Time Travel and its Black Holes

WSTS17
4-6th April 2017

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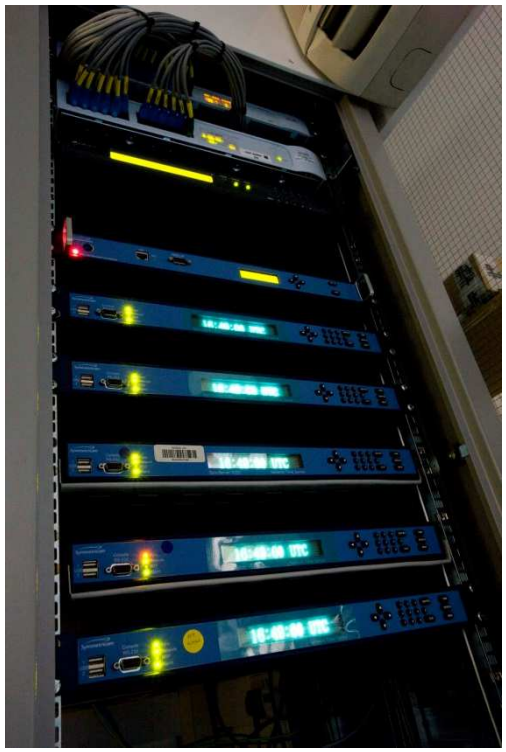
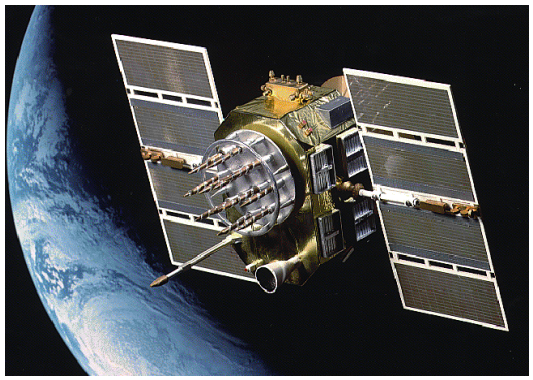
Chronos Technology Ltd

Presentation Contents

- About Time
- Time travel
- Who needs Time?
- Black Holes
- Is there hope?



Black Swan Events

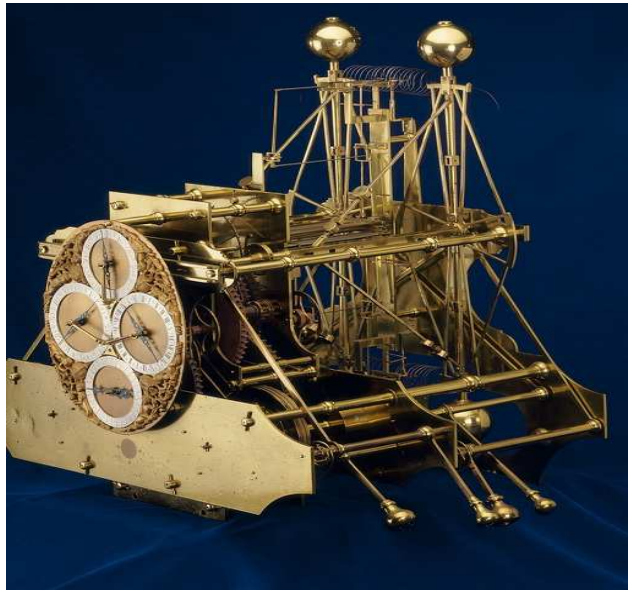


Nassim Nicholas Taleb
2007 “The Black Swan”

- **Surprise** to the **observer**
- **Significant impact**
- With **hindsight** – could have been **predicted.**
- **Not necessarily a surprise to all**

3 Types of Time

- Time of Day
  - What time is it?
  - Time stamping
- Timing “Frequency”
  - Frequency syntonisation
  - Constant Speed
- Alignment to Timescale “Phase”
  - UTC /1pps/Phase/Synchronisation
  - Time slot alignment (TDD)



