UK Progress on Resilient PNT

Professor David Last

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General Lighthouse Authorities of the UK & Ireland

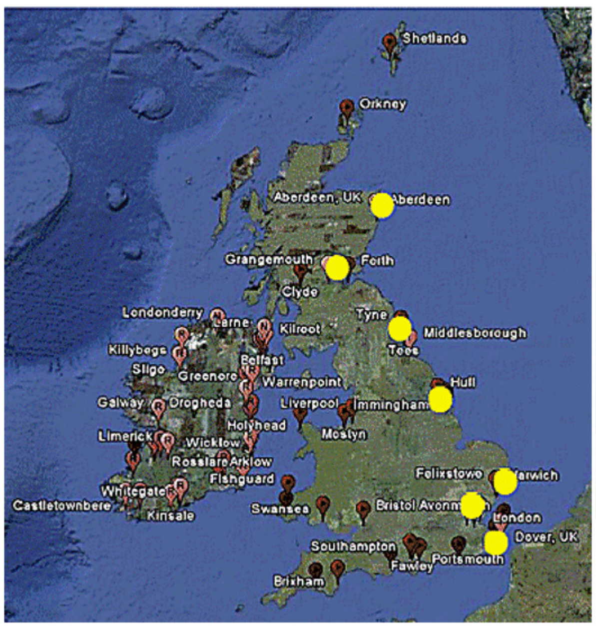
National Space-Based PNT Advisory Board

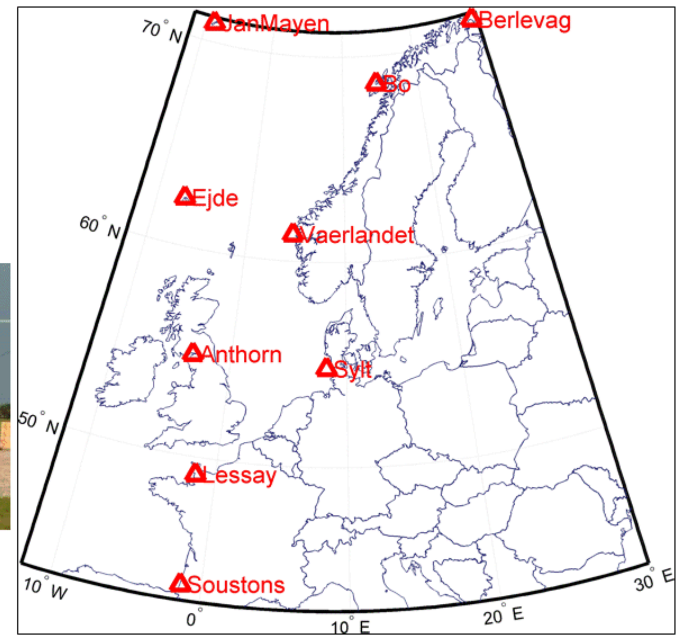
Baltimore, MD, USA

16 May 2018

Picture: earthobservatory. Nasa. gov//newsroom/BlueMarble/

Prototype eLoran using the stations of the North-West European Loran System: UK Initial Operational Capability was declared on 31 October 2014





Ports served by IMO-quality differential eLoran

Legacy Loran-C stations

Government Office for Science

GOV.UK

What we do

We advise the Prime Minister and members of the Cabinet, to ensure that government policies and decisions are informed by the best scientific evidence and strategic long-term thinking.

We are responsible for:

- giving scientific advice to the Prime Minister and members of the Cabinet, through a programme of projects that reflect the priorities of the Government Chief Scientific Adviser

Professor Sir Mark Walport


FINAL

Economic impact to the UK of a disruption to GNSS

Showcase Report

April 2017

LE London Economics

Commissioned by

Innovate UK

UK SPACE AGENCY

ROYAL INSTITUTE OF NAVIGATION

Given the … widespread use (including safety-critical applications) and the vulnerability of GNSS:

What would happen if GNSS were not available, temporarily?

Estimate: the economic impact:

- **lost Gross-Value Added (GVA)**
- **loss of utility benefits, including damages**

Assume: the disruption to GNSS is a standalone event (agnostic as to its source)

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/619545/17.3254_Economic_impact_to_UK_of_a_disruption_to_GNSS_-_Showcase_Report.pdf

The economic impact to the UK of a 5 day disruption of GNSS is estimated at £5.2Bn ($7.1Bn).

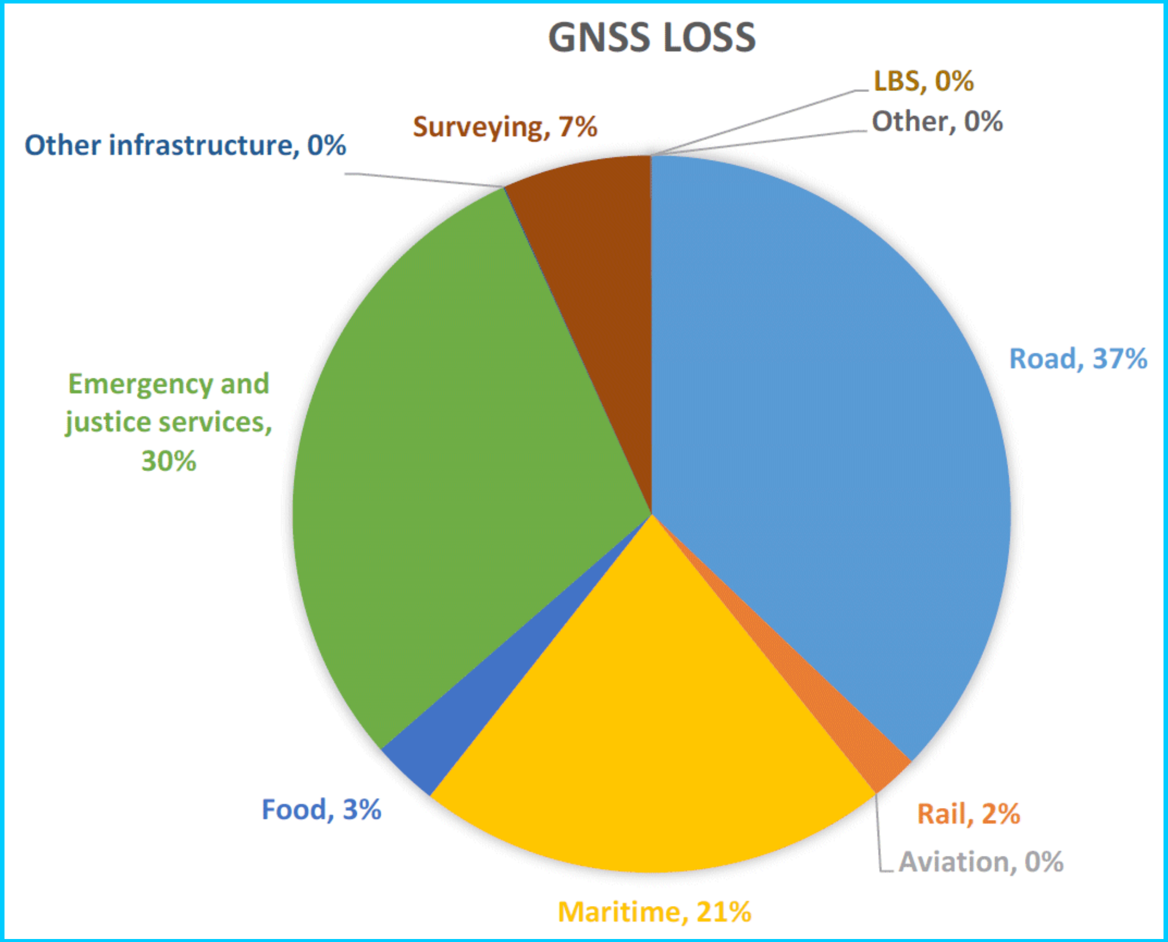


Table 1 Summary of economic loss to the UK as a result of a five-day loss of GNSS

Domain	Applications	RAG	Loss of GVA (£m)	Loss of utility (£m)	Total loss for five days (£m)
Road	Road transport infrastructure Road navigation / Advanced Driver Advisory Systems Logistics and fleet management Insurance telematics Emergency and breakdown call		24.2	1,896.0	1,920.2
Rail	Rail transport infrastructure Passenger information systems Asset management Driver advisory systems		94.9	15.5	110.4
Aviation	Automatic Dependent Surveillance - Broadcast system Air transport infrastructure Navigation under visual flight rules Cospas-Sarsat search-and-rescue (SAR) system Mobile satcoms		0.1	0.3	0.4
Maritime	Maritime transport infrastructure Navigation and shipping Search and rescue applications Fishing Recreational boating		1,103.7	0.1	1,103.8
Food	CAP and CFP compliance monitoring Cultivation Livestock tracking, hunting and silviculture		151.6	4.3	155.7
Emergency and justice services	TETRA Public-safety answering point Emergency vehicles Offender tracking		0.4	1,531.5	1,531.9
Surveying	Cadastral surveying Mapping Mining Construction (person and machine-based) Marine surveying Infrastructure monitoring		344.8	-	344.8
LBS	Smartphones Pedestrian navigation Fitness tracking		-	0.8	0.8
Other infrastructure	Transport of dangerous or classified goods Telecommunications – fixed-line & cellular Broadcast – DVB & DAB Internet data centres Electricity transmission Fixed-location noise loggers		0.7	2.3	3.0
Other	Banking and stock exchanges Weather forecasting People tracking LEO satellites and ground stations Timesheets and billable hours		2.5	1.1	2.6
Total			1,721.9	3,451.8	5,173.6

The use of GNSS by road, emergency and justice services, plus maritime, accounts for 88% of all economic impacts.

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Road

Domain	Applications	RAG	Loss of GVA (£m)	Loss of utility (£m)	Total loss for five days (£m)
Road	Road transport infrastructure Road navigation / Advanced Driver Advisory Systems Logistics and fleet management Insurance telematics Emergency and breakdown call		24.2	1,896.0	1,920.2

- ***Navigation devices for road applications fail.***
- ***GNSS-dependent drivers (particularly delivery and cab drivers) lose their preferred method of navigation.***
- ***Congestion and journey times increase for all drivers – including commuters who know their routes.***
- ***$2700 million***

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Emergency and Justice Services

Domain	Applications	RAG	Loss of GVA (£m)	Loss of utility (£m)	Total loss for five days (£m)
Emergency and justice services	TETRA Public-safety answering point Emergency vehicles Offender tracking		0.4	1,531.5	1,531.9

- ***Services severely impacted, struggle to cope with demand.***
- ***Longer emergency calls due to less efficient dispatching and navigation plus congested roads.***
- ***$2200 million***

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/619545/17.3254_Economic_impact_to_UK_of_a_disruption_to_GNSS_-_Showcase_Report.pdf

Maritime

Domain	Applications	RAG	Loss of GVA (£m)	Loss of utility (£m)	Total loss for five days (£m)
Maritime	Maritime transport infrastructure Navigation and shipping Search and rescue applications Fishing Recreational boating		1,103.7	0.1	1,103.8

- ***Disruption to all ports and the loading and unloading of containers for 5 days***
- ***Factories relying on just-in-time deliveries run out of inputs within 1 day***
- ***All goods imported by bulk container or vehicle severely delayed, causing immediate impacts far beyond the maritime industry.***
- ***$1600 million***

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/619545/17.3254_Economic_impact_to_UK_of_a_disruption_to_GNSS_-_Showcase_Report.pdf

Mitigation Technologies and Strategies

- ***Alternatives to GNSS, specific to each application***
- ***No universally-applicable alternative for positioning and navigation***
- ***Higher quality (more expensive) oscillators for timing***
- ***"The most applicable mitigation strategies for the largest number of applications are eLoran and Satelles"***
- ