

### eLoran – The Future of Resilient PNT



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UrsaNav / Taviga Ltd

### **Black Swan Events**





Nassim Nicholas Taleb 2007 "The Black Swan"

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

### What is the cost of loss of time accuracy?



### **Presentation Contents**

- eLoran Background
- eLoran Today
- Testing: Anthorn (UK) & Wildwood (USA)
- UTC Delivery Vulnerability Analysis
  - What can possibly go wrong?
  - Mitigation
- Further Reading & Conclusion

### Loran Background



- USA Switched off Loran-C
- Russia, India, Saudi Arabia, Korea Operational
- France Switched off Loran-C Control Centre Brest – Dec 31<sup>st</sup> 2015
  - France Lessay & Soustons
  - Denmark Ejde
  - Germany Sylt
  - Norway Vaerlandet, JanMayen, Boe, Berlevag
- Anthorn UK eLoran station not switched off!
  - National Security



### eLoran Today



UK – Anthorn/EU – Timing Testing

– Anthorn given "Master" status

- USA Wild Wood NJ NYSE Trials
- Korea Recent GPS Jamming by North Korea

🏠 UrsaNav	ELEGAN	T: CCRP11							
File View \	Window	About							
TOAA Lo	ogs								
Timestamp: Update Interval: Integration Time:		1842857.25 1.00 10.00	Version: Clock status: Clock error:		1.0 FINESTEERING 0.0000E+00		Noise Loop 1: Noise Loop 2: Num Stations:	46.51 38.22 2	
Station	SS	SNR	B-Q	ECD	CI-Q	State	TOA (us)	Doppler	LockTime
6731M	51.33	10.72	0.882	-0.831	0.580	0x0200	1224.0065	-3.41E-009	1230909.00
6731Y	50.33	9.73	0.885	-0.960	0.620	0x0200	28523.9945	-5.02E-009	1213500.00

## **UK Anthorn Operations**

- UK Government Support
   On grounds of National Security
- Maintained UTC Traceability
  - Despite France switching off CCB!
- Planning a Resilient Timing Service
  - Terrestrial UK navigation service
  - Maritime navigation service
  - Expansion into neighbouring countries

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Conversations with Governments



Anthorn Antennas: @Martin and Jean Norgate

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### Anthorn UTC



- Was traceable to CCB Brest in France
- Dec 2015 Cs steered to UTC (GPS)
  - Using development system "CsWatch"
  - Steers Cs to UTC using equivalent of 30 day loop time constant









## **Current UK Research Project**

- Innovate UK the "GAUL" Project
  - Galileo Assist Using eLoran
- Using the Loran Data Channel
  - GNSS ephemeris
  - Local eLoran ASF offset



Enables UTC alignment for indoor eLoran Rx



### **Anthorn Timing Results**



#### Microsemi TimeMonitor Analyzer

Phase deviation in units of time; Fs=999.4 mHz; Fo=1.0000000 Hz; 2016/05/05; 19:07:51

1 (blue): HP 53132A; Test: 1471; A: CCRP11; B: PRS45A; eLoran H 1pps; Samples: 907824; Gate: 1 s; Start: 525000; Total Points: 1432823; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; 53131A sn 13743; 2016/05/05; 1 2 (red): HP 53132A; Test: 1469; A: EDTR01; B: PRS45A; GPS 1pps; Samples: 907824; Gate: 1 s; Start: 525000; Total Points: 1432823; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; 53131A sn 6658; 2016/05/05; 1 9:07:5



### Anthorn MTIE



#### Microsemi TimeMonitor Analyzer MTIE; Fo=1.000 Hz; Fs=999.4 mHz; 2016/05/05; 19:07:51

1 (blue): HP 53132A; Test: 1471; A: CCRP11; B: PRS45A; eLoran H 1pps; Samples: 907824; Gate: 1 s; Start: 525000; Total Points: 1432823; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; 53131A sn 13743; 2016/05/05; 1 2 (red): HP 53132A; Test: 1469; A: EDTR01; B: PRS45A; GPS 1pps; Samples: 907824; Gate: 1 s; Start: 525000; Total Points: 1432823; Ref ch2: 10.00 MHz; TI/Time Data Only; TI 1->2; 53131A sn 6658; 2016/05/05; 1 9:07:5



#### **Red – GPS outdoor antenna. Blue eLoran indoor H-Field antenna**

### **eLoran Timing Evaluation NYSE**



UrsaNav

#### eLoran Transmissions from former USCG Loran Support Unit Wildwood, NJ

- Synchronized to UTC via Two Way Satellite Time Transfer (TWSTT) provided by US Naval Observatory
- 360 kW of Effective Radiated Power
- Broadcasting dual rated as 8970 Master and Secondary
- Data sent via LDC only on Secondary rate at raw data rate of 56 bps and effective data rate of 21 bps

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

#### **Demonstration Results – NYSE**





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

#### Coverage From Former Wildwood, NJ Transmitting Site



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## Jamming & Spoofing - Who and Why?

