The Navigation of Navigation

Professor David Last

Past-President

Royal Institute of Navigation

PNT Challenges & Opportunities Symposium

29 October 2014

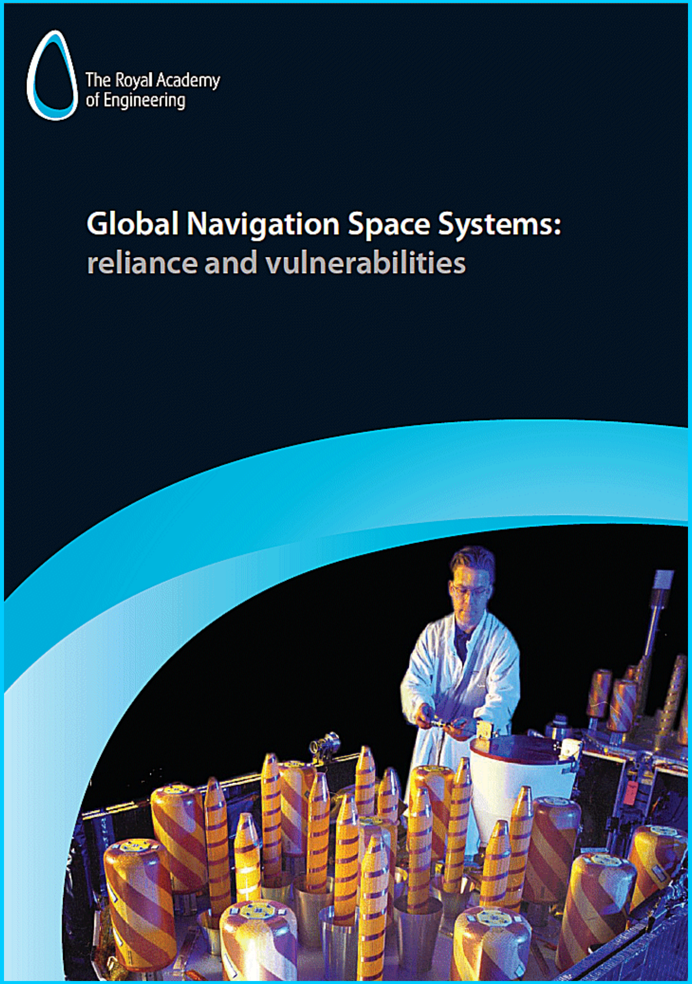
Stanford University

Picture: earthobservatory.nasa.gov//ewsroom/BlueMarble/

A Proper Navigator

Photo: Dreamstime.com

Photo: Ashtech Inc., Optron Pty.



- GPS and other satellite navigation services … have applications so pervasive that there is now a real threat to global security if the systems should fail.

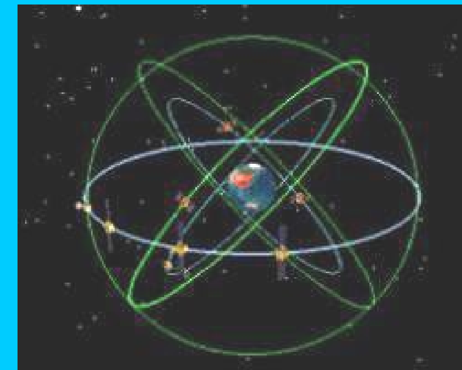
- GNSS signals are used internationally by almost every industry: rail, road, aviation, space, maritime, agriculture, energy, surveying, construction, law enforcement and communications.

- Dependence on GNSS connects many independent services into an ‘accidental system’ with a single point of failure: the satellite PNT signal.

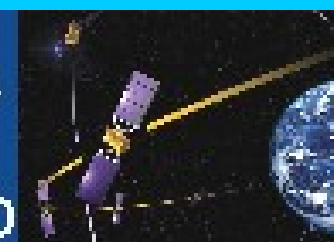
- A satellite signal is a weak foundation for important services … and can fail in dozens of ways.

