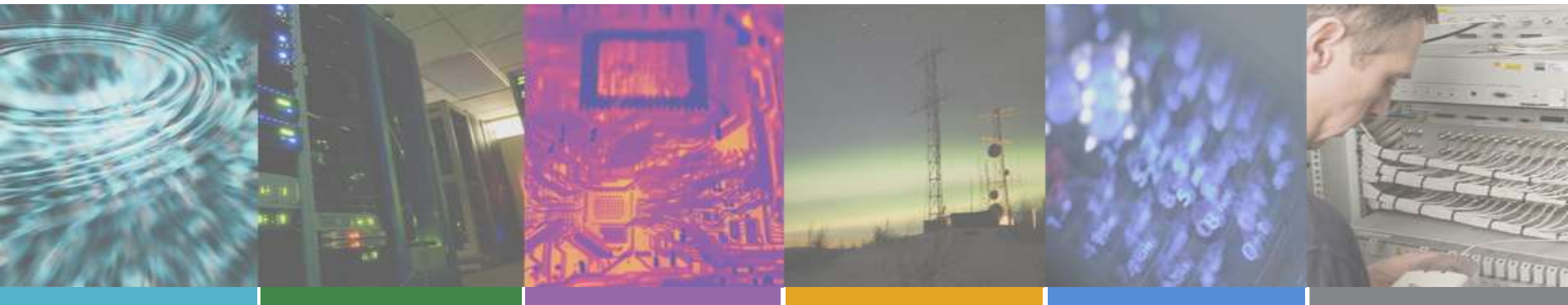


# “Black Swans” and “White Elephants”

## GPS Jamming and Resilient PNT



Charles Curry BEng, CEng, FIET

Managing Director  
Chronos Technology Ltd

**ITSF 2014**

4-6<sup>th</sup> Nov 2014

Budapest, Hungary

# 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

- GPS SVN/PRN23
  - 1<sup>st</sup> Jan 2004 Rb failure, massive loss of GPS timing
- GPS - The “San Diego Incident”
  - 2004 - US Navy Own Goal – CDMA Network down 3 hours
- GPS - North Korea
  - 2010 & on-going! South Korea suffers wide area GPS Jamming
- GPS - The “Newark Incident”
  - 2012 - White Van man on I95, Honeywell “SmartPath” GBAS
- Glonass
  - 1<sup>st</sup> April 2014 Failure of all sats for 11 Hours, Bad ephemerides upload
  - 14<sup>th</sup> April 2014 8 sats set unhealthy for 30 minutes
- Galileo
  - Failure of GSAT104 on 27<sup>th</sup> May 2014

# UK Research on topic



# Sennybridge Jammer Testing



# GPS Jamming Assisted Crime

- Top end vehicles
  - Doors open in 10 seconds
  - Jammer on back seat
  - Gone in 20 seconds!
- Plant
  - Jammer in cab
  - Drive away
  - Park in container for export





# Easy Targets

- Lost any Mercedes Sprinter Vans lately?



Photo courtesy of Hampshire Police



# Unauthorised Truck Journeys



Truck driver uses Jammer so he  
can sleep at home not at the  
Highway Truck-Stop.  
Cell Site off-air for 8 hours!!

