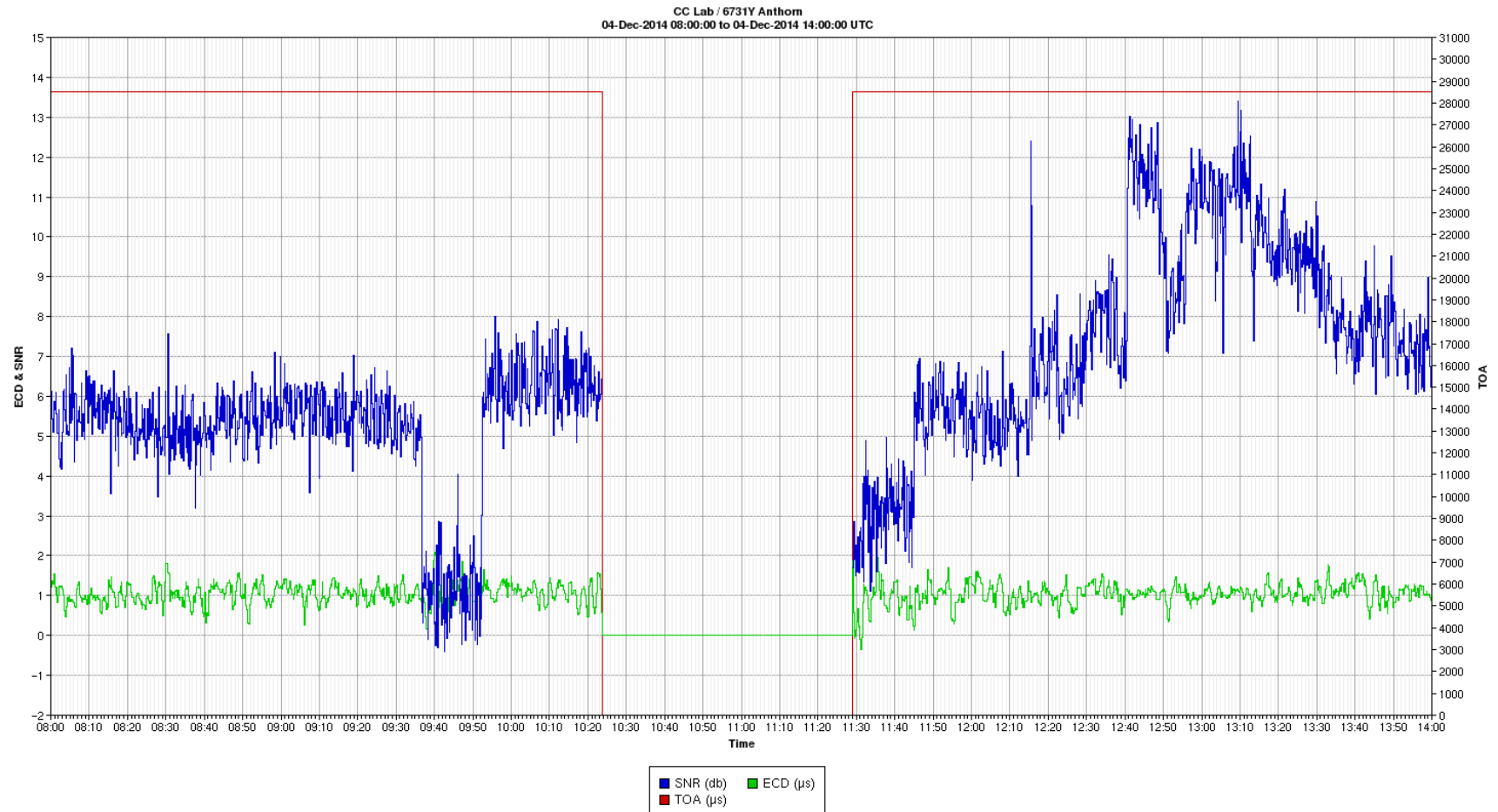
1st Thursday at Anthorn – Feb15



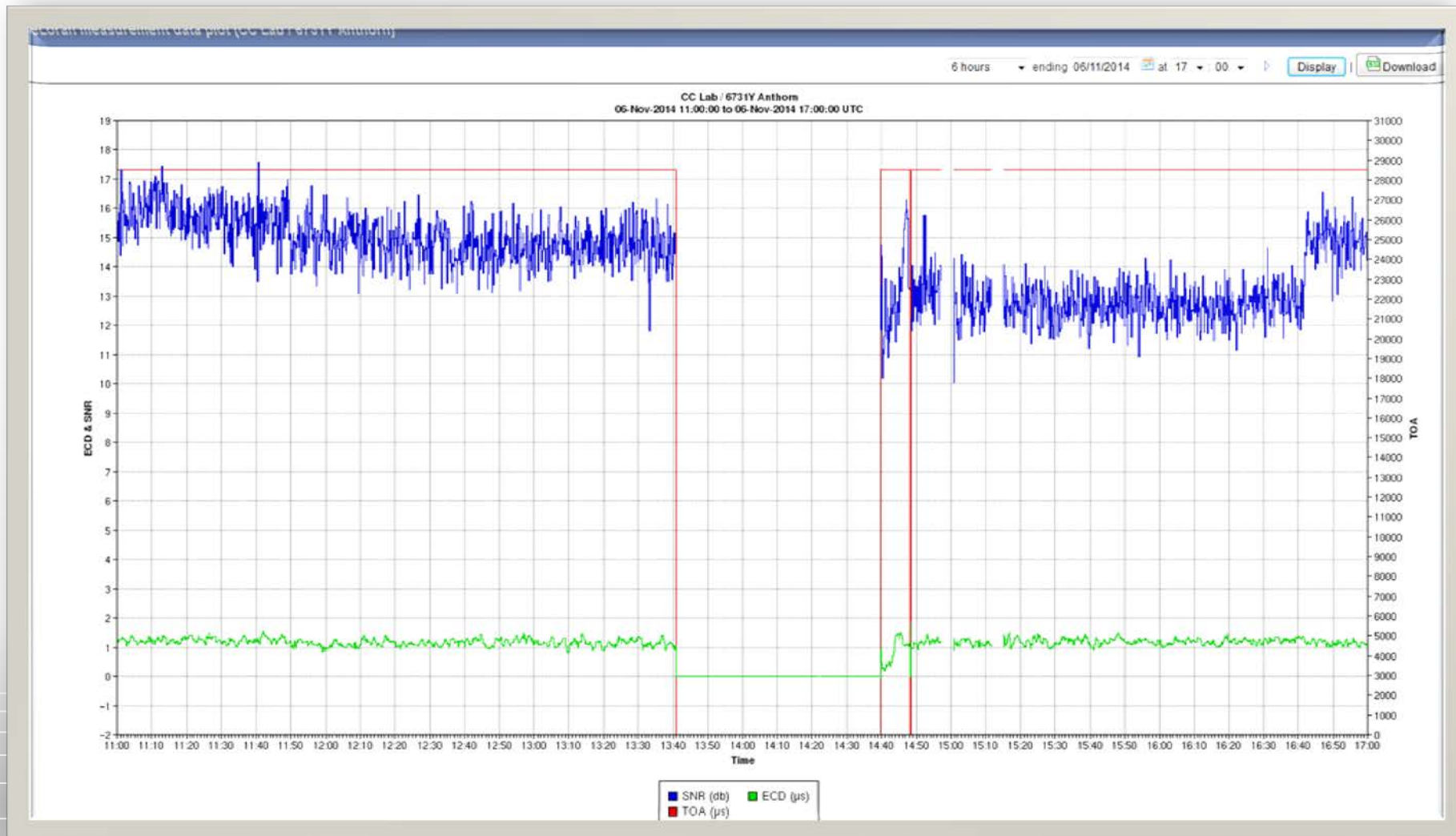
1st Thursday at Anthorn – Dec14

eLoran measurement data plot (CC Lab / 6731Y Anthorn)

6 hours ending 04/12/2014 at 14:00 Display Download

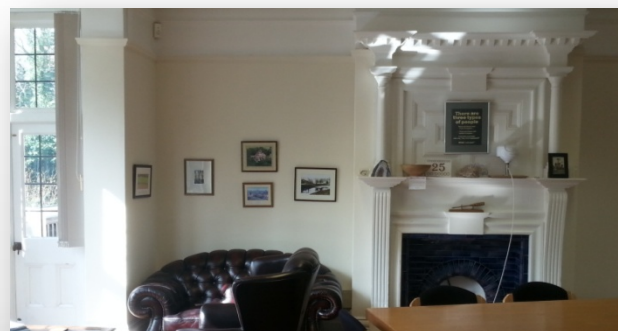
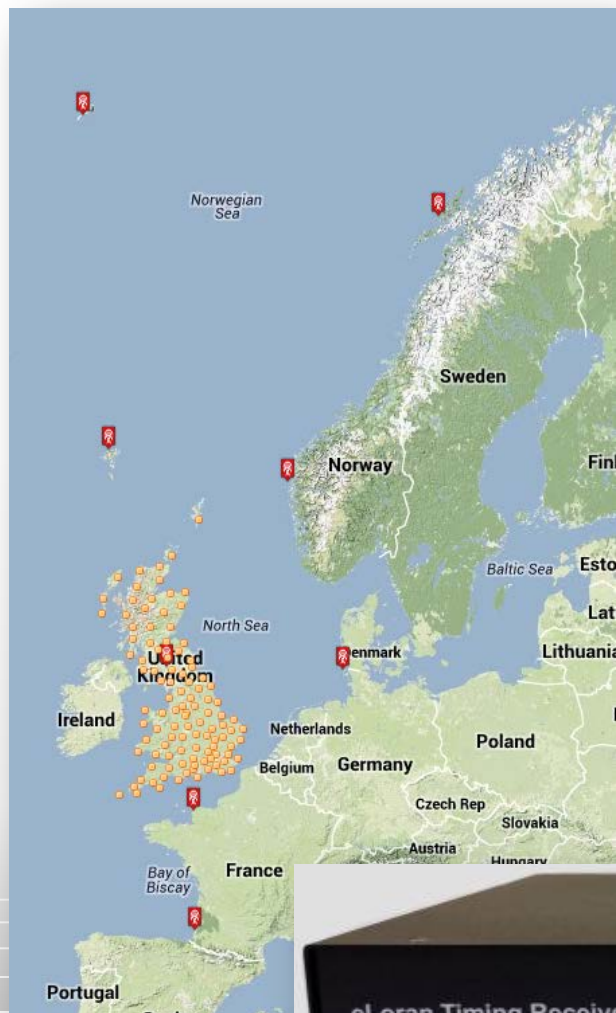


1st Thursday at Anthorn – Nov14

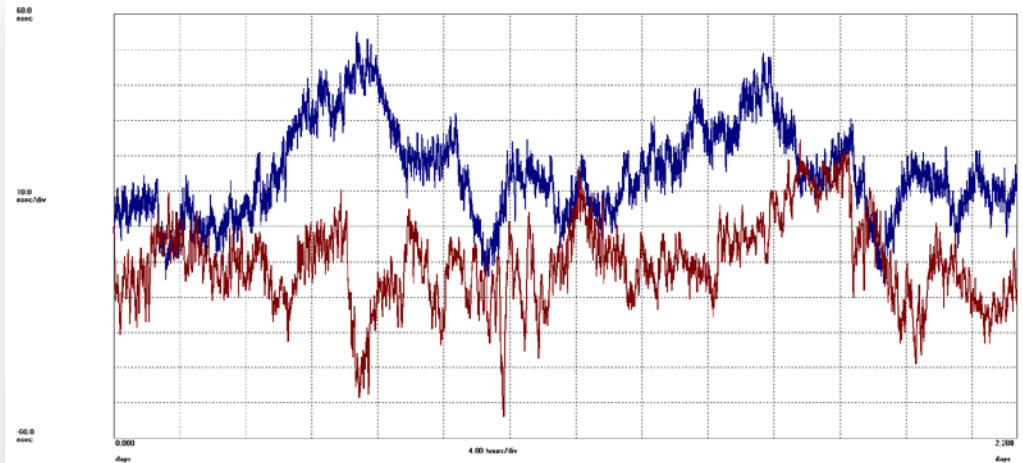


Research Tools

- SENTINEL Research Platform
- Combined eLoran and GPS PoC Timing Receiver CTL8200
- H-Field Antenna

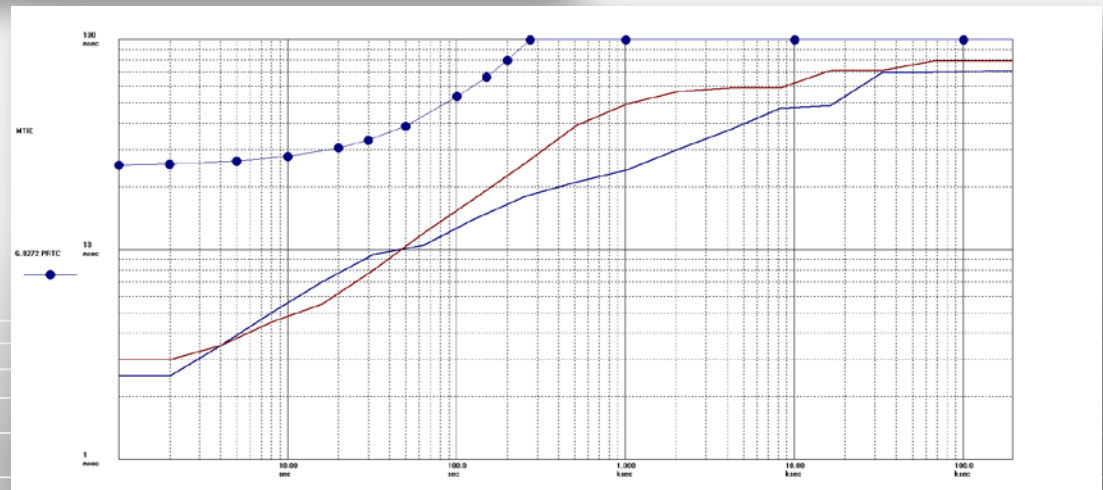


Some Results – TIE and MTIE



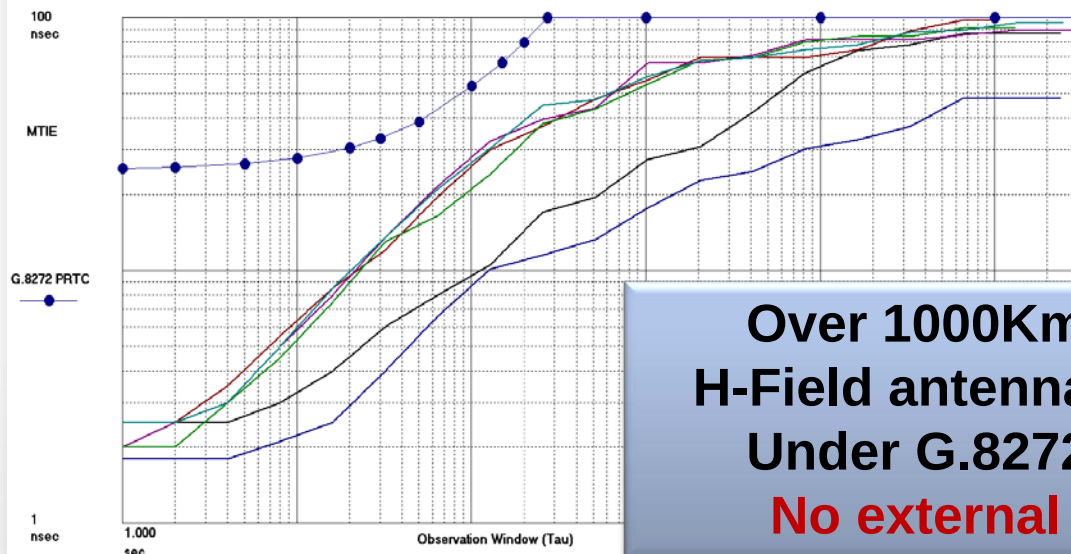
TIE Graphs
Blue: GPS
Red: Indoor eLoran
3 days, 10ns/div

MTIE Plots
Mask: G.8272 PRTC
Blue: GPS
Red: Indoor eLoran
3 days



Distant Station Testing

Symmetricom TimeMonitor Analyzer
MTIE; F₀=1.000 Hz; F_s=1.000 Hz; 2014/03/10; 18:51:14



Over 1000Km away!
H-Field antenna indoors
Under G.8272 PRTC
No external GNSS

Colour	Station	Range	Location	Path
Red	Lessay	300km	Northern France	Land and Sea
Blue	Anthorn	350km	North-West England	Land
Cyan	Sylt	800km	North Germany	Land and Sea
Green	Soustons	900km	Southern France	Land and Sea
Magenta	Vaerlandet	1150km	South-West Norway	Land and Sea

How do we get UTC?

- Loran Data Channel (LDC) transmits a UTC message
- LDC is key differentiator between Loran-C and eLoran
- Aligns the 1pps close to UTC
 - Error due to Additional Secondary Factor (ASF)
 - Dependent on land path and seasonal conditions
 - A few microseconds
 - Fixed with low seasonal variations (100ns)
- Can be calibrated out
- Either at installation or automatically

eLoran Differential Timing Rx

- eLoran Differential Timing Receiver – EDTR
- Measures ASF and establishes Local Time Error
- Enables UTC alignment to a few 10s of ns
- Sends Local Time Error to eLoran Transmitter to broadcast on the LDC
- UTC corrections can now be received indoors
- Local eLoran Rx with **no sky view** are now UTC aligned to G.8272 PRTC

Loran Data Channel

- Eurofix Message Format ver 2.15
 - Radio Technical Committee for Maritime Services (RTCM) Special Committee-104, Eurofix working group, and the International Telecommunication Union (ITU) Recommendation M.589-3
- 16 “Message Types” can be broadcast
- Message Type 6 is the Eurofix Message
 - Rough correction to UTC
- Message Type 13 is now allocated for Chronos for Local Time Error correction research
- Experimental Transmissions from Anthorn

UTC Alignment Process

In Lab

Switch
on

Wait for UTC
Message

Measure
Offset to GPS

Track in and Filter

With
LDC

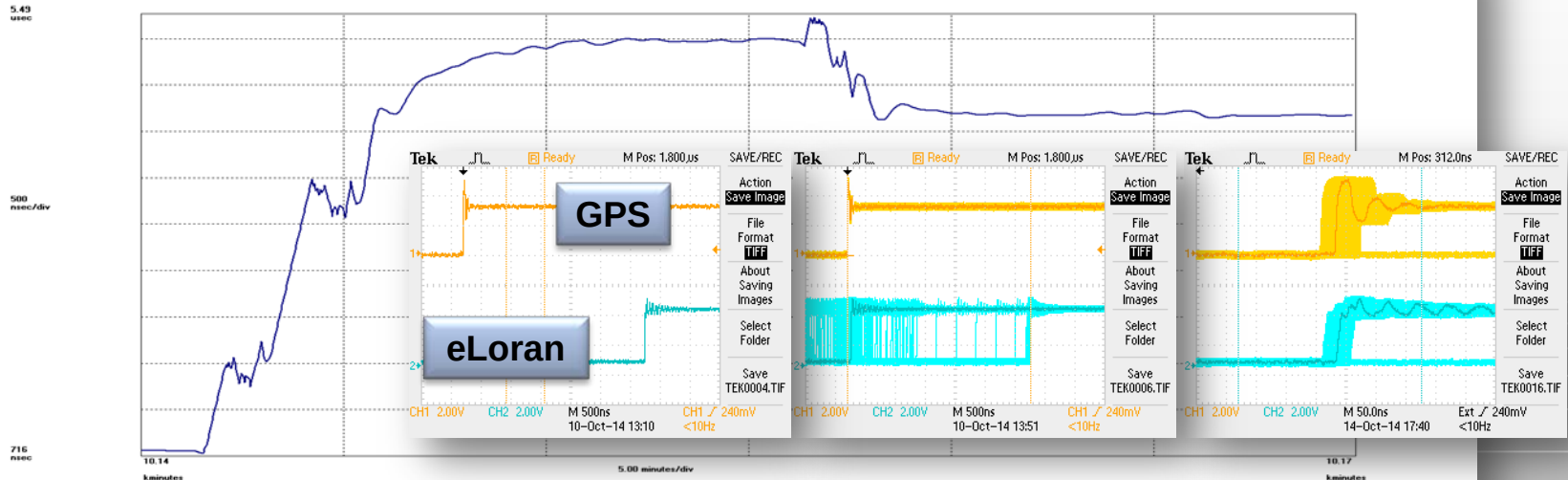
Switch
on

Wait for UTC and ASF Offset
Message over LDC

Track in and Filter

No sky view required!

Symetrix TimeMonitor Analysis
Phase deviation in units of time: F₀=1.000 Hz; F₀=1.0000000 Hz; *03/10/2014 15:49:58*
HP 53132A; Test: 579; A: CCR11 eLoran; B: PPS45A; eLoran H Tps; Samples: 856823; Gate: 1 s; Ref ch2: 10.00 MHz; T1/Time Data Only; T1 1>2;
53132A in 252



Why not GNSS alone for timing?

- Can be jammed and spoofed
- Does not work inside buildings
- Does not work underground
- Does not work underwater
- eLoran/GNSS only solution for Resilient PNT
- Chronos researching eLoran/GPS/Galileo/PTP
- True resiliency uses multiple dissimilar sources of PNT



Chronos eLoran Research Partners

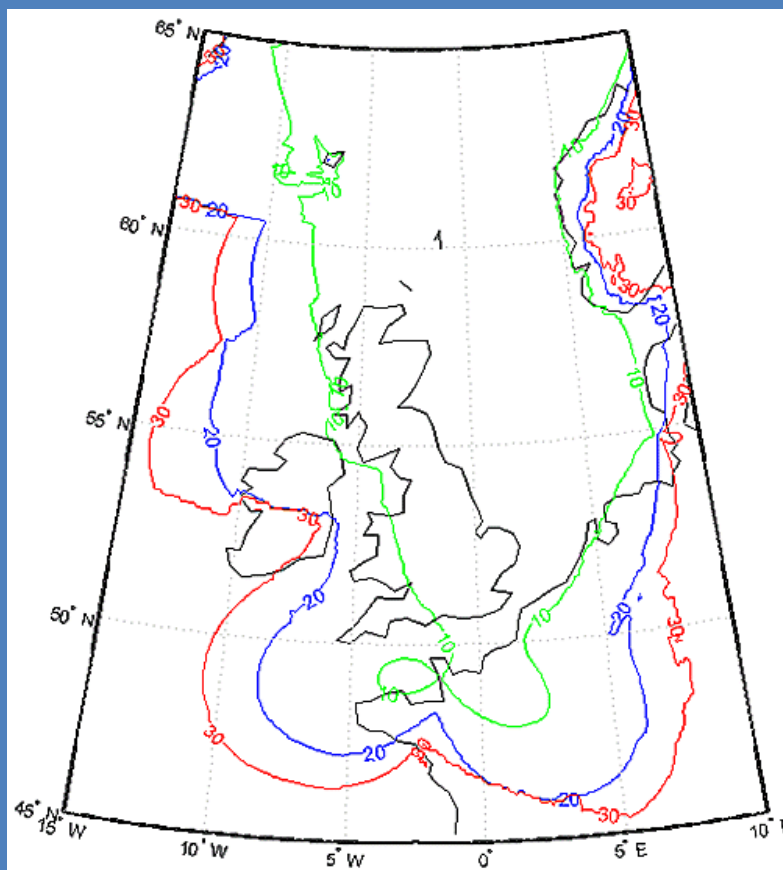
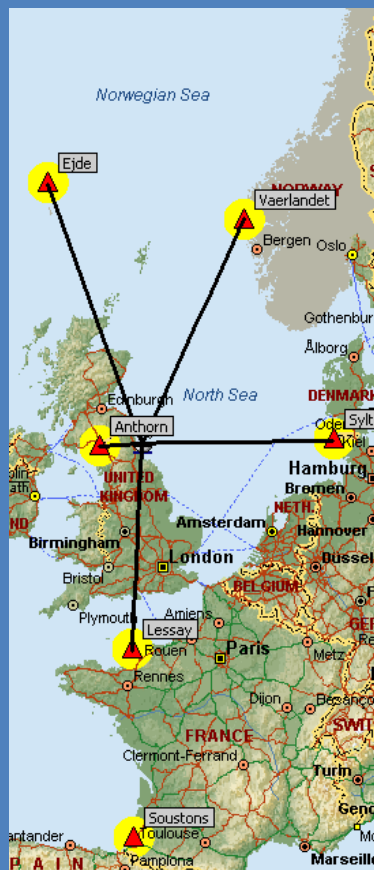
- Telecom Industry
 - BT, EE, H3G
 - Critical Infrastructure Timing
- Broadcast Industry
 - Arqiva
 - Critical Infrastructure Timing
- Maritime
 - Royal Navy, Lockheed Martin, GLA (Since 2008)
 - Timing and Position
- Utilities
 - National Grid
 - Critical Infrastructure Timing

Partners in the Sea Trials

- Royal Navy – HMS Mersey
- Lockheed Martin – RN WECDIS Contract
- GLA – Differential eLoran Stations



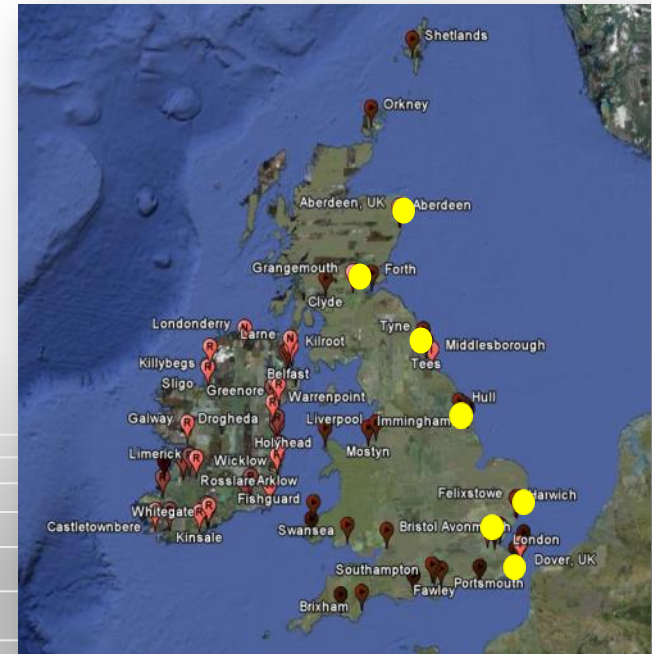
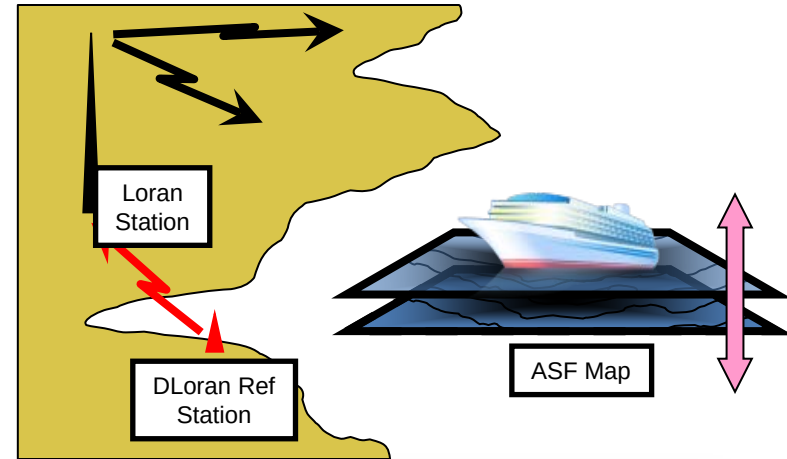
GLA - UK prototype eLoran system on air



**Runs continuously; available since May 2010;
10-20m accuracy in ports with differential service (green area)**

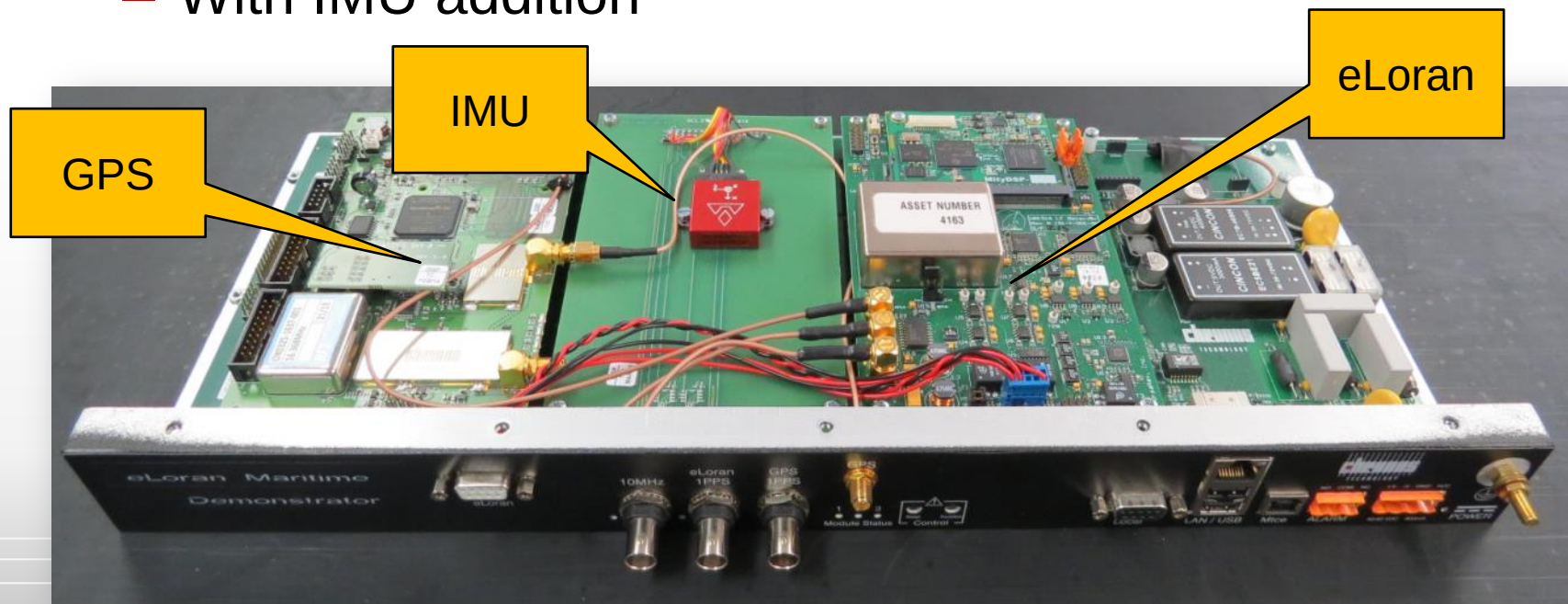
GLA - eLoran Initial Operational Capability

- Initial Operational Capability
 - 7 major east coast ports
 - completion end 2014
- Full Operational Capability
 - all major ports UK/Ireland
 - planned by 2019



Chronos - Equipment on Trial

- eLoran Maritime Demonstrator
 - Based on our SENTINEL Sensor
 - With IMU addition

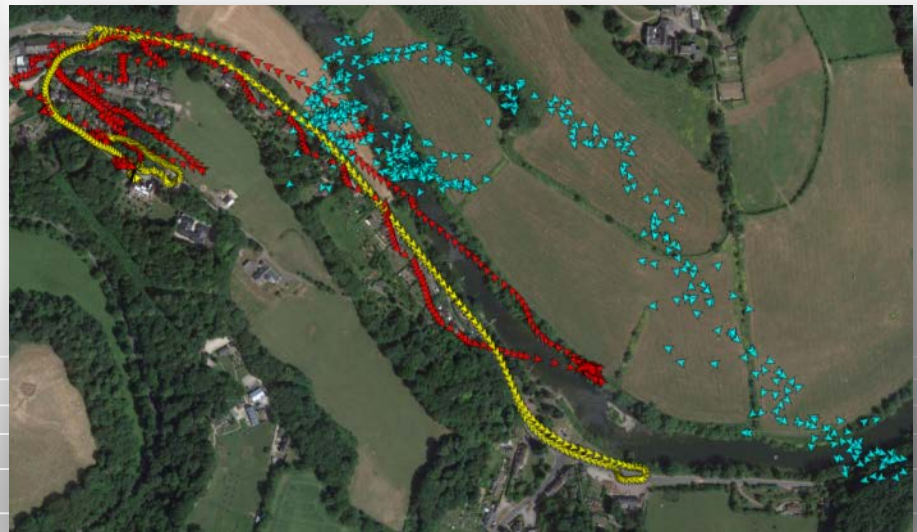


Early “Road” Tests



Vehicle
mounted trial
unit

Blue: Raw eLoran no ASF
correction
Red: eLoran and IMU
Yellow: GPS

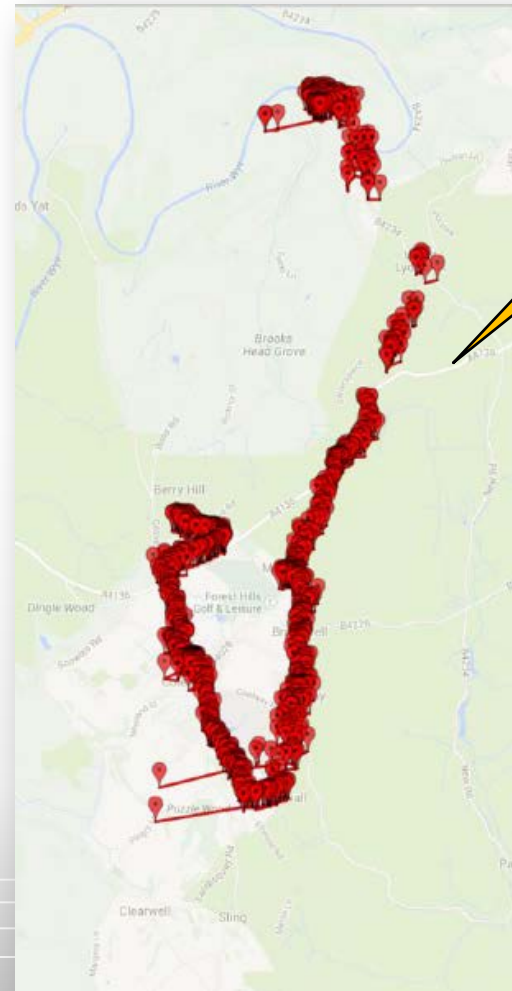


Longer Road Test

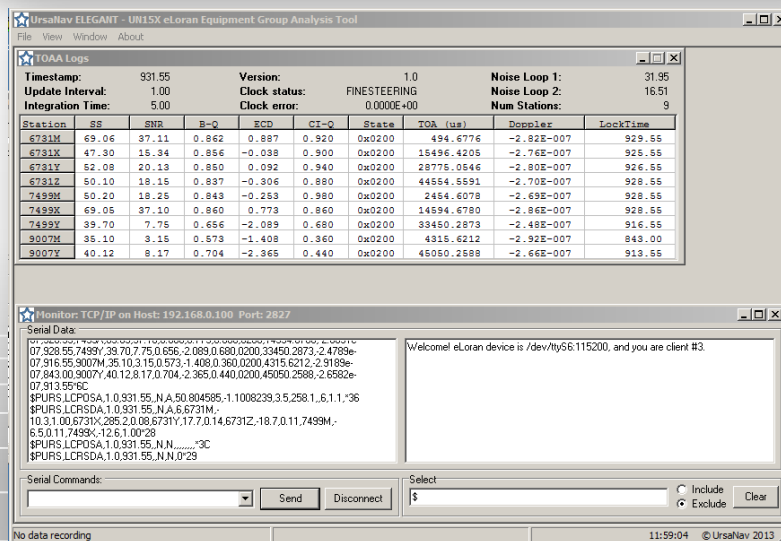
GPS



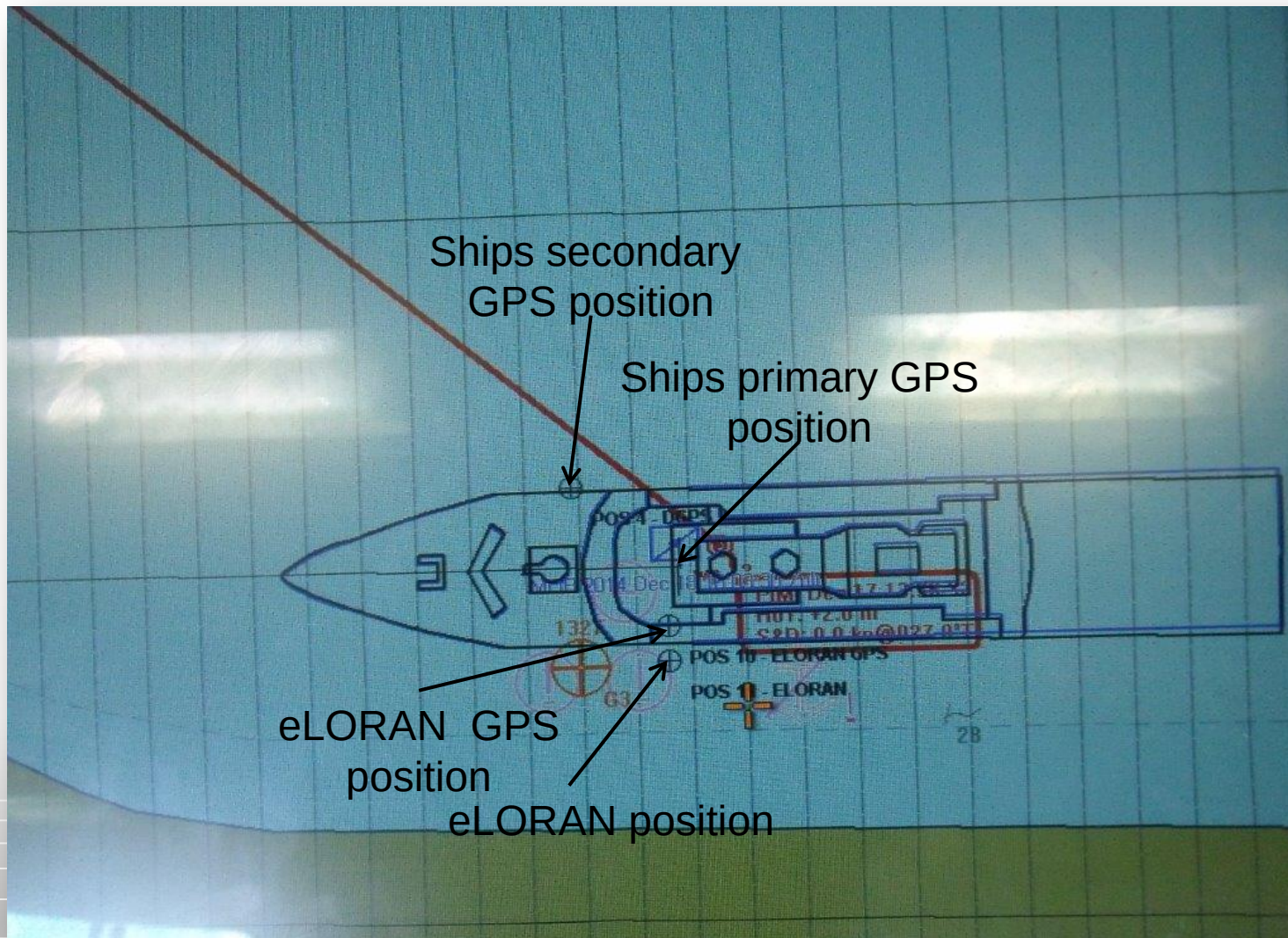
eLoran



Marine Installation Progress



eLoran Position on HMS MERSEY WECDIS



Conclusion



Thankyou

www.chronos.co.uk

www.gpsworld.biz

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Acknowledgements

Tom Smoker, Programme Manager, Maritime Innovation – Lockheed Martin

George Shaw, Principal Development Engineer, Research and Radionavigation Directorate - GLA's