UTC Traceability

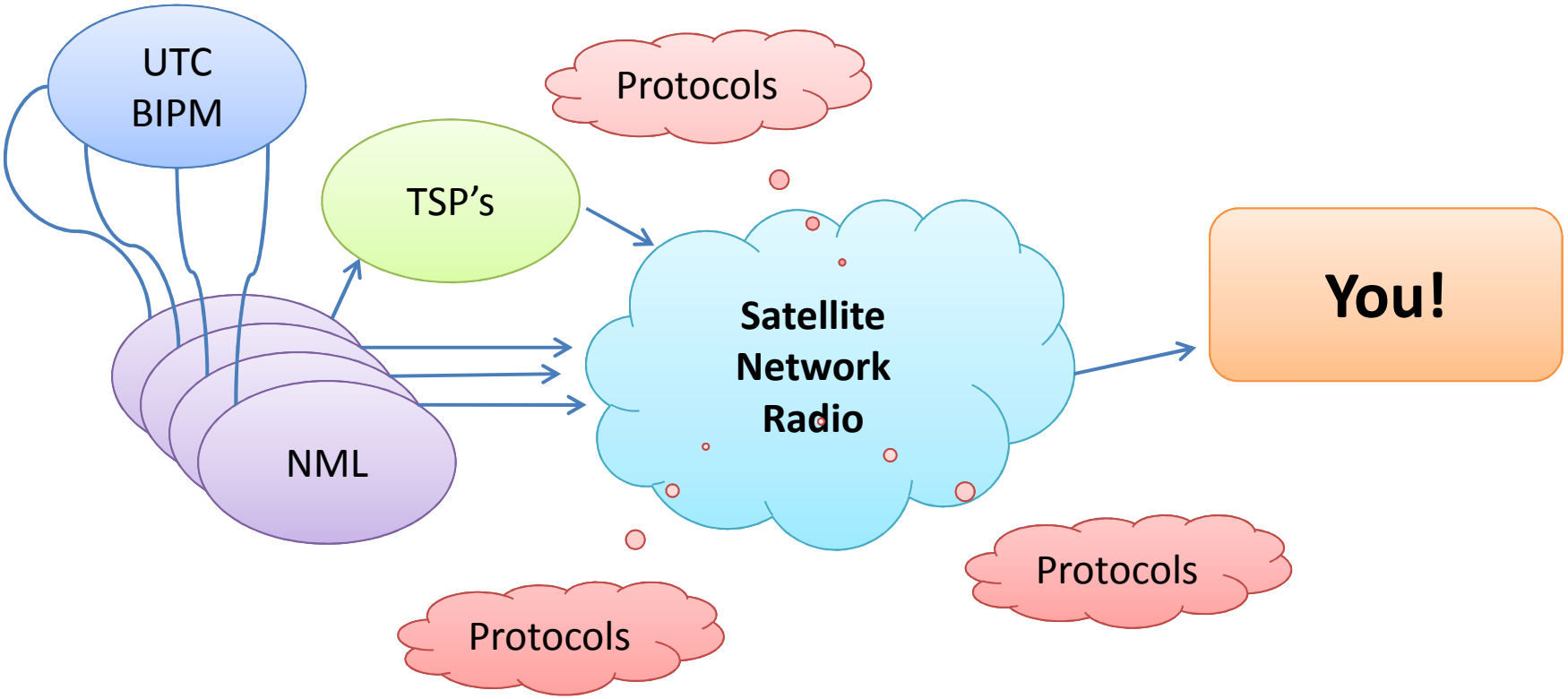
- Coordinated Universal Time
  - ‘Temps Universel Coordonné’
  - Compromise Acronym ‘CUT’ & ‘TUC’ = ‘UTC’
- UTC = Time Standard
  - Not a ‘time zone’ like GMT or BST
- BIPM in Paris coordinates ‘Time’ globally
  - from ~400 Atomic ‘Quantum1’ Clocks at ~70 Metrology Labs
  - e.g. NPL, NIST, USNO
- Traceability – via GNSS or National Metrology Lab

Courtesy USNO

Time Travel!