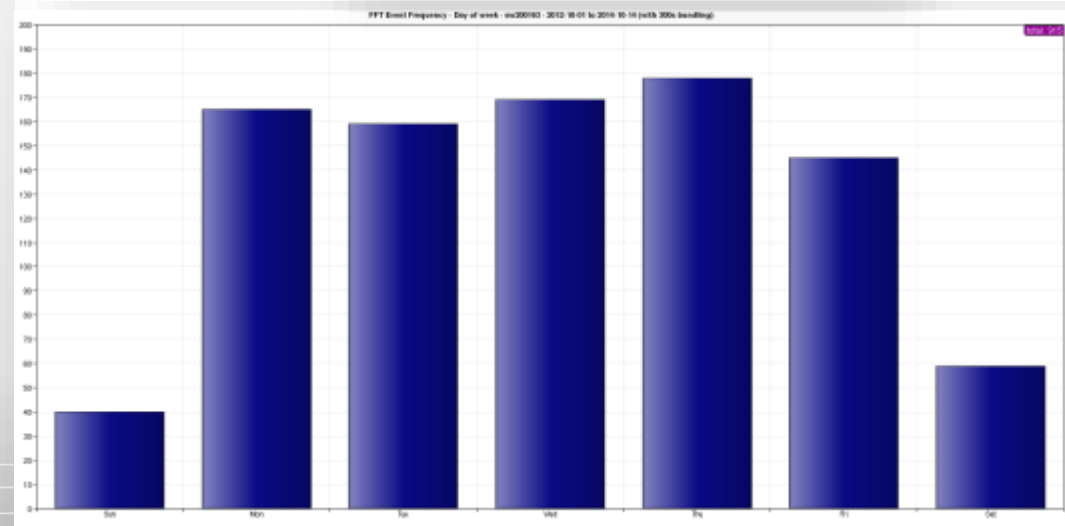
*Presentation @ WSTS June 2014*

*Richard Linzy – Windstream Communications*



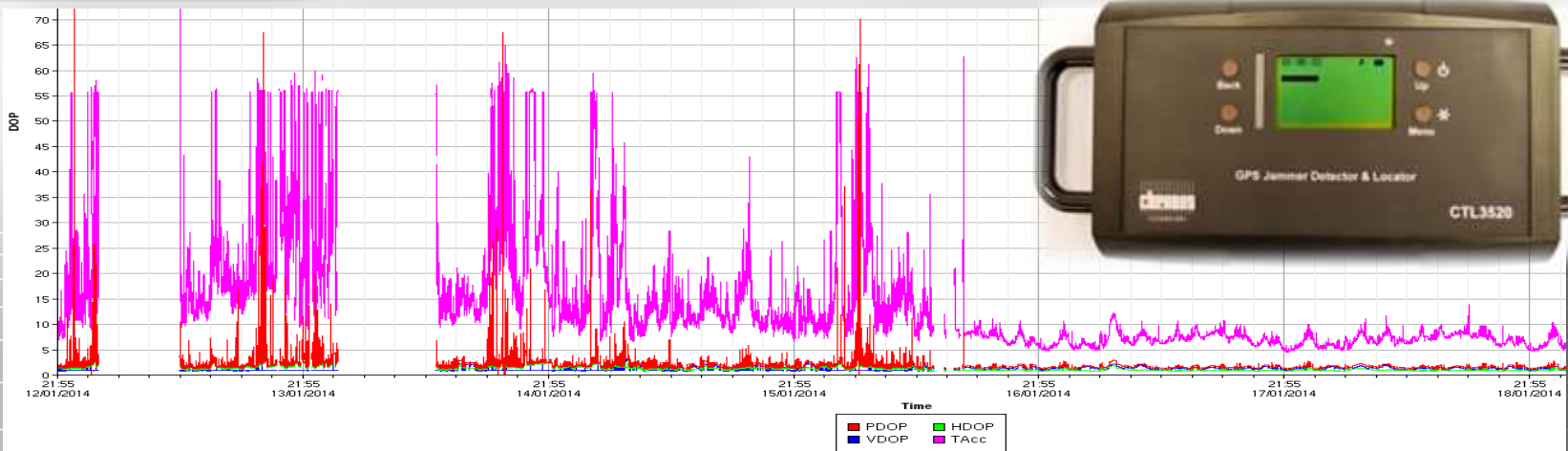


# “White Van Man”



Events By Day Indicates Working Week Use

# Rogue Antennas

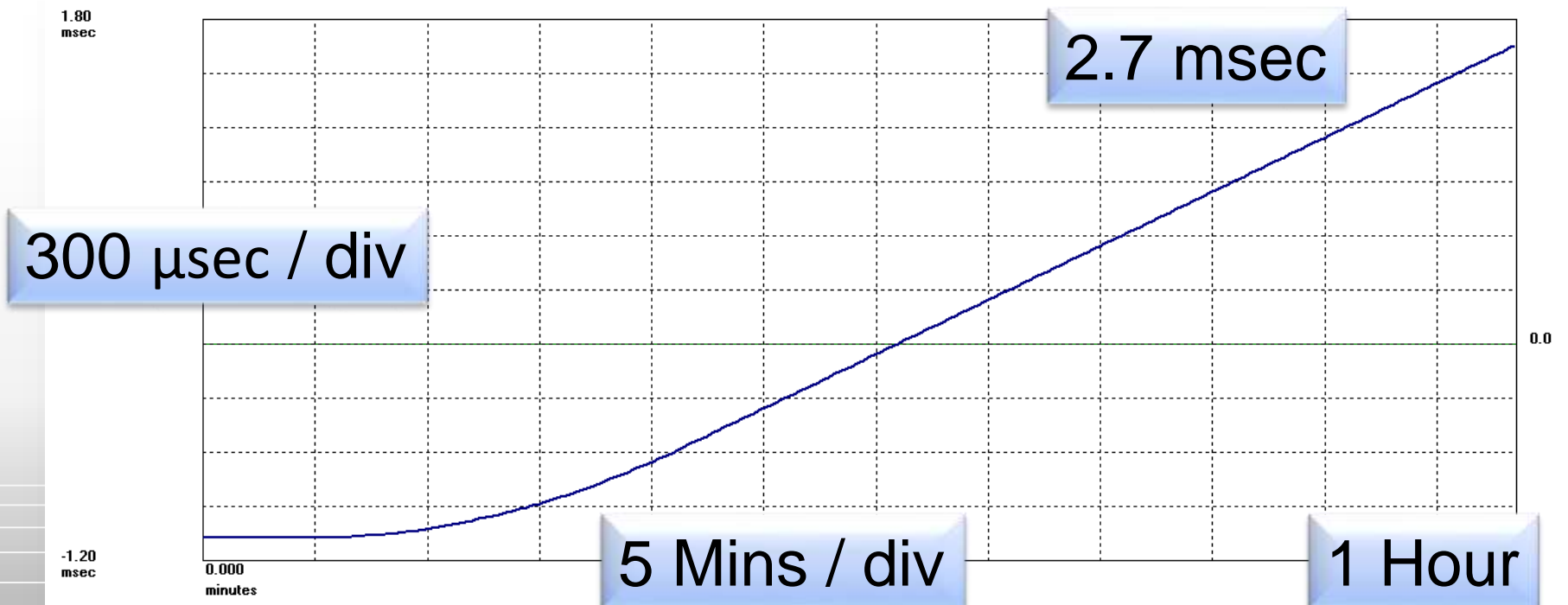


# Where to buy Jammers

- Over 50 active Chinese Web Sites
- Power ~ 100mW to 50W!



# Spoofing



# Dissimilar Detection Techniques

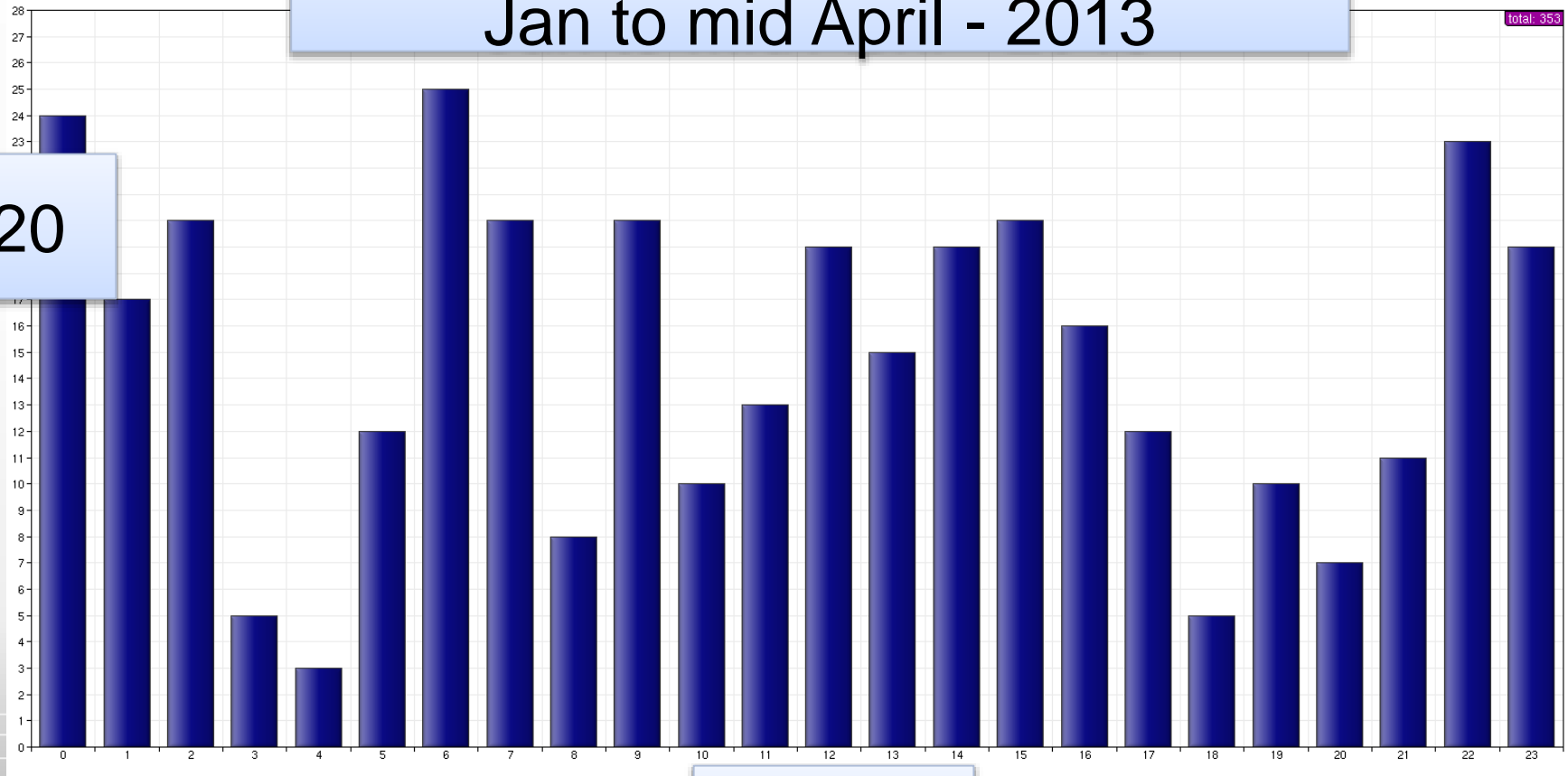
- A recent 10 minute “event” outside the Stock Exchange!
- 1: Power in L1 Spectrum using FFT
- 2: Susceptibility of GPS by measuring C/No





