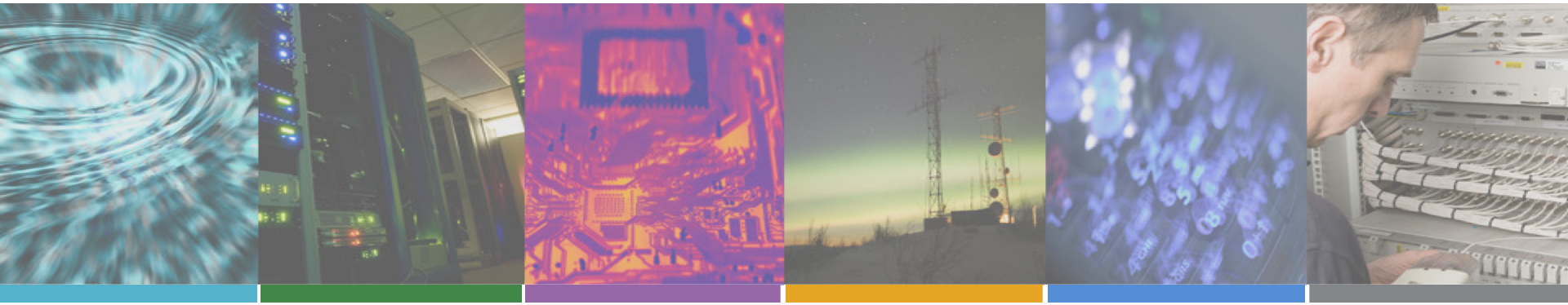
# *"Black Swans", "White Elephants" and Delivering a New National Timescale with eLoran*



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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.gcpierce.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

Imperial College London

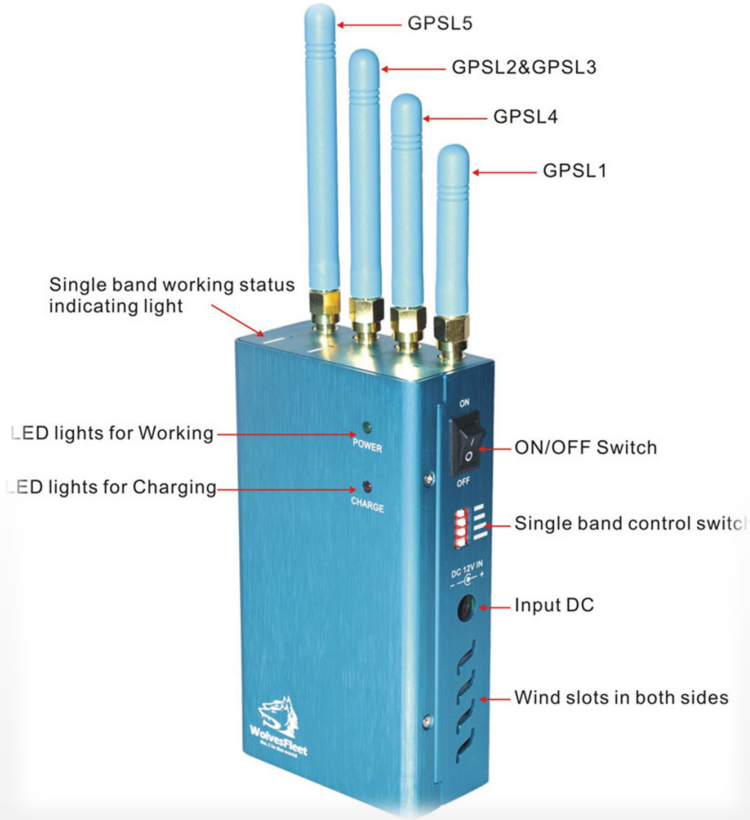






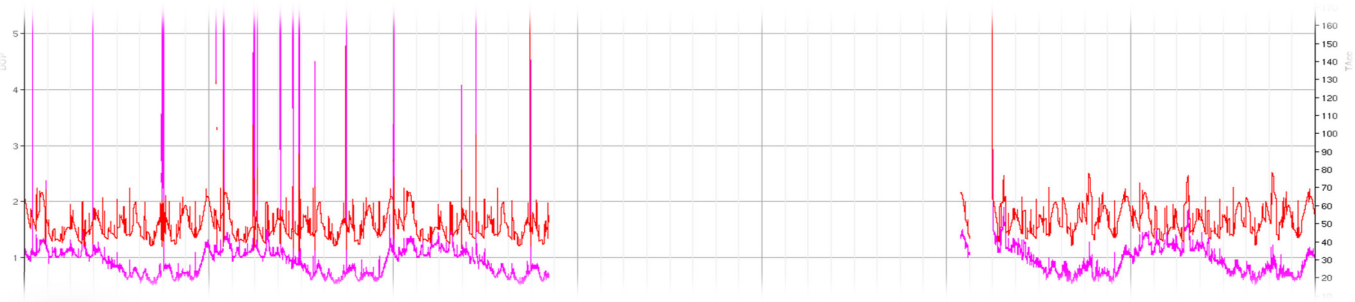

Thatcham

# Jammer Testing




# SENTINEL - Research Platform

chronos TECHNOLOGY



U.S. DEPARTMENT OF HOMELAND SECURITY

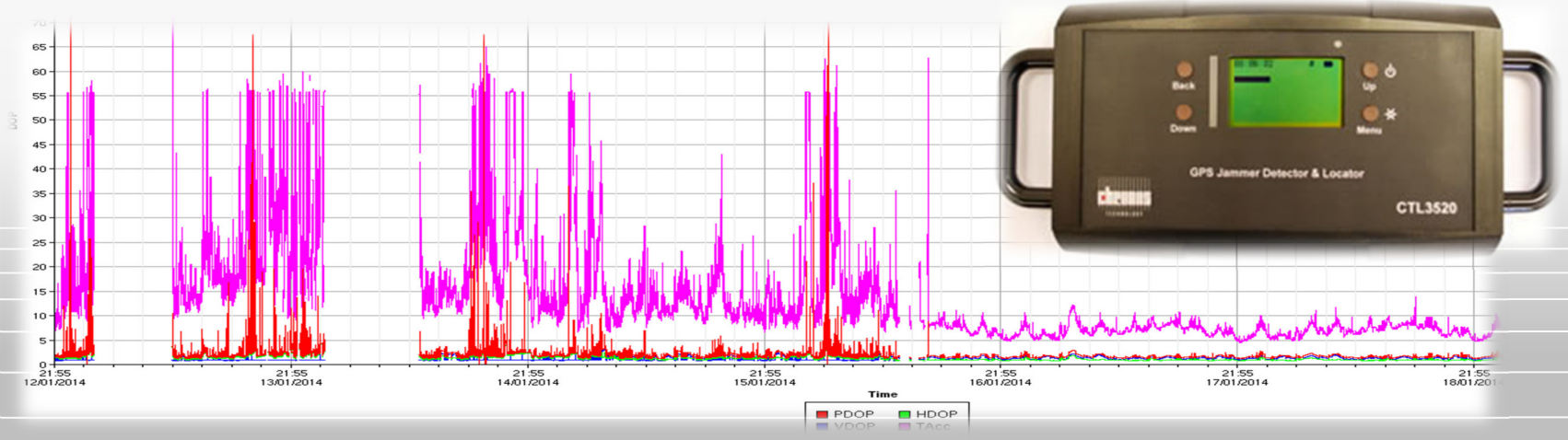


CPNI
Centre for the Protection of National Infrastructure

EXELIS

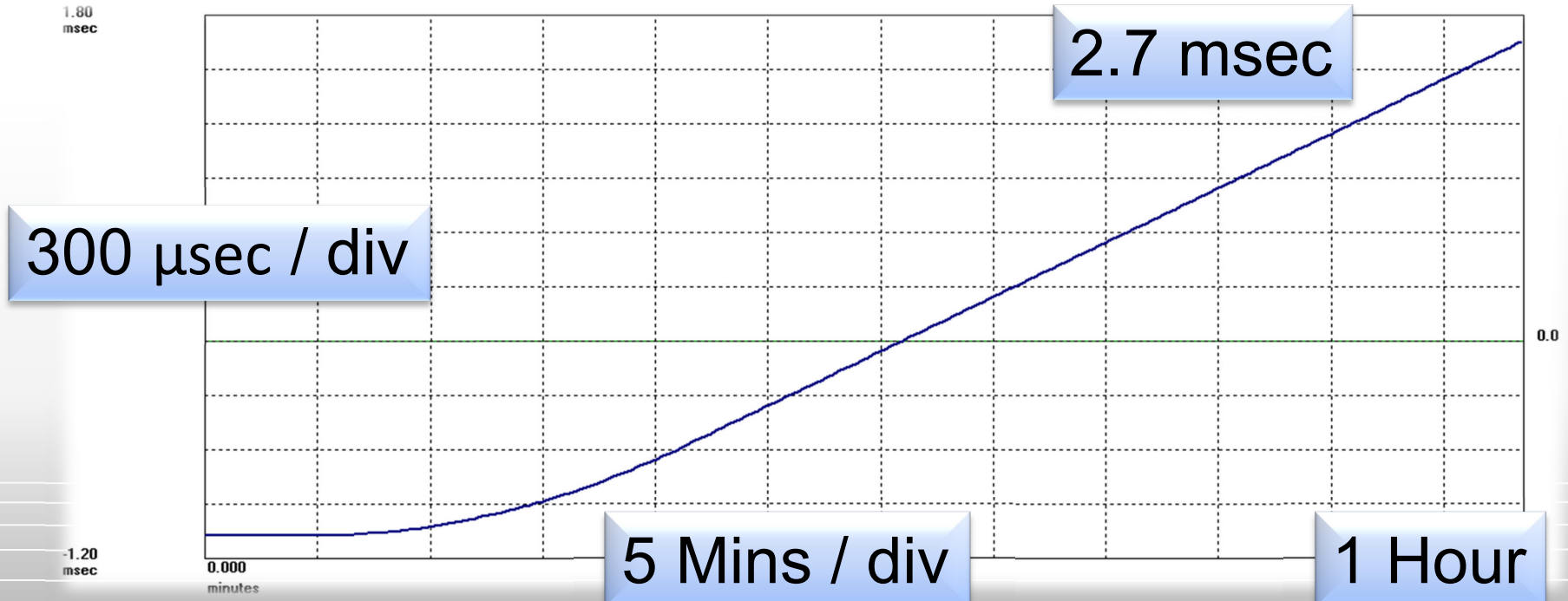
NIST
National Institute of Standards and Technology
U.S. Department of Commerce

# Rogue Antennas

# Spoofing


COHERENT
NAVIGATION
Reset
Power
DSP
SBC
10 MHz
Clock In
10 MHz
Clock Out
GPS
RF In
GPS
RF Out


1.80
msec
2.7 msec
300 µsec / div
0.0
-1.20
msec
0.000
minutes
5 Mins / div
1 Hour

# 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/1µs/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?

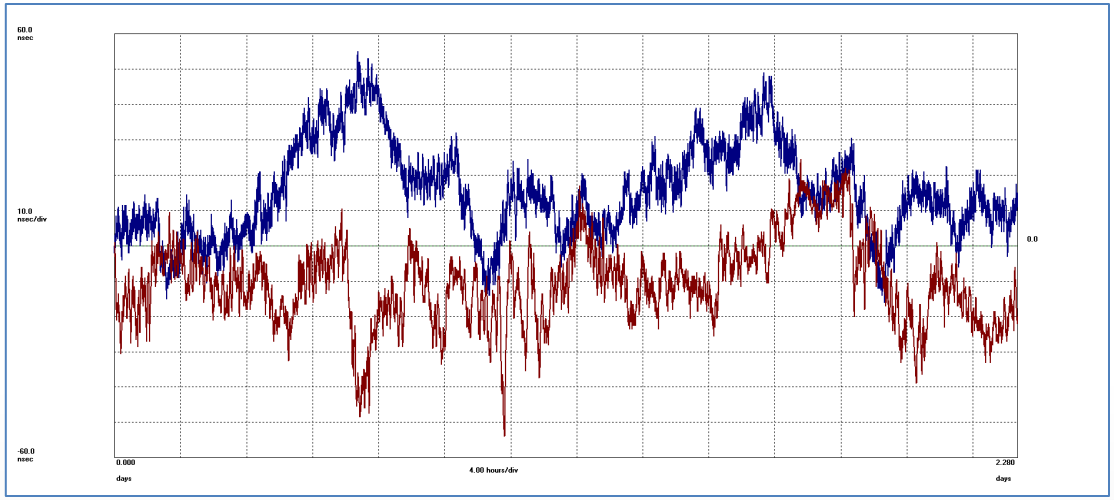
# Mitigation Ideas – LF PNT?

- 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

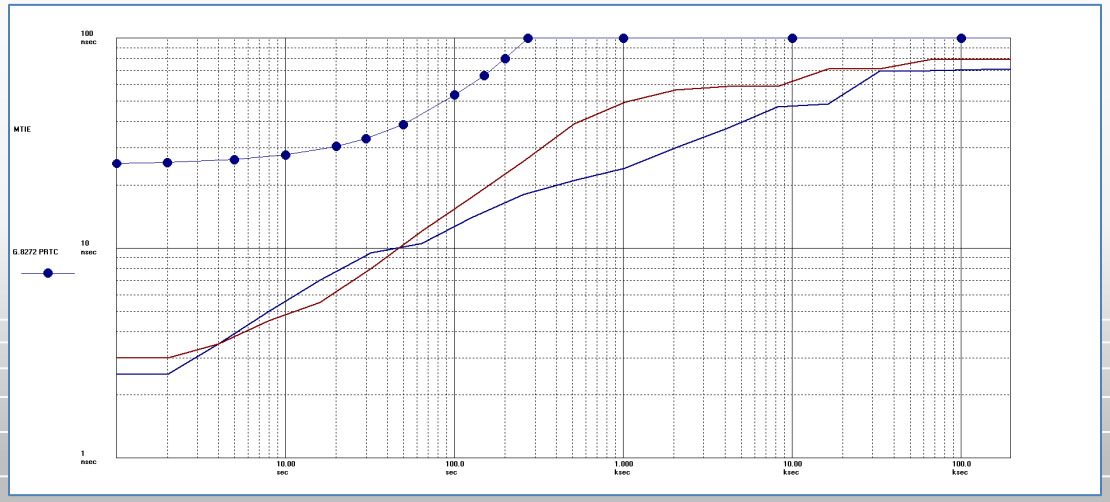

- SENTINEL Research Platform
- Combined eLoran and GPS PoC Timing Receiver CTL8200
- H-Field Antenna

# Some Results – TIE and MTIE

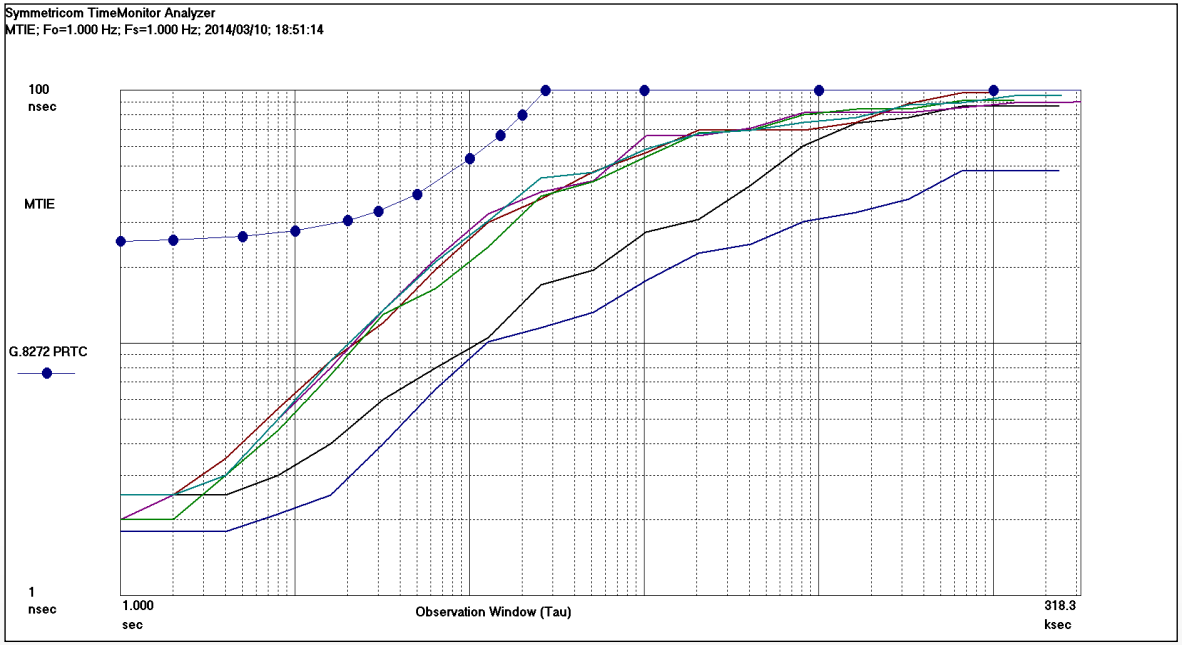



**TIE Graphs**
Blue: GPS
Red: Indoor eLoran
3 days, 10ns/div

**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?

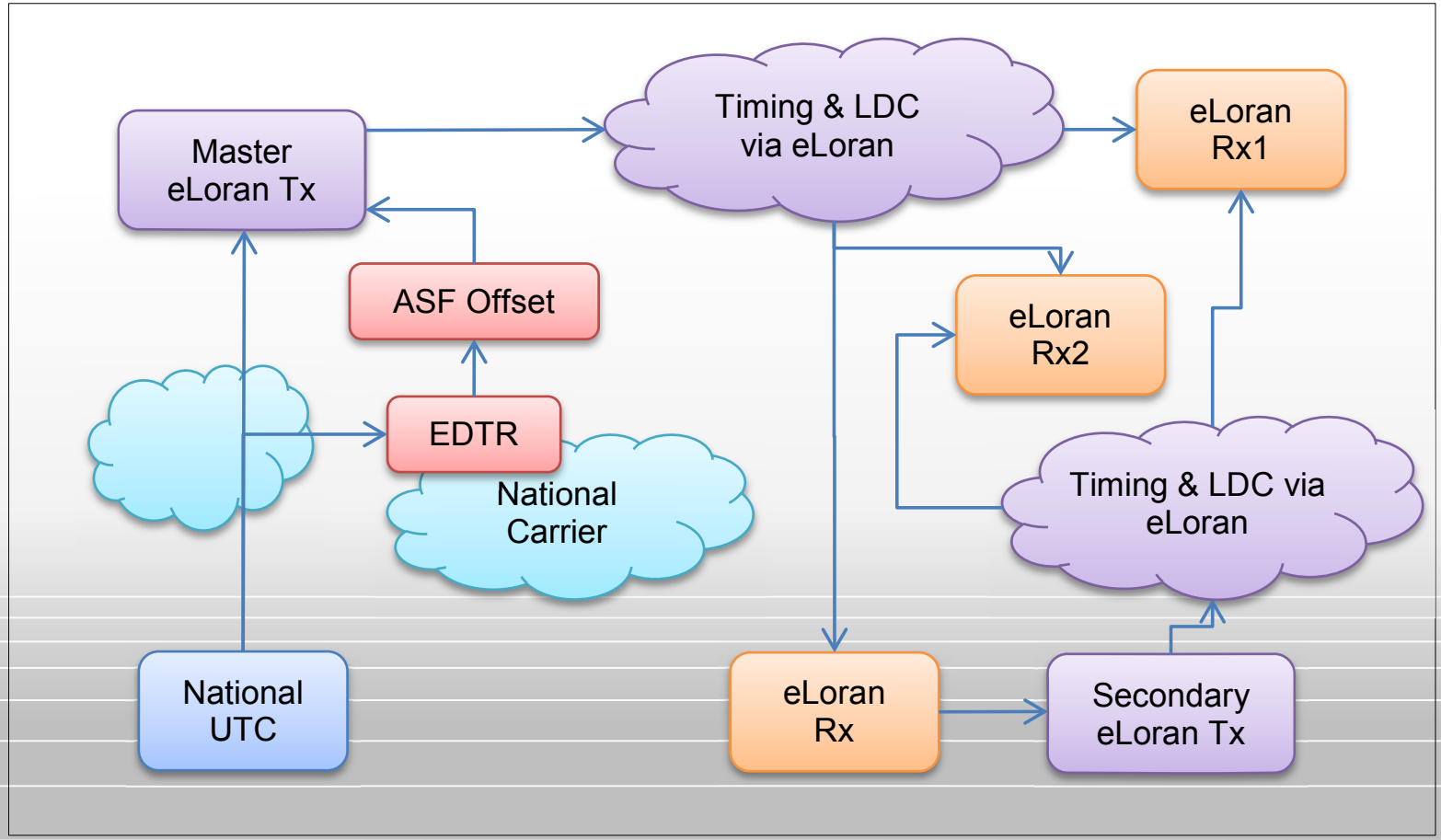
- Loran Data Channel (LDC) transmits a UTC message
- Aligns the 1pps close to UTC
  - Error due to Additional Secondary Factor (ASF)
  - Dependent on land path and seasonal conditions
  - A few microseconds
  - Fixed with low seasonal variations (100ns)
- Can be calibrated out
- Either at installation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