- Network
  - NTP, PTP, SyncE,
  - White Rabbit
- Sky
  - GNSS (GPS, Galileo, Glonass, etc.)
  - Iridium
- Terrestrial LF Radio
  - MSF ‘Rugby’ 60 KHz, eLoran 100 KHz, Droitwich 198 KHz, DCF77

Your Timing Universe



Who Needs Time?

- Critical National Infrastructure
- Telecom
- Broadcast
- Utilities
- Financial Services
- Transport
- Defence
- + many more

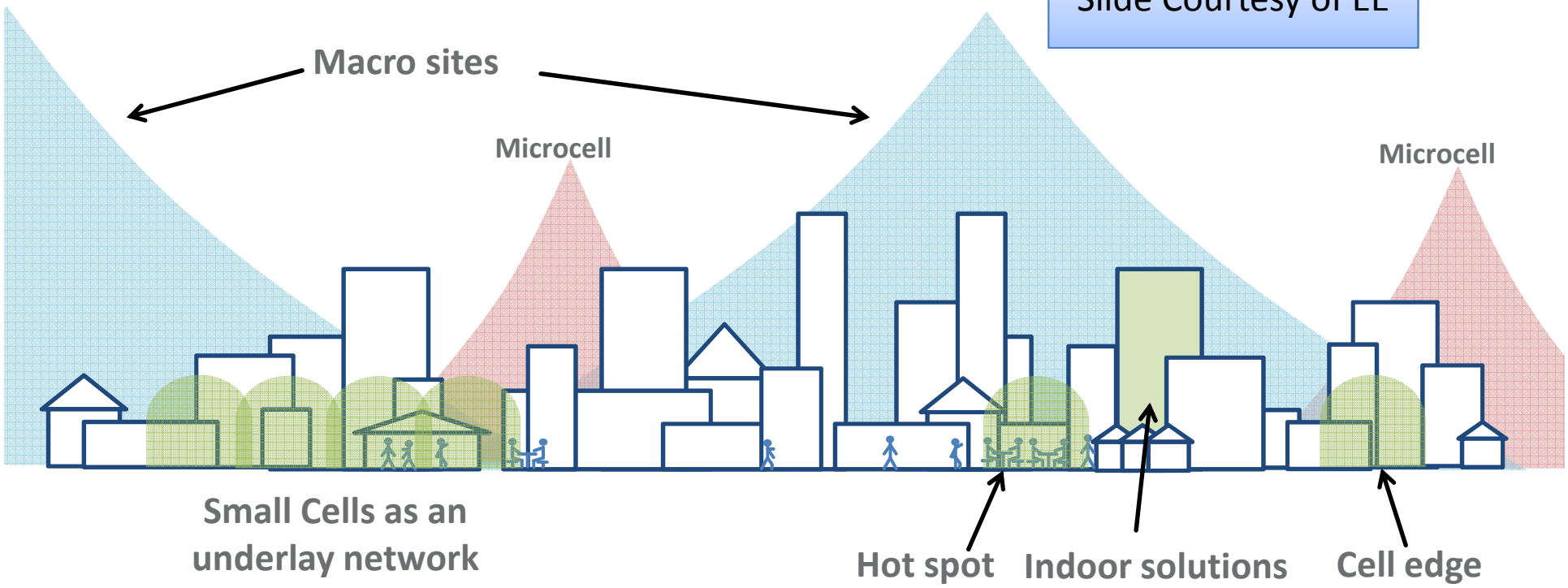
Chronos 24x7 Time System Support Operations

Why is Time Critical?

- Time Stamping of Calls/Trades
  - Time of Day - (ms, µs, ns?)
- Consistent data rates
  - Data Traffic Timing (µs, ns)
- Using TDD in 4G/5G (ns)
- Inter-Cell Interference Cancellation (ns)
  - Phase
- Emerging Standards
  - MiFID II

Small cells and Heterogeneous Networks

Slide Courtesy of EE



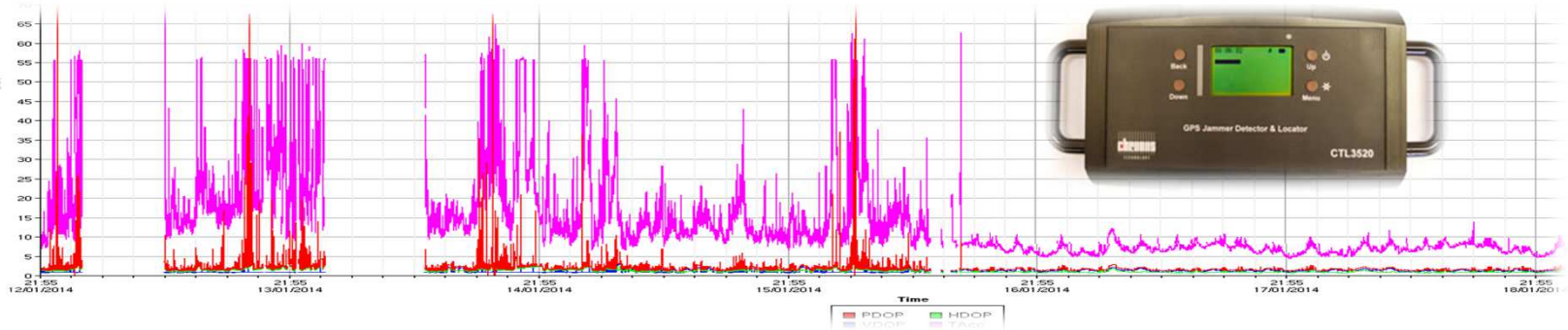
Why is Time Critical? – Broadcast

- Synchronising Programmes
  - Time of Day (ms)
- Broadcast
  - Frequency – Tuning (ms, µs)
- Digital Audio/Video Broadcast (DAB, DVB)
  - Phase - Single Frequency Networks (SFN) (ns)

Black Holes

- Rogue Antennas
- Poor Installations
- Jamming Problems
- Satellite Problems
- Receiver Problems

Rogue Antennas

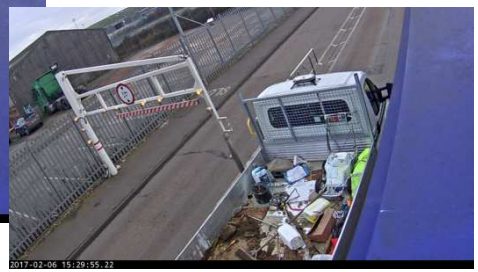


Poor Installations

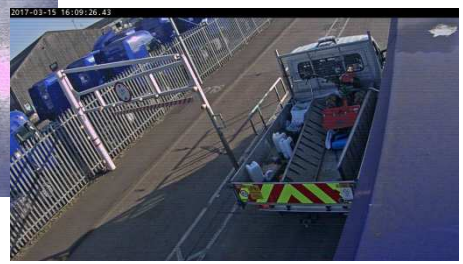
Every Day Jamming – Container Port

October

6th Feb

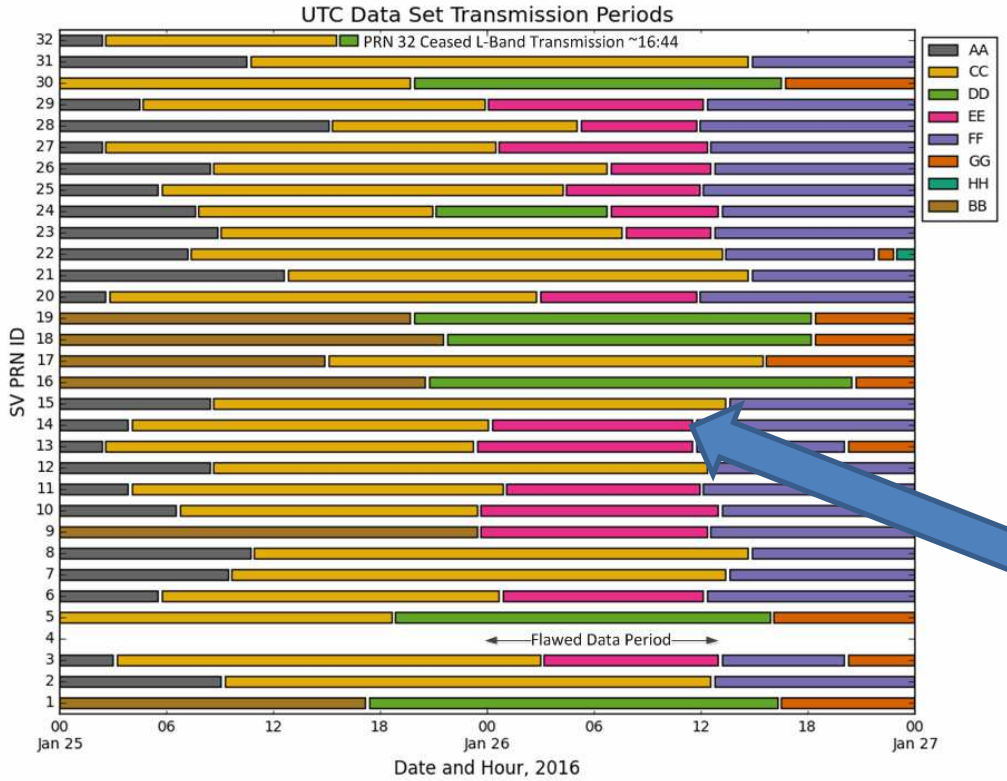


Feb/Mar



Innovate UK Project AJR

GPS UTC Offset Anomaly - 2016



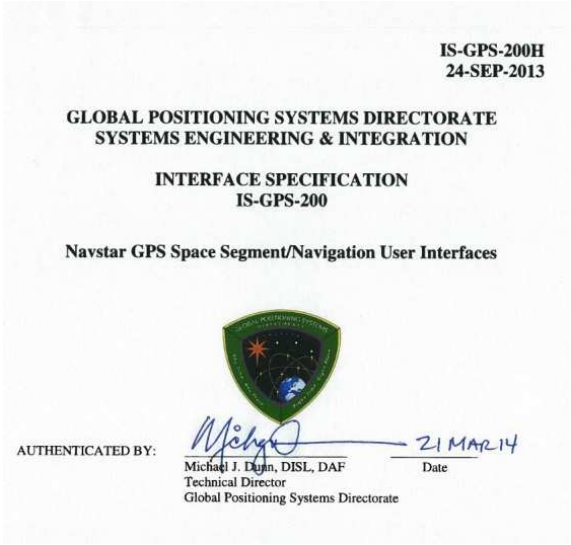
ION 2016 Portland OR
GPS Receiver Impact from the UTC Offset (UTCO) Anomaly of 25-26 January 2016

Karl Kovach, Philip J. Mendicki, The Aerospace Corporation; Ed Powers, US Naval Observatory; Brent Renfro, ARL, The University of Texas at Austin

EE Dataset Value of Δt_{UTC} was -13.025 µs

Shown pink and impacted 15 satellites

Calculating the UTC Offset



IS-GPS-200H
24-SEP-2013

GLOBAL POSITIONING SYSTEMS DIRECTORATE
SYSTEMS ENGINEERING & INTEGRATION

INTERFACE SPECIFICATION
IS-GPS-200

Navstar GPS Space Segment/Navigation User Interfaces

AUTHENTICATED BY:
Michael J. Dunn, DISL, DAF
Technical Director
Global Positioning Systems Directorate
21 MAR 14
Date

Page 123 - Section 20.3.3.5.2.4
Coordinated Universal Time (UTC)

$\Delta t_{UTC} = \Delta t_{LS} + A_0 + A_1(t_E - t_{ot} + 604800(WN - WN_t))$, seconds

Where:

Δt_{LS} = current leap second
t_E = GPS receiver's estimate of current GPS TOW
t_{ot} = reference time for UTC data secs in week
604800 = number of seconds in a week
WN = current full GPS week number
WN_t = UTC reference week number

Let's use real data

Values are taken from the navigation message from SVN43/PRN13 (one of the first satellites to be impacted) for times before the event (23:13) and during (23:26)

$$\Delta t_{UTC} = \Delta t_{LS} + A_0 + A_1(t_E - t_{ot} + 604800(WN - WN_t))$$

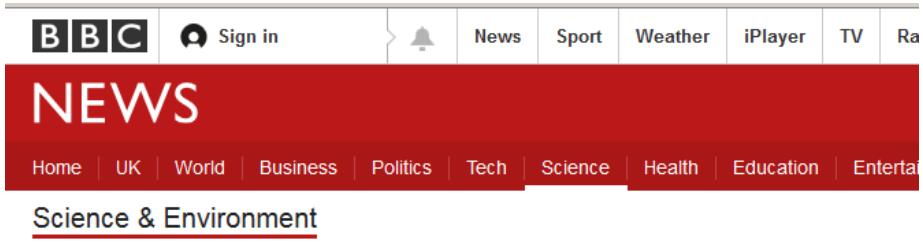
Date	Time	Δt_{UTC} µs	Δt_{LS}	A_0	A_1	t_E	t_{ot}	WN	WN_t
25 Jan	23:13	-0.002	17s	-9.93132e-10	5.33e-15	170034	319488	89	89
25 Jan	23:27	-13.025	17s	-1.3696e-05	1.24e-14	170874	0	89	0

Data and method courtesy John Lavrakas

Glonass in 2014

- Glonass 1st April 2014
  - All satellites broadcast corrupt data for 11 hours
  - Massive positional errors
- Glonass 14th April 2014
  - 8 satellites set unhealthy for 30 minutes
- Press Coverage
  - http://gpsworld.com/the-system-glonass-fumbles-forward/
  - http://gpsworld.com/the-system-glonass-in-april-what-went-wrong/

Galileo in 2017



Science & Environment

Galileo satellites experiencing multiple clock failures

By Jonathan Amos
BBC Science Correspondent

18 January 2017 | Science & Environment

The onboard atomic clocks that drive the satellite-navigation signals on Europe's Galileo network have been failing at an alarming rate.

Across the 18 satellites now in orbit, nine clocks have stopped operating.

Three are traditional rubidium devices; six are the more precise hydrogen maser instruments that were designed to give Galileo superior performance to the American GPS network.

Galileo was declared up and running in December.

Beware the Ides of March!

- Week Number Rollover 2019
  - 31st March 2019 – WN = 1023
  - 7th April 2019 – WN = 0

- Zeroing terms in Δt_{UTC} caused grief in January 2016
  - What will happen in April 2019?

Is there hope?

- Complementary Technologies
- ‘Best of 3’ Architecture
- Lots of Literature

eLoran

- Anthorn, UK Sovereign Time (ns)
- Sole Survivor of the European Loran Network
  - UTC Traceability via Chronos equipment
- Working with GO-Science and Cabinet Office
  - to get Norway, Germany, Denmark & France back on air
- eLoran is an important complement to GNSS
  - LDC can provide ephemeris data, differential data, PRS Keys, NANU/NAGU and spoofing alerts

Anthorn Antennas: ©Martin and Jean Norgate

Two out of Three Ain't Bad

- True resilience is 3 dissimilar sources of UTC over 3 dissimilar technological routes
  - Network time using PTP or SyncE
  - Multiple GNSS helps
  - Another off-air non-satellite UTC Traceable PNT e.g. eLoran
- One solution - easily compromised like a simple password
- Two solutions – dilemma - whose right and whose wrong?
- Three solutions - perfect Meat Loaf number!

Further Reading

- SVN 23 Case Study
- SVN 23 White Paper
- Detecting Rogue GPS Antennas
- RAEng Report on GNSS Vulnerabilities
- RAEng Report on Space Weather
- Blackett Review Recommendation

Blackett Quantum Review Recommendation 2: *(UK) Cabinet Office and the Government Office for Science should review the critical services dependent on GNSS timing signals and mitigate the risks by analysing how long they should be capable of operating with back-up or holdover technology.*

Thankyou

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