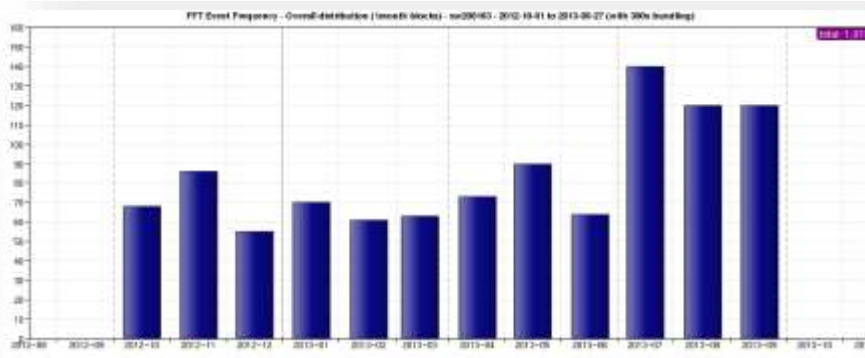
# City – Data Analysis

Total of all events by Hour of Day  
Jan to mid April - 2013

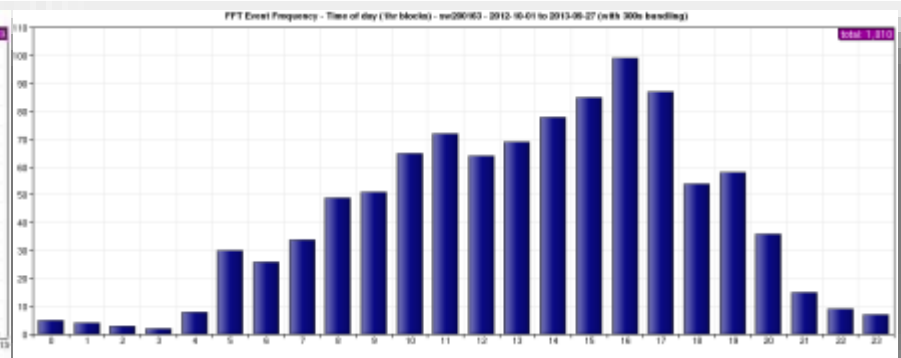


Midday

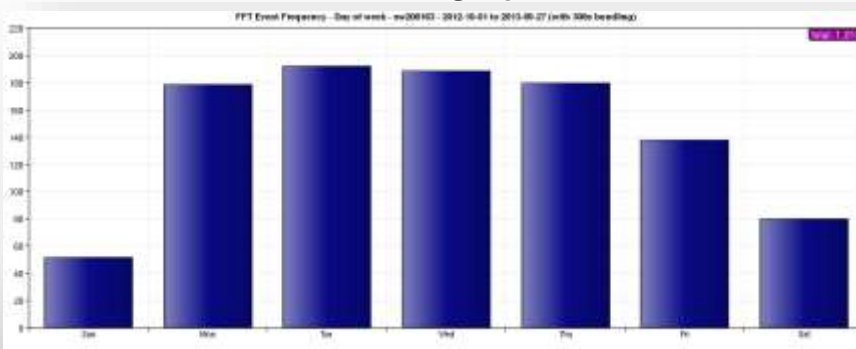
# Events detected on rural motorway 200ft from ILS cabin at provincial airport



Events by  
Month



Events by Hour through Day

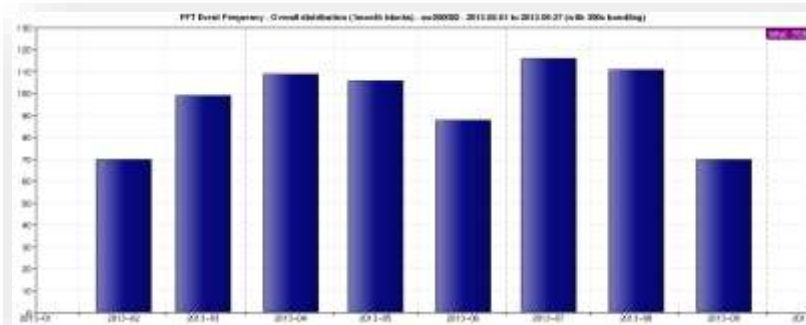


Events by Day of Week

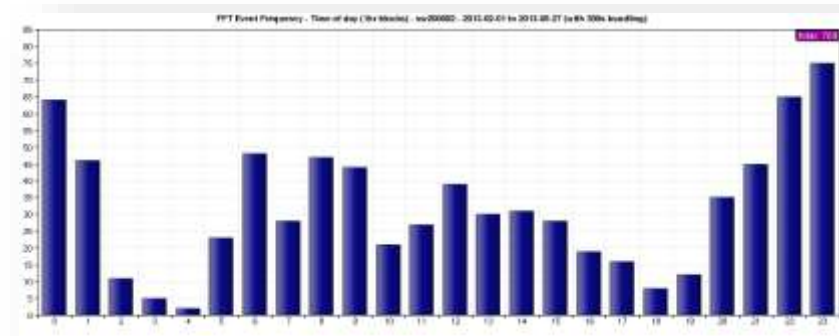


Typical Event

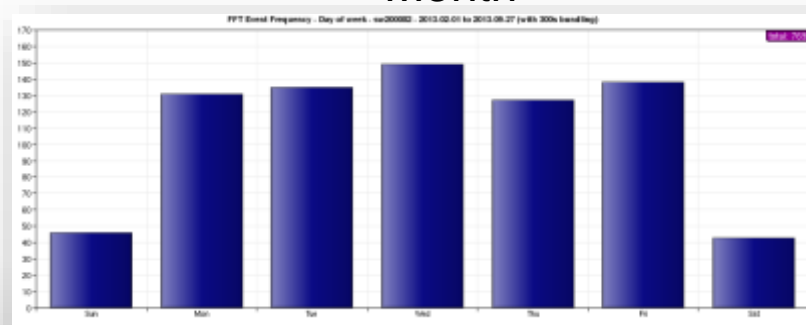
# Events detected - London Stock Exchange



Events by  
Month



Events by Hour through Day



Events by Day of Week



Typical Event

**July 2013 – 100 events : July 2014 – 150 events**

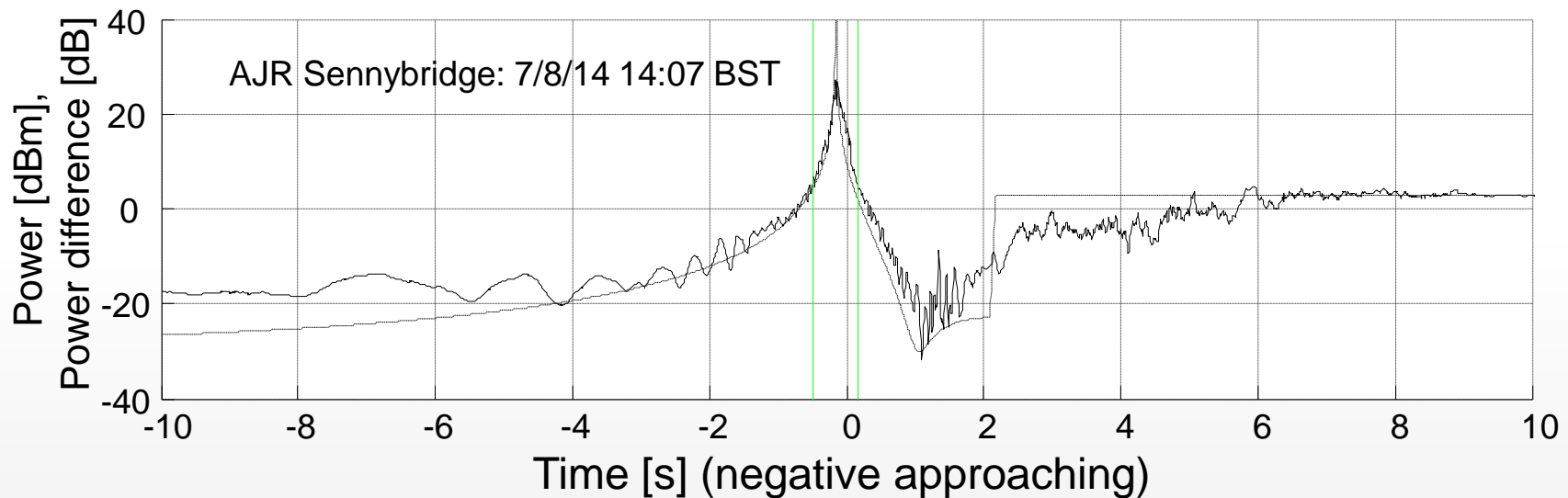
# Sennybridge Testing



*Photos: With the permission of the Commandant, Sennybridge Training Area*

# AJR – Automatic Jamming Recognition

Estimated jammer speed: 38 mph, detector angle: 15.00 deg ccw



T0-0.33s



T0



T0+0.33s





# 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 $\mu$ s/100ns?

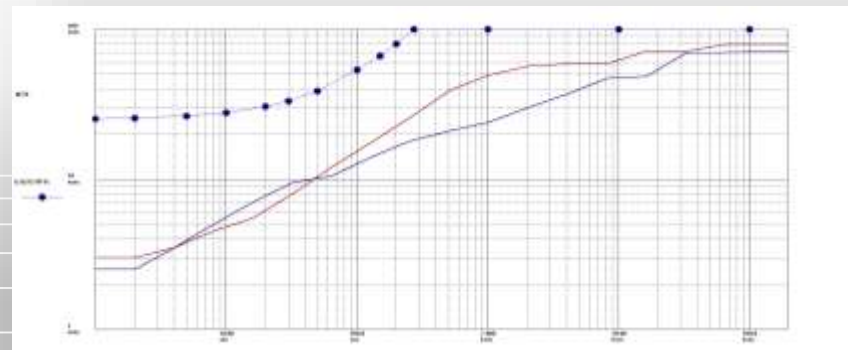
# Mitigation Ideas – Galileo

- GPS 1984 – 9 Satellites – the year of “Big Brother”
  - Galileo 2014 – 4 Satellites
- [www.gsa.europa.eu/security/prs](http://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?



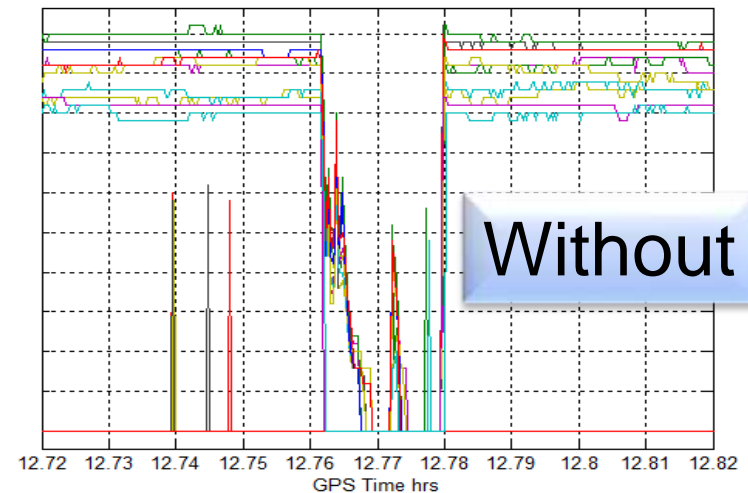
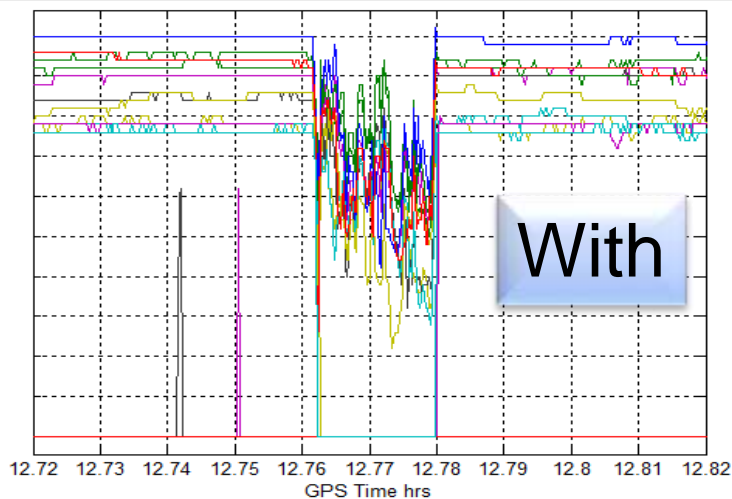
# Mitigation Ideas – LF PNT

- Significant Outcomes from SENTINEL Research
- eLoran extensively researched for timing
- eLoran “PRTC Ready” Off-Air Signals In-Doors
  - Presentation Tuesday “Time for the Future”
- **eLoran is fit for purpose for PRTC Indoors**
- **Meets G.8272**

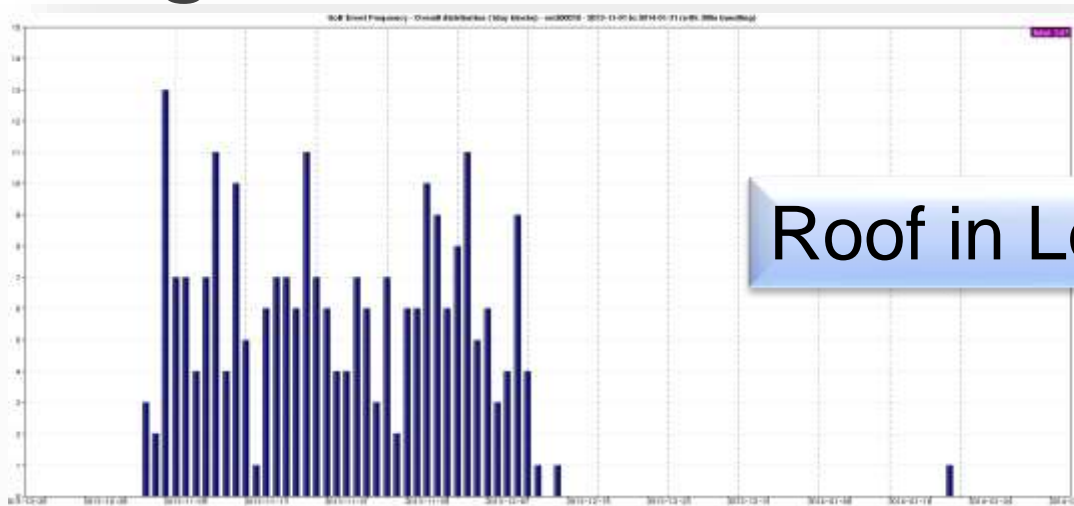


# Mitigation Ideas – CRPA?

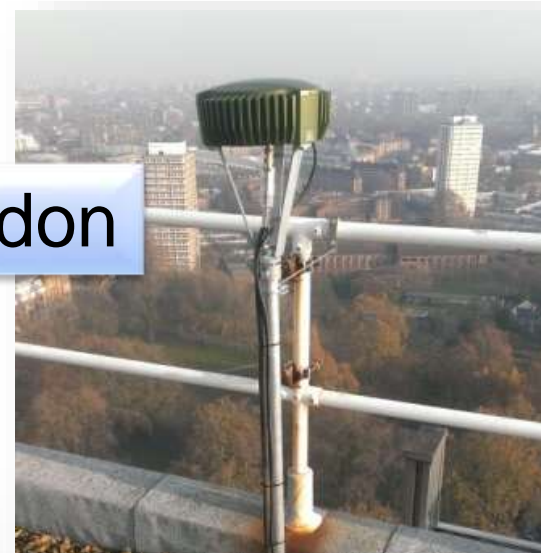
- CRPA - Controlled Radiated Pattern Antenna
- Two Experiments
  - Roof in London & Sennybridge
- Sennybridge test below



# Mitigation Ideas - CRPA



Roof in London



Loan of GAJT-700ML courtesy Novatel, Inc. Photo: Canadian Army



# Find Out More?

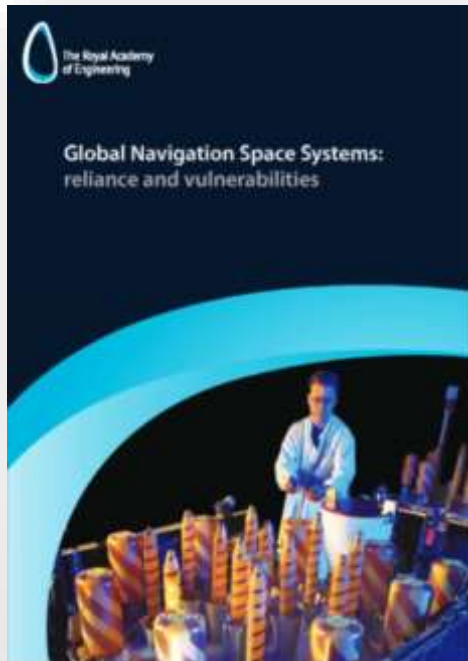


<http://www.rntfnd.org>

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

Dana Goward - [dgoward@rntfnd.org](mailto:dgoward@rntfnd.org)

# Further Reading



- Royal Academy of Engineering Reports
  - GNSS Vulnerabilities & Space Weather
- Chronos Report
  - SENTINEL Research

# 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: a blue and white abstract pattern resembling a vortex or a stylized 'C'; a dark blue server rack with glowing lights; a purple and red abstract pattern resembling a circuit board; a yellow and orange abstract pattern resembling a landscape or a stylized 'C'; a blue and white abstract pattern resembling a network or a stylized 'C'; and a photograph of a man in a dark shirt working on a server rack.

Chronos Technology Ltd

[www.chronos.co.uk](http://www.chronos.co.uk)

[charles.curry@chronos.co.uk](mailto:charles.curry@chronos.co.uk)

© Chronos Technology Ltd - 2014