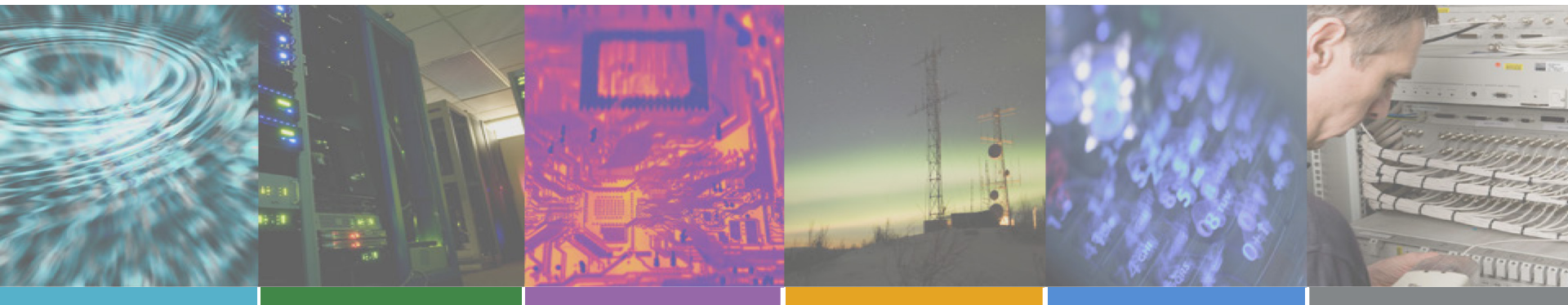


“Black Swans”, “White Elephants” and Delivering a New National Timescale with eLoran



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Managing Director
Chronos Technology Ltd

WSTS 2014

10 - 12th June 2014

San Jose, USA

PNT – First Experiences



Photo, Gary Pierce, Texas. www.gcpiere.com/

Black Swan Events



Nassim Nicholas Taleb

- **Surprise to the observer**
- **Significant impact**
- **With hindsight – could have been predicted**

Not necessarily a surprise to everyone

Recent Black Swan Events

- SVN/PRN23
 - 1st Jan 2004 Rb failure, massive loss of GPS timing
- The “San Diego Incident”
 - 2004 - US Navy Own Goal – CDMA Network down 3 hours
- North Korea
 - 2010 & on-going! South Korea suffers wide area GPS Jamming
- The “Newark Incident”
 - 2012 - White Van man on I95, Honeywell “SmartPath” GBAS
- Glonass
 - 2014 - Last month! Total failure (x2) first incident 36 hours