Source: www.ingenia.org.uk/ingenia/issues/issue43/issue43_opinion.pdf (Dr Martyn Thomas)

GPS plus …

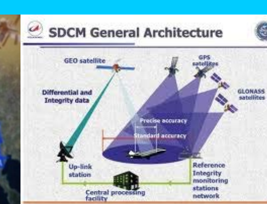


GLONASS (Russia) **Compass-Beidou (China)**



QZSS (Japan) **GALILEO (Europe)** **IRNSS (India)**

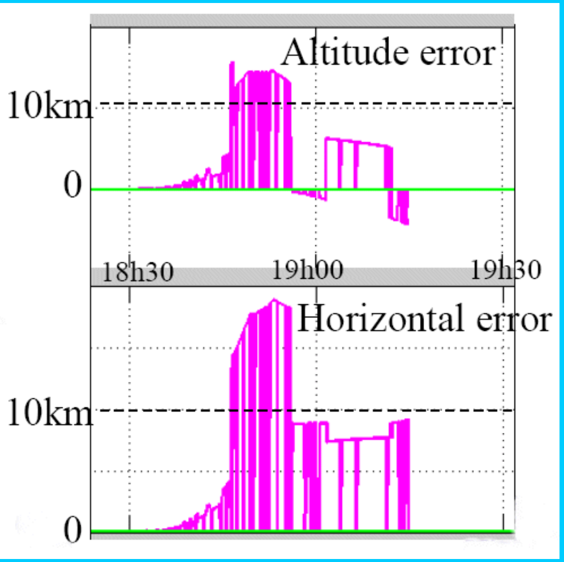
… and all the augmentations:



Satellite and Control System Failures

Official announcement: *"A significant GPS anomaly occurred on 1 Jan 04... (which) … resulted in the transmission of Hazardously Misleading Information."*

SVN23 clock failure



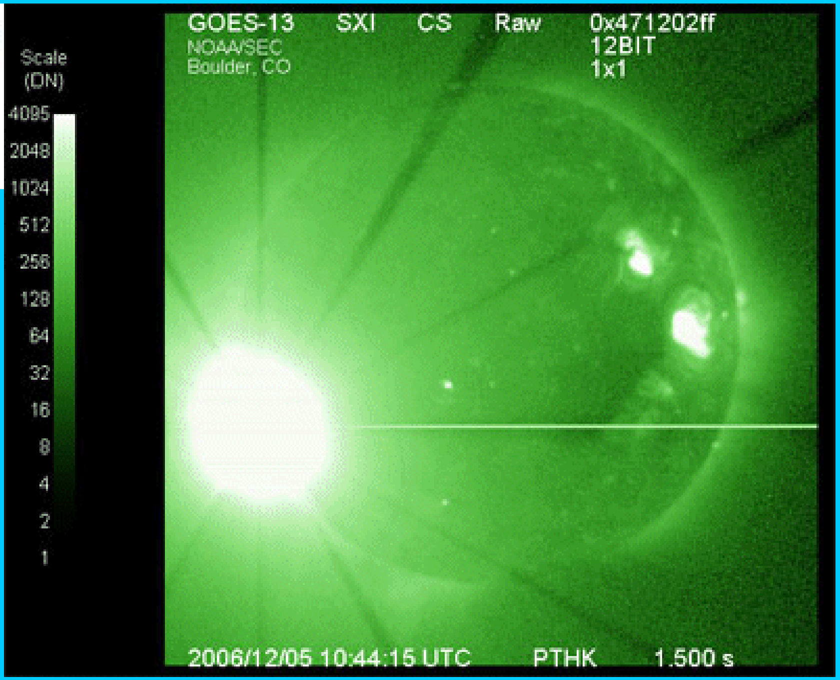
Sources: Vogel, Macabiau & Suard, 'Effect of a GPS Anomaly on Different GNSS Receivers', ION GNSS 2005, Long Beach, CA, Sep 13-16, 2005, Hoppe & Walterfang, 'Investigation of a GPS Satellite Problem with respect to DGPS and GPS users', European Journal of Navigation, May 2004, www.lr.tudelft.nl/live/pagina.jsp?id=400f4487-ed8c-4274-95cb-ebc2afa7385e&lang=en

Solar flares

GPS significantly impacted by powerful solar radio burst

NOAA NEWS RELEASE

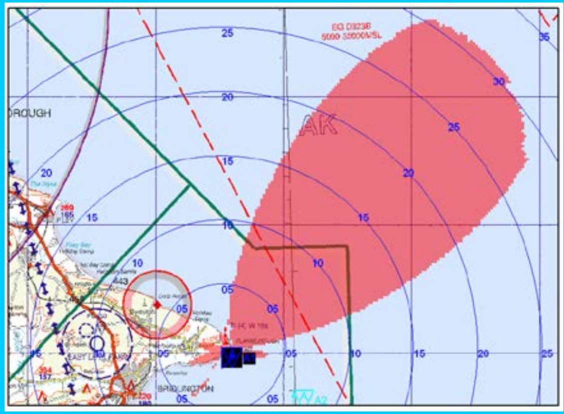
Posted: April 4, 2007

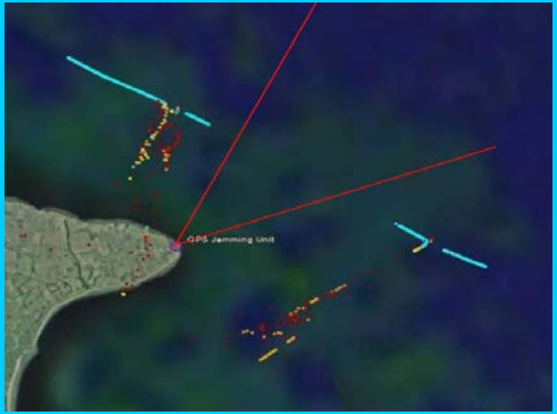


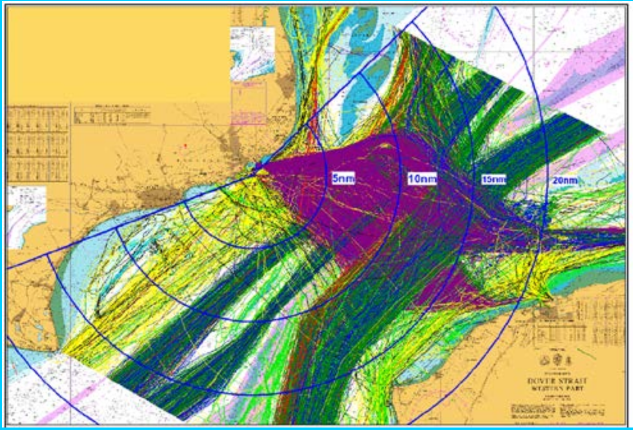
"The burst produced 20,000 times more radio emission than the … rest of the sun … and swamped GPS receivers over the entire sunlit side of the Earth."

Picture: www.flickr.com/photos/l23productions/1451697290/

A small jammer on this cliff-top disrupted GPS on vessels out to ranges as wide as the Dover Strait







Low-powered GPS jammer on ship

THV *Galatea*

Jammer of less than 1 milliWatt:

- **False positions, and velocities**
- **Autopilot may turn vessel**
- **But no alarms!**

With a little more jammer power:

- **Electronic Chart Displays**
- **Autopilot**
- **Automatic Identification System**
- **Differential GPS**
- **Satellite voice and data comms**
- **Maritime distress safety system**

plus …

Ship's Radar & Gyrocompass

N. Korea accused of jamming commercial flight signals

By Julie Yoo, NBC News in Seoul, and msnbc.com news services

JAMMER ALL

Free shipping by DHL or FedEx

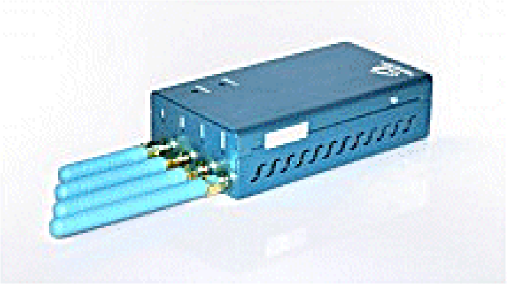
* Only for Legal Use

Product Description

Are you sick of being tracked like a criminal? This certain device is a gorgeous GPS jammer which can totally solve your troubles. The can prohibit signals from tracking your current location; pay a private space for you. All of this owes to the **high power portable GPS (GPS L1/L2/L3/L4/L5) jammer**.

High Power Portable GPS (GPS L1/L2/L3/L4/L5) Jammer

Free Shipping



RRP: ~~GBP £110.26~~

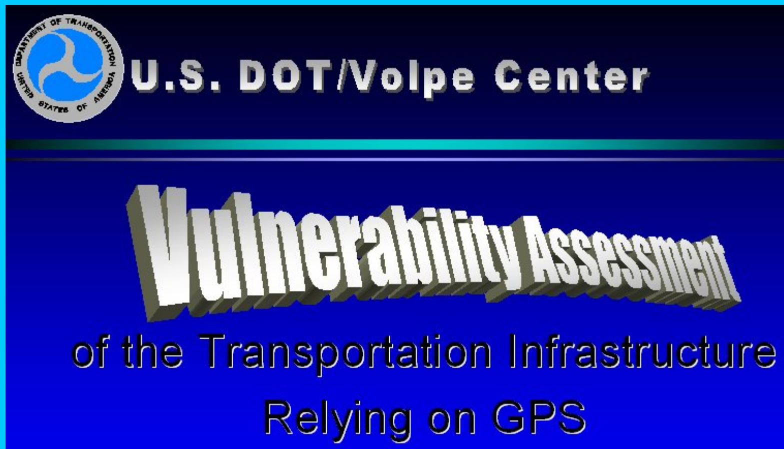
Your Price: GBP £101.43
(You save GBP £8.83)

SKU: JM110838

Rating: (6 product reviews)

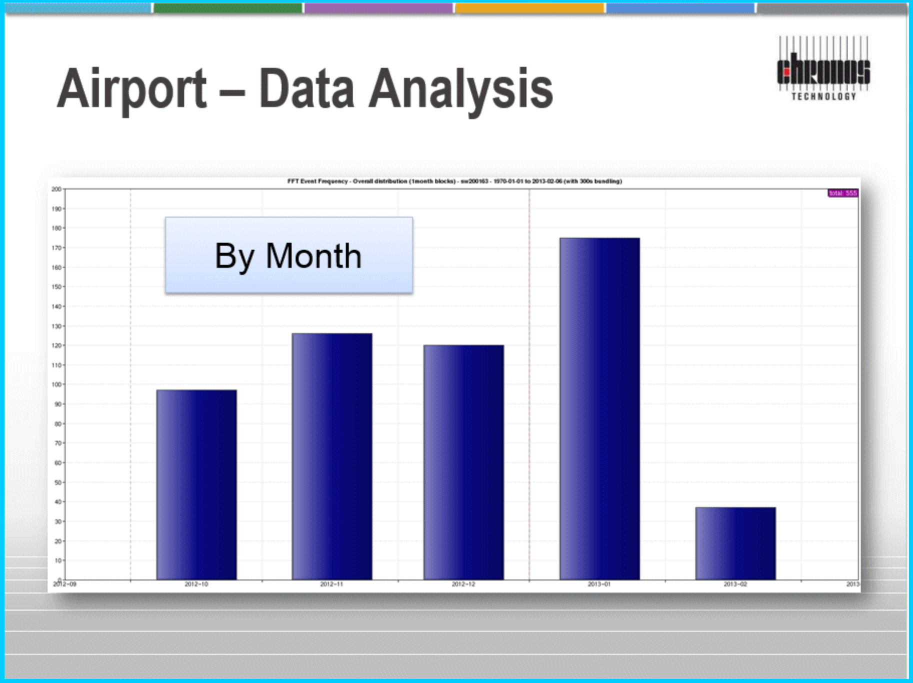
Shipping: Calculated at checkout

Quantity: 1 Add to cart



GPS provides many benefits to civilian users. It is vulnerable, however, to interference and other disruptions that can have harmful consequences. GPS users must ensure that adequate independent backup systems or procedures can be used when needed.

From: Carroll, J.V., 'Vulnerability assessment of the transportation infrastructure relying on GPS',
30th Annual Convention & Technical Symposium of the International Loran Association, Paris, 10 October 2001


Airport – Data Analysis
TECHNOLOGY
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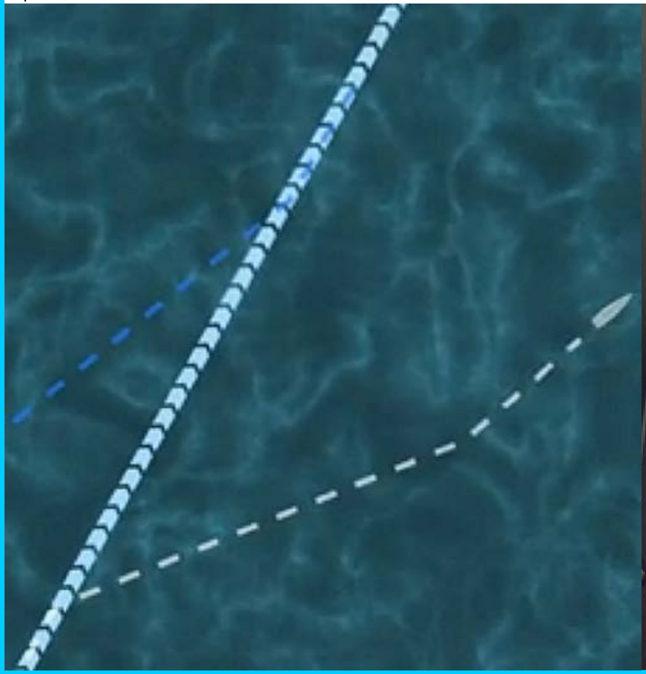
Researchers show how a major GPS flaw could allow terrorists and hackers to hijack commercial ships and planes

By DAILY MAIL REPORTER

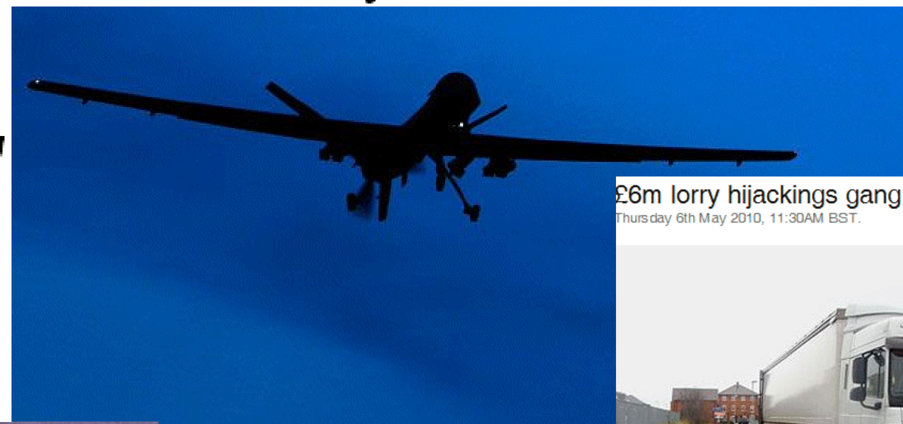


Pictures: wikipedia.org, dailymail.co.uk, insidegnss.com, youtube.com

EXCLUSIVE: Drones vulnerable to terrorist hijacking, researchers say

'Spoofing a GPS receiver on a UAV is just another way of hijacking a plane.'

- University of Texas Radio Navigation Laboratory researcher Todd Humphreys



£6m lorry hijackings gang face ten years

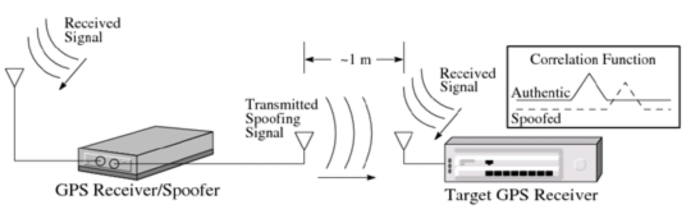
Thursday 6th May 2010, 11:30AM BST.

REE METRO

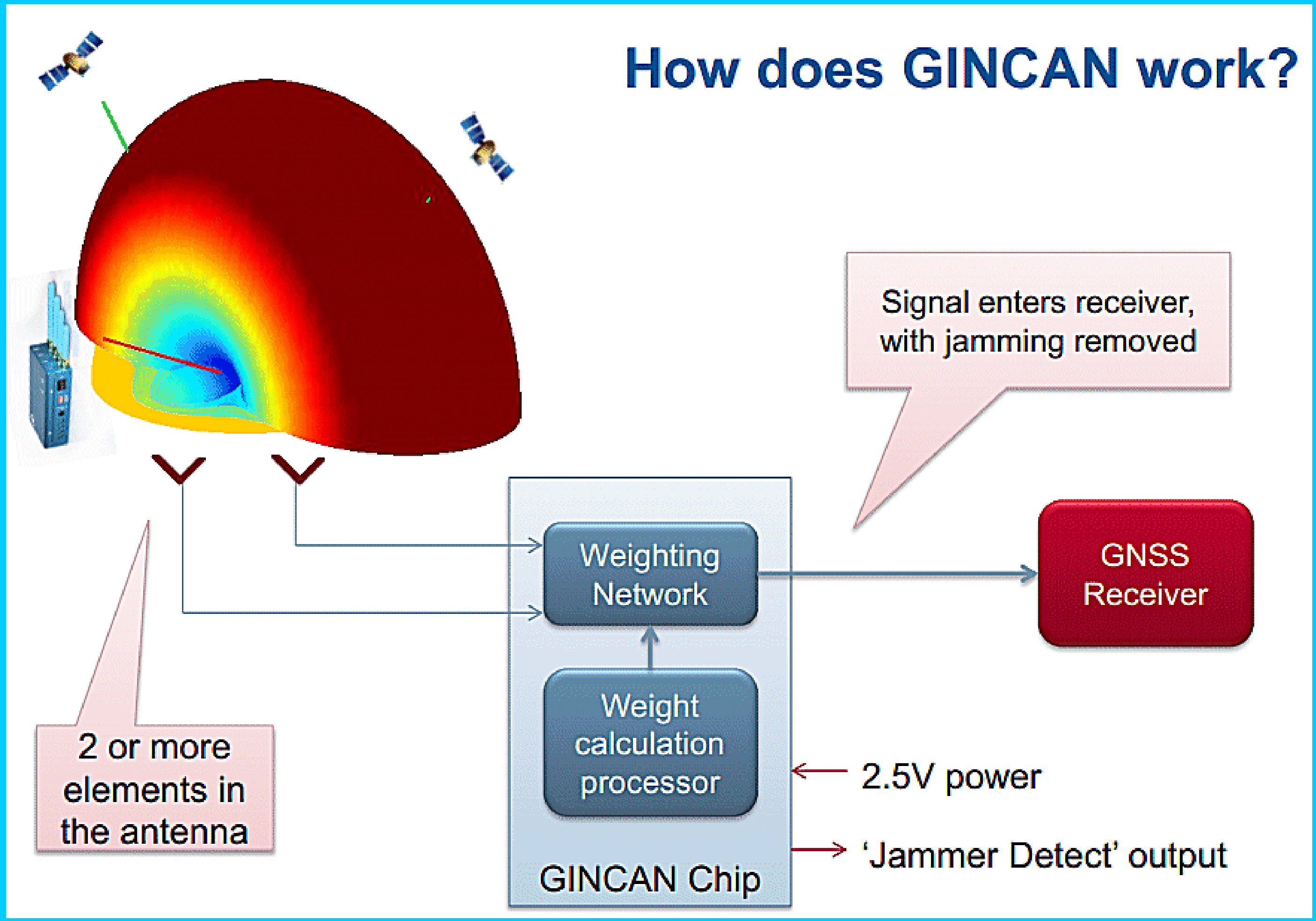
Wednesday, February 22, 2012 The world's most popular free newspaper

GPS threat to stock markets

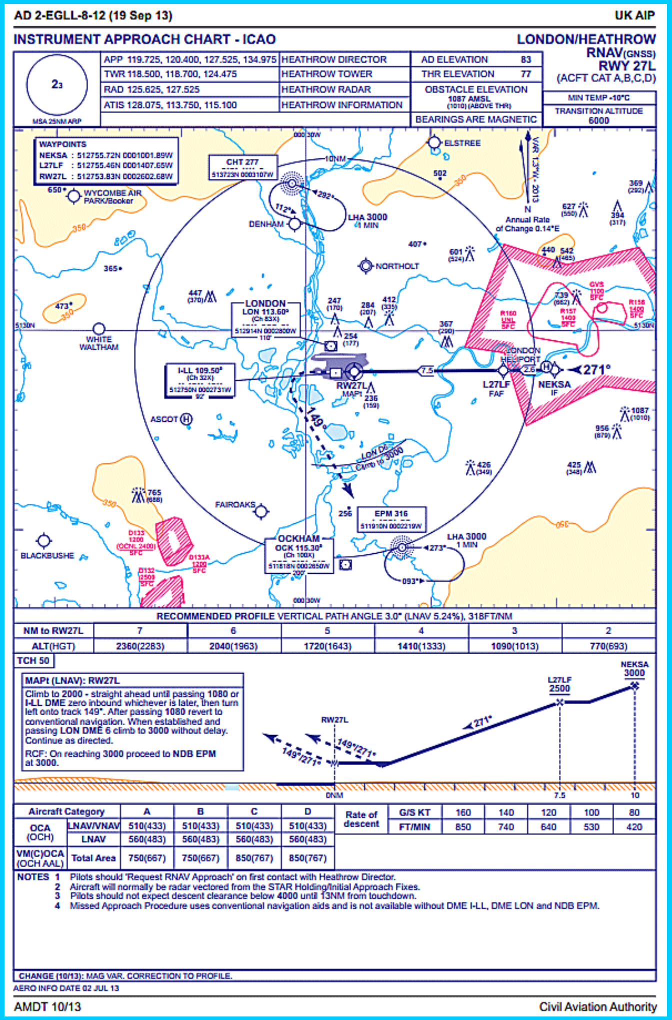
The Most Likely Threat: A Portable Receiver-Spoofer



The portable receiver-spoofer architecture simplifies a spoofing attack



From: https://connect.innovateuk.org/documents/3347783/3709538/gnss_anti_jam_tech_jones.pdf/56097f6d-1055-4897-9236-a3dc7490d60d



London Heathrow Runway 27L

GNSS Instrument Approach

Supporting cast:

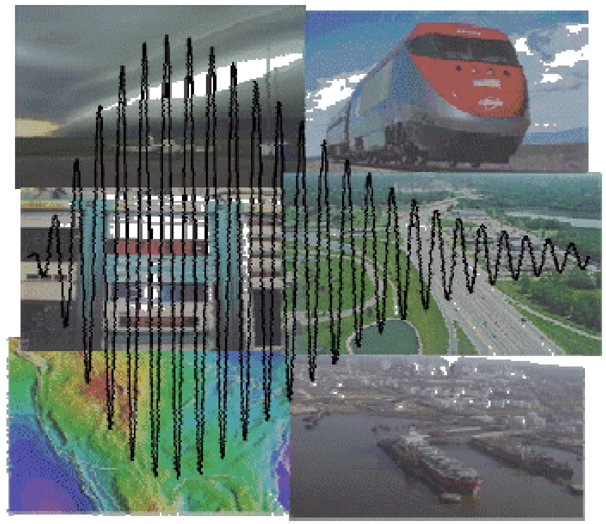
- ILS/DME (I-LL)
- LOC/DME (I-LL)
- MLS/DME

Starring …

- Instrument Landing System Localiser
- Instrument Landing System Glideslope
- Distance Measuring Equipment
- Microwave Landing System
- Barometric altimeter
- High-Intensity Lighting System

From: http://www.ead.eurocontrol.int/eadbasic/pamslight-23AE573F59E3C0B9AB33BC5B126A385E/7FE5QZZF3FXUS/EN/Charts/AD/AIRAC/EG_AD_2_EGLL_8-12_en_2013-09-19.pdf

Loran's Capability to Mitigate the Impact of a GPS Outage on GPS Position, Navigation, and Time Applications



Prepared for the
FEDERAL AVIATION ADMINISTRATION
VICE PRESIDENT FOR TECHNICAL OPERATIONS
NAVIGATION SERVICES DIRECTORATE

March 2004

Press Office
U.S. Department of Homeland Security

Homeland Security

February 7, 2008
Contact: (202) 282-8010

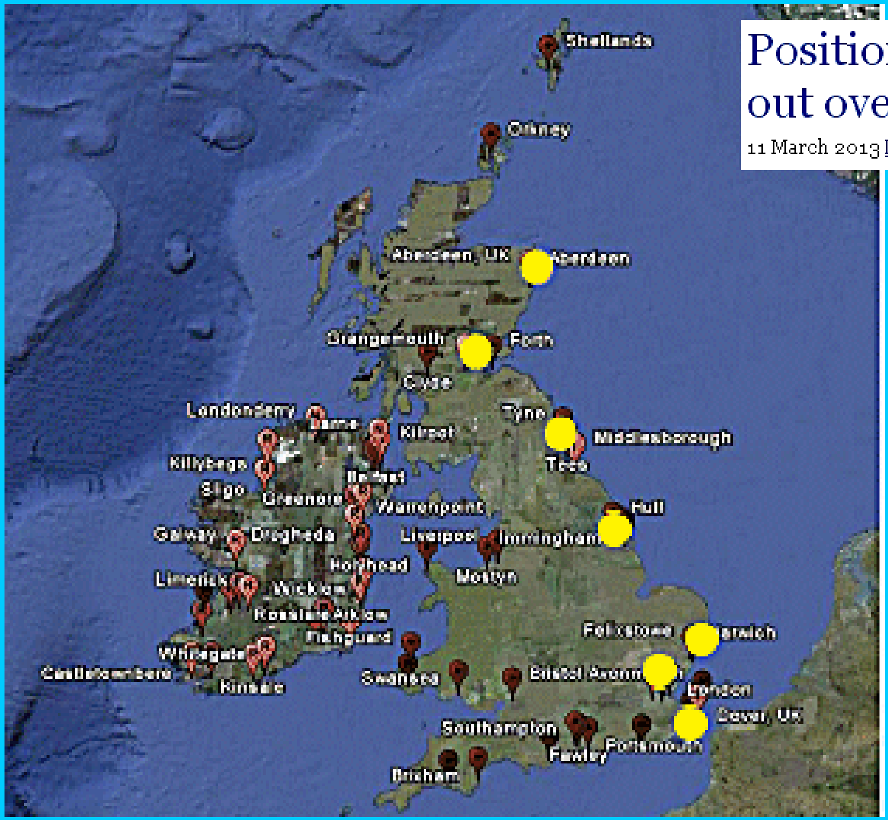
STATEMENT FROM DHS PRESS SECRETARY LAURA KEEHHNER ON THE ADOPTION OF NATIONAL BACKUP SYSTEM TO GPS

Today the U.S. Department of Homeland Security will begin implementing an independent national positioning, navigation and timing system that complements the Global Positioning System (GPS) in the event of an outage or disruption in service.

The enhanced Loran, or eLoran, system will be a land-based, independent system and will mitigate any safety, security, or economic effects of a GPS outage or disruption.

GPS is a satellite-based system widely used for positioning, navigation, and timing. The eLoran system will be an enhanced and modernized version of Loran-C, long used by mariners and aviators and originally developed for civil marine use in coastal areas.

In addition to providing backup coverage, the signal strength and penetration capability of eLoran will provide support to first responders and other operators in environments that GPS cannot support, such as under heavy foliage, in some underground areas, and in dense high-rise structures. The system will use modernized transmitting stations and an upgraded network.



Positional assistance for ships – eLoran rolls out over the English Channel

11 March 2013 Liam Stoker

Digital Ship

MarineLink.com

Maritime Reporter and *MarineNews* magazines online

New Ship-based System Takes Out GPS Jamming Threat

PC Advisor — Monday, March 11, 2013

With GPS jamming a growing worry for UK shipping, a new device seamlessly switches systems to counter the navigational menace.

Enhanced Differential Loran Maritime Trials in The Netherlands Declared Successful

Picture: www.insidegnss.com

InsideGNSS

WASHINGTON VIEW

OCX Program Restructured, Delayed Again

Details are emerging about another restructuring of the contract for the new GPS ground system, a deal that pushes completion of the project back another two years and recasts the remaining work to fit within the Air Force's strained financial profile.

Pictures: www.insidegnss.com, gps.gov

Who Pays for GPS?

The American taxpayer pays for the GPS service enjoyed throughout the world. All GPS program funding comes from general U.S. tax revenues.

The bulk of the program is budgeted through the Department of Defense, which has primary responsibility for developing, acquiring, operating, sustaining, and modernizing GPS.

The Navigation of Navigation

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Picture: earthobservatory.nasa.gov//ewsroom/BlueMarble/