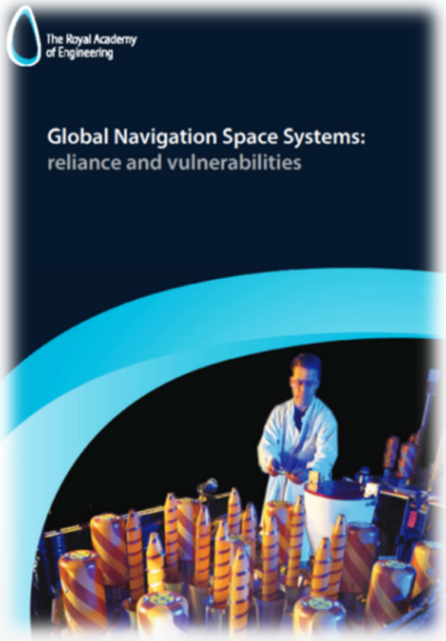
# Find Out More?


http://www.rntfnd.org

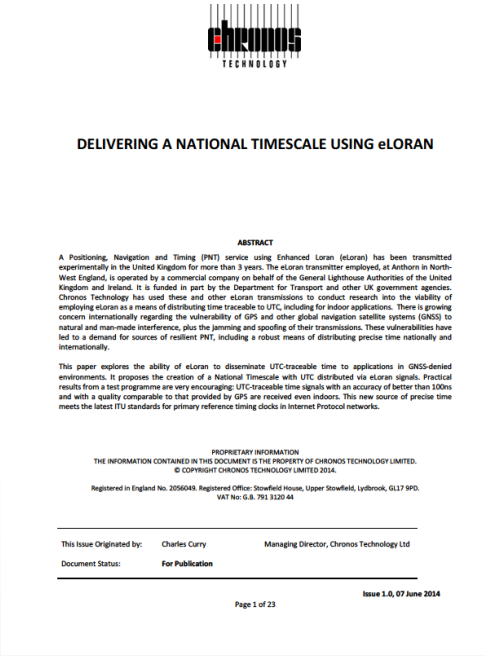
- Improve anti-jamming and spoofing deterrence and enforcement
- Promote establishment of resilient terrestrial navigation and timing systems

Dana Goward - dgoward@rntfnd.org

# Further Reading






- 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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