UK Research on topic

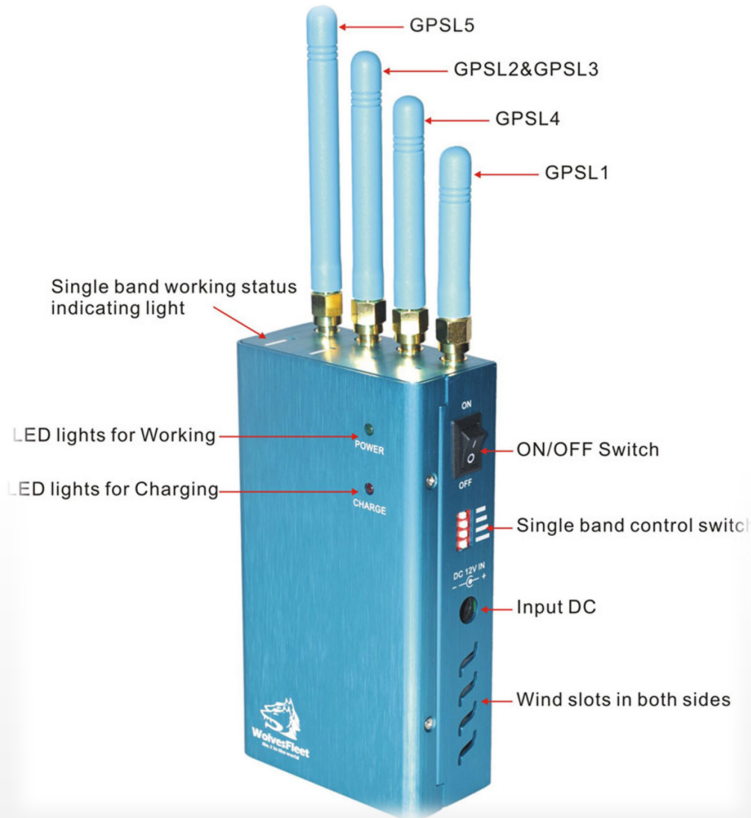


Technology Strategy Board
Driving Innovation

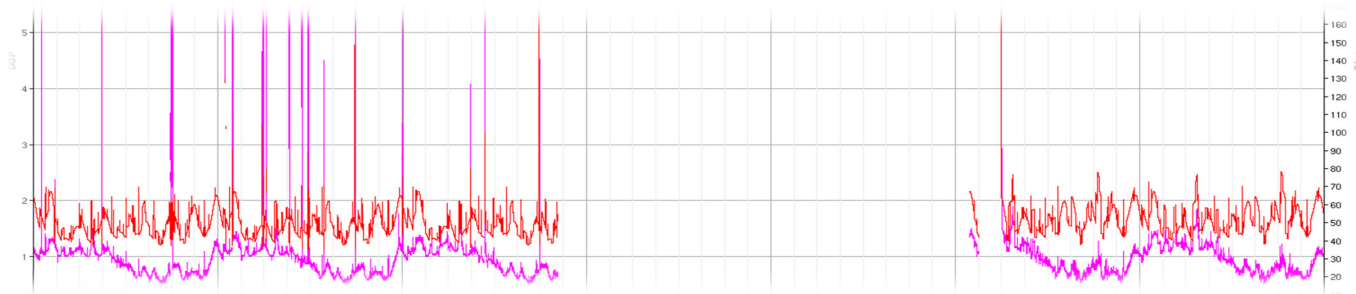


Thatcham

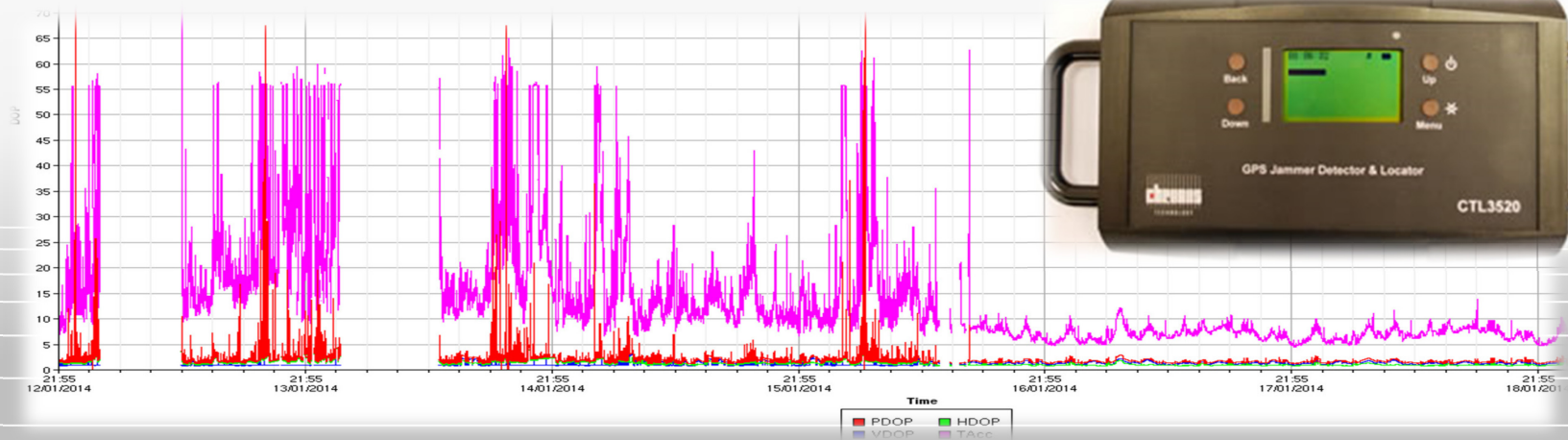
Jammer Testing



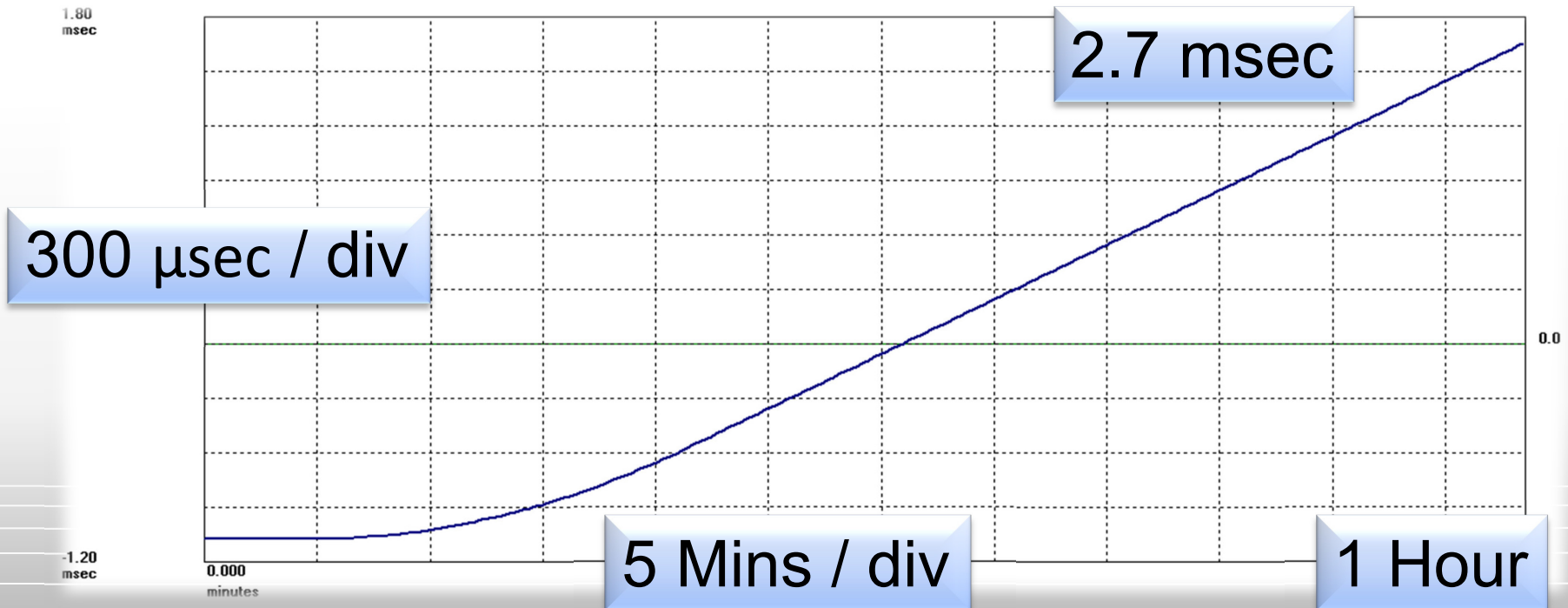
chronos
TECHNOLOGY



Rogue Antennas



Spoofing



GPS Vulnerability Mitigation

- In band?
 - PTP, SyncE, NTP
- Sticking Plaster?
 - CRPA, High stability oscillator
- Alternative PNT?
 - Other GNSS, Other PNT
- Depends on 1pps Phase Accuracy to enable application
 - 1ms/1 μ s/100ns?

Mitigation Ideas – Galileo?

- GPS 1984 – 9 Satellites – the year of “Big Brother”
 - Galileo 2014 – 4 Satellites
- www.gsa.europa.eu/security/prs
 - Jamming: “PRS will help to reduce this risk and make it easier to identify potential jammers”
 - “...under exceptional circumstances, the existence of a protected signal for critical applications would allow denial of the open signal to hostile users...”
- Disguised mandating policy
 - E112?
 - PRS for critical applications?



Mitigation Ideas – LF PNT?

- Significant Outcomes from SENTINEL Research
- eLoran extensively researched for timing
- In particular – indoor signal reception
- Publications
 - *“The SENTINEL Report”*
 - http://www.chronos.co.uk/files/pdfs/gps/SENTINEL_Project_Report.pdf
 - *“Delivering a National Timescale using eLoran”*
 - ***Not yet on the web site, please email me***
- Report on research.....

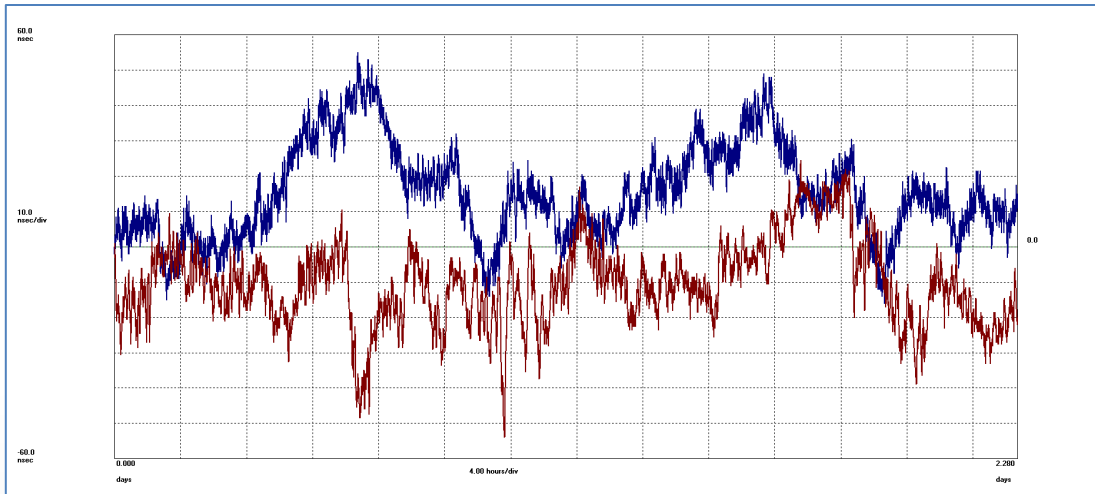
Research Tools

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

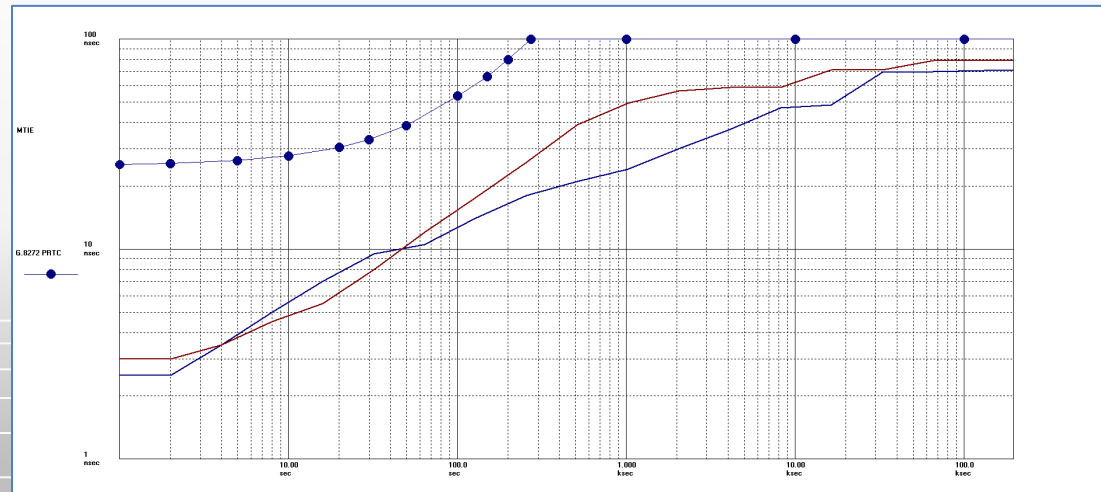


Some Results – TIE and MTIE

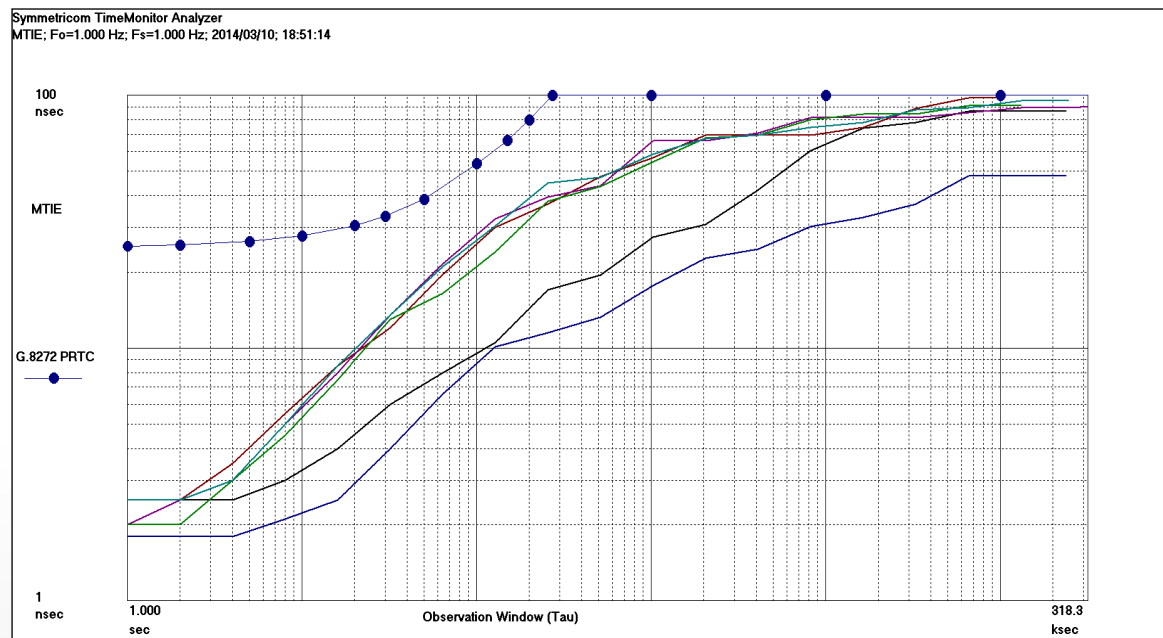
TIE Graphs
 Blue: GPS
 Red: Indoor eLoran
 3 days, 10ns/div



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



Distant Station Testing



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	North Germany	Land and Sea
Magentas	Vaerlandet	1150km	South-West Norway	Land and Sea

How do we get UTC?

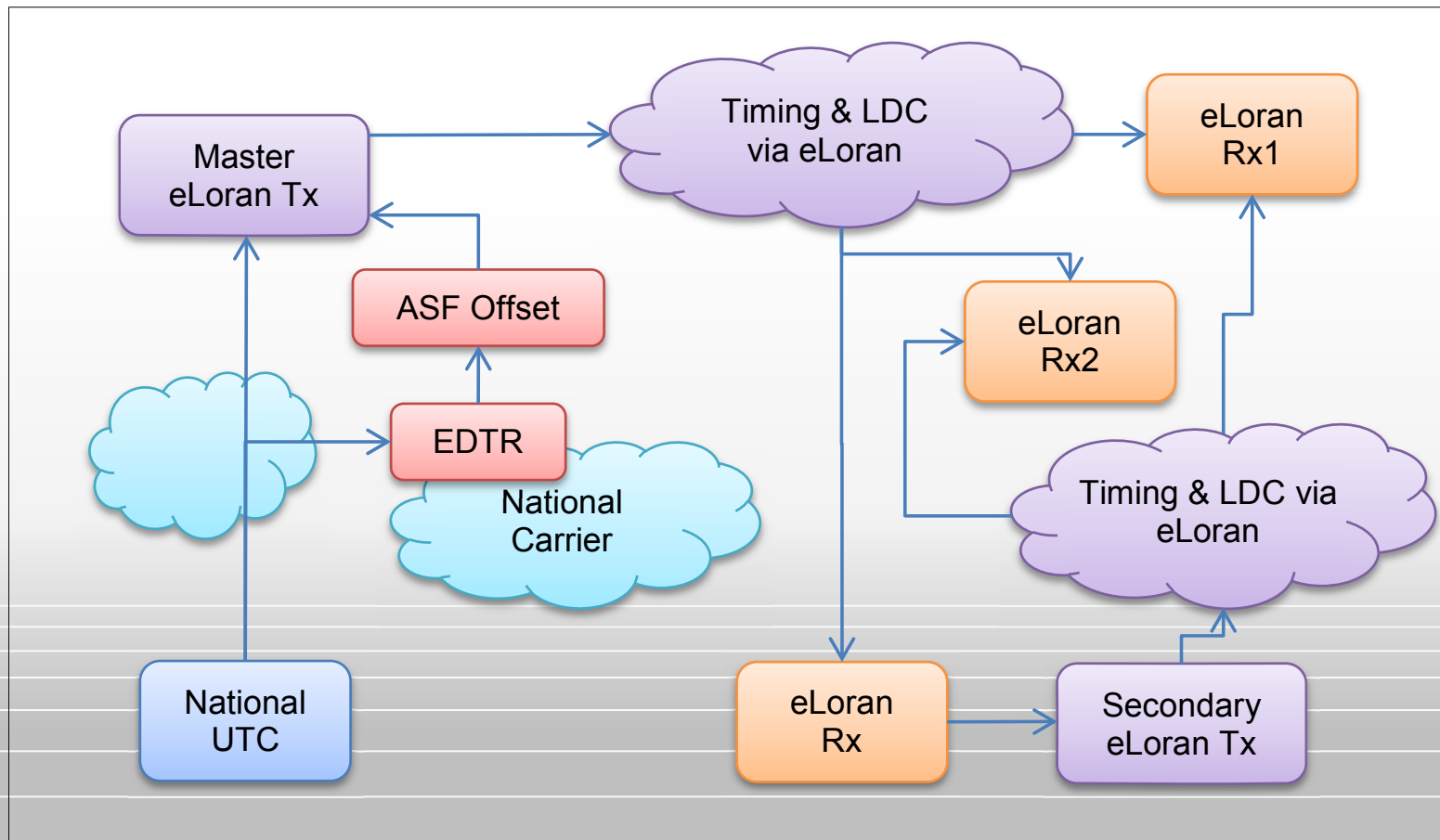
- Loran Data Channel (LDC) transmits a UTC message
- Aligns the 1pps close to UTC
 - Error due to Additional Secondary Factor (ASF)
 - Dependent on land path and seasonal conditions
 - A few microseconds
 - Fixed with low seasonal variations (100ns)
- Can be calibrated out
- Either at installation or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

eLoran Differential Timing Rx

- eLoran Differential Timing Receiver – EDTR
- Measures ASF
- Enables UTC alignment to a few 10s of ns
- Sends ASF 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 (LDC)

LDC can broadcast a local regional differential UTC correction



eLoran – for UTC “Time”

- Independent source of UTC
- Works in-doors, no expensive antenna roofwork
- Seamless cutover to back-up stations
- Meets ITU telecom PRC masks. (G.8272)
- LDC Broadcast Messaging enables continuous fine tuning of UTC
- Enabler for new LTE features - CoMP, eICIC indoors in GNSS denied locations
- Complements PTP, GNSS

eLoran Status

- Operational in UK and Europe
- International Upgrade projects
 - South Korea, Saudi Arabia, India
- Chronos – Ongoing research
 - Use of LDC for Differential Timing Corrections
 - Seasonal variations
 - Indoor H-Field antenna deployments
 - Combined PTP/eLoran
 - Combined GNSS/eLoran

Research Topics – (100ns limits)



- Spatial and Temporal ASF variations
 - <100ns?
- EDTR regional grid size
 - >500 miles/100ns?
- H-Field performance in indoor environments
 - <100ns Deep inside, under ground/water
- Long term LDC operations for remote UTC sync
 - <100ns/12 months/GNSS denied
- Studies with complementary technologies
 - PTP, SyncE, A-GPS, Low cost XO

Collaborators Wanted!!

- Too much for one organisation to undertake
- Undertake research and share results ahead of publication
- International data sharing via internet accessed SENTINEL research platform
- Multi-disciplinary Collaborations
 - Industrial Supply – near-term exploitation
 - User Community – clear benefits and cost saving
 - Academic Research – work out the TRL1-6
 - Government innovation via intervention grants

Find Out More?



<http://www.rntfnd.org>

- Improve anti-jamming and spoofing deterrence and enforcement
- Promote establishment of resilient terrestrial navigation and timing systems

Dana Goward - dgoward@rntfnd.org

Further Reading



Global Navigation Space Systems: reliance and vulnerabilities



Extreme space weather: impacts on engineered systems and infrastructure



SENTINEL PROJECT REPORT ON GNSS VULNERABILITIES



SENTINEL Project – GNSS Vulnerabilities

The SENTINEL Project investigated a number of interconnected activities involving mission-critical or safety-critical services which need to be able to "trust" GNSS signals at the point of use. The SENTINEL Project was concerned with GNSS interference and jamming, and techniques for mitigating such jamming. This Report also records some of the world-wide press and television coverage stimulated by presentations of the results of SENTINEL at numerous conferences and symposia.

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Originated by:	Prof. Charles Curry, BEng, CEng, FIET	Title: Managing Director, Chronos Technology SENTINEL Project – Report on GNSS vulnerabilities
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Page 1 of 59

04 March 2014



DELIVERING A NATIONAL TIMESCALE USING eLORAN

ABSTRACT

A Positioning, Navigation and Timing (PNT) service using Enhanced Loran (eLoran) has been transmitted experimentally in the United Kingdom for more than 3 years. The eLoran transmitter employed, at Ardhorn in North-West England, is operated by a commercial company on behalf of the General Lighthouse Authorities of the United Kingdom and Ireland. It is funded in part by the Department for Transport and other UK government agencies. Chronos Technology has used these and other eLoran transmissions to conduct research into the viability of employing eLoran as a means of distributing time traceable to UTC, including for indoor applications. There is growing concern internationally regarding the vulnerability of GPS and other global navigation satellite systems (GNSS) to natural and man-made interference, plus the jamming and spoofing of their transmissions. These vulnerabilities have led to a demand for sources of resilient PNT, including a robust means of distributing precise time nationally and internationally.

This paper explores the ability of eLoran to disseminate UTC-traceable time to applications in GNSS-denied environments. It proposes the creation of a National Timescale with UTC distributed via eLoran signals. Practical results from a test programme are very encouraging: UTC-traceable time signals with an accuracy of better than 100ns and with a quality comparable to that provided by GPS are received even indoors. This new source of precise time meets the latest ITU standards for primary reference timing clocks in Internet Protocol networks.

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This Issue Originated by:	Charles Curry	Managing Director, Chronos Technology Ltd
Document Status:	For Publication	

Page 1 of 23

Issue 1.0, 07 June 2014

- Royal Academy of Engineering Reports
 - GNSS Vulnerabilities & Space Weather
- Chronos Publications
 - SENTINEL Research & National Time Service

Conclusions

- When will the next “Black Swan” happen?
 - North Korean, San Diego, Newark.....
- “Sticking Plaster” solutions....
- In band solutions – strong option....
- Will Galileo fix it?
 - Or is it a “White Elephant”?
- Standardised LF PNT (eLoran) deserves attention

Thank You for Listening

A horizontal banner composed of six rectangular panels. From left to right: 1. A blue and white abstract image of concentric circles or ripples. 2. A photograph of server racks in a data center with blue and green lights. 3. A close-up of a circuit board with a red and orange color scheme. 4. A photograph of a power line tower against a sunset sky. 5. A blue-tinted image of binary code (0s and 1s) floating in space. 6. A photograph of a man in a dark shirt working on a rack of electronic equipment.

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