### Privacy & Covert Operations – Mainly Jamming

- Personal Aggravation Disruption
- Personal Privacy
- Criminal Privacy
- Organised Crime Gangs (OCG)
- Cyber Security Service Denial Jamming & Spoofing
  - Cyber Crime
  - Civil Disruption/Terrorism
  - Nation State





### Personal Privacy – Case Study





# Professional Car Thief - Toolkit

- GPS L1 1575.42 MHz **2W**
- GPS L2 1227.60 MHz 2W
- GPS L5 1176.45 MHz **2W**
- WIFI 11b/g/n 2.4 GHz **2W**
- Remote Control 315MHz 3W
- Remote Control 868MHz 3W
- Remote Control 433/434MHz 3W
- Lojack 173MHz 3W





- Disables.....
  - Remotes for Cars, Garages, Gates 315/433/868 MHz
  - CCTV, UAVs, Quadcopters, Drones 2.4 GHz



\$1,250 www.jammer4u.com

### Korea – GPS Jamming





### Intentional High-Power GPS Jamming

[The Central Radio Management Office, South Korea]

Dates	Aug 23-26, 2010 <b>(4 days)</b>	Mar 4-14, 2011 <b>(11 days)</b>	Apr 28 – May 13, 2012 <b>(16 days)</b>
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

http://rntfnd.org/2015/02/01/resilient-pnt-forum-ii-presentations/



## Korea – GPS Jamming - 2016



### North Korea 'jamming GPS signals' near South border

O 1 April 2016 Asia

"North Korea is using radio waves to jam GPS navigation systems near the border regions, South Korean officials said."

### National



#### N. Korea halts GPS jamming



South Korea's ICT ministry said North Korea's disruptions of Global Positioning System (GPS) signals, which started last week, stopped as of Wednesday, although they may resume soon, as the signals have been constantly lessening and increasing.

## Impact of similar Jammer on London





**CTS-BBOX 1** 

#### Specifications:

Specifications: Model No:CTS-BBOX Output signal strength: 100W Effective range: Up to 500~1000 meters Frequency:GPS L1/L2/L3/L4/L5 24\*7 long time working Waterproof System: All systems worldwide Input power: 110-240V

- 100 Watt Jammer Shard Floor 72
- Simulation courtesy Mike Jones
  - Roke Manor Research

## London Events/Month >30 Seconds



Event Frequency Graph - HUNTSMAN #4 Distribution (1month block	* (from 02/04/2016) 코 모 to 12/04/2016 코 D, on Belect days of week 이 D, during the hours of 0 to 23 D.
FFT Event Frequency - Overall distribution (1month	of min. duration 30 s, exc. filtered 💌 P Display 🗠 Download
150 April 2015 to En	d March 2016
100	
75 -       70 -       85 - <th></th>	
2015-02 2015-03 2015-04 2015-06 2015-07 2015-06 2015-09 2015- 2015-02 2015-03 2015-04 2015-06 2015-07 2015-06 2015-09 2015- 	10 + 2015-11 + 2015-12 + 2016-01 + 2016-02 + 2016-03 + 2016-04 + 2016-05 + 2016- Angel St
42 minute event – 12 <sup>th</sup> April	Near London Stock Exchange
	The same
812 816 133566 134568 134528 134566 135508 135528 13556 145528 145528 145528 145568 145528 145528 145528 145528 145528	White Hard St.

Square

The second

vm Fitness First

1

## Spoofing?



- "A GPS spoofing attack attempts to deceive a GPS receiver by broadcasting counterfeit GPS signals" – Wikipedia 2016
- Spoof Position
- Spoof Time
- Academic Research topic
  - Dr Todd Humphreys



...until 2015....





## What Happened in 2015?





### **GPS SPOOFING**

Low-cost GPS simulator

HUANG Lin, YANG Qing Unicorn Team – Radio and Hardware Security Research Qihoo 360 Technology Co. Ltd.

### **A Beginners Guide to low** cost Spoofing <£200!

https://www.youtube.com/watch?v=jwJKMti aw0

#### **Bingo! Samsung Note 3**

 Located at Namco Lake in Tibet but the cellphone is actually in Beijing.

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	in view 17	11 Unit	Coordina	tes Latilon	(WG584)		Local Date	2-15	Local Ten 16:	- 3214
	30 30 30 30 30 30 3	35 39 39 39 39 39 60					5 08:	<b>39</b> 01	turnet 19:	4215
+	01 03 04 08 11 1	4 16 22 25 31 32 65			-					
-	00 10 20 30	50 99								
1. Ren	dig ree	0 16:32	<b>3</b> D		U	16:32	• 30		595	0

#### Try to spoof cars

≓路线 ▲导航

522

2. 附近

· Demo video: The car, BYD Qin,was located in a lake center.



# Space Weather – June 19<sup>th</sup> 2015

- 11 Year Solar Cycles
- Aurora Borealis
- "Carrington" Event 1859
- Solar Flares (8 Minutes)
- Coronal Mass Ejection
  - CME
  - Up to 2 days
- June 19<sup>th</sup> 2015 Impacted UK Broadcast Services
- Met Office Space Weather Alerts <u>http://www.metoffice.gov.uk/publicsector/emergencies/space-weather</u>



Nasa

### **Rogue Antennas**













### **Poor Installation Practice!**



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### GPS SVN23 – 26<sup>th</sup> Jan 2016

- January 25<sup>th</sup> 2016 SVN23 retired
- A -13.7µsec UTC offset accidentally set on satellites
- Only impacted (some) timing receivers
- USNO had no idea until users called!



- Case Study
- Video
  - Courtesy Ted Driver at Analytical Graphics via John Lavrakas
- Read the <u>BBC Headlines</u>

	Network Type	Region	Qty GPS Elements	Notes
Customer A	Fixed Line	UK	Large	Generated nearly 2000 alarms and standing condition events throughout duration
Customer B	Transport Comms	UK	Small	Customer in panic mode as systems in holdover
Customer C	Fixed Line	Global	Large	Nearly 2500 alarms generated during event. Roughly 40 elements entered holdover due to lack of backup inputs.
Customer D	Fixed Line	UK	Small	Element in holdover
Customer E	Transport Comms	UK	Small	TimeSource only systems. Caused local switches to go into free run.
Customer F	Mobile	UK	Medium	No adverse impact. All systems have backup network feeds and Rb clocks
Customer G	Private Network	UK	Small	System backed up by Caesium
Customer H	Mobile	ик	Medium	Difficult to determine number of affected element but majority of elements have backup sync feeds taken from another Telecom operator.
Customer I	Fixed Line	Sweden	Medium	Affected all SSU 2000 units
Customer J	Mobile	UK	Medium	Some TimeSource inputs reporting high MTIE and MTIE alarms on SSU2000
Customer K	Mobile	UK	Medium	All SSU2000 disqualified GPS inputs. Systems reverted to line timing traceable to another carrie



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

## **Mitigation Options**



- Better & Safe (!) installation practice
- Distributed GPS architecture
- Special jam–proof GNSS antennas
- Better holdover oscillators
- Built in redundancy
- Multiple sources of UTC
  - Using different technologies
  - Over differing transport technologies
  - Self checking regime

### UTC - Traceability Through Diversity







## Further Reading – Reports

- GPS Interference & Jamming
  - Royal Academy of Engineering Report 2011
  - <u>http://www.raeng.org.uk/news/publications/list/reports/RAoE\_Global\_Navigation\_Systems\_Report.pdf</u>
- Extreme Space Weather
  - Royal Academy of Engineering Report 2013
  - <u>http://www.raeng.org.uk/news/publications/list/reports/Space\_Weather\_Full\_Report\_Final.PDF</u>
- UK Research SENTINEL Project
  - Innovate UK, Chronos, NPL, Bath Uni. et al. 2014
  - <u>http://www.chronos.co.uk/files/pdfs/gps/SENTINEL\_Project\_Report.pdf</u>



#### Extreme space weather: impacts on engineered systems and infrastructure









### **Further Information**





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## Conclusion



- GNSS jamming & interference increasing
- eLoran enhances UTC traceability through technological diversity
- Roof top antenna not necessary
  - Saves \$\$\$\$\$
- Not susceptible to the same challenges as GNSS
- Proven and tested in the UK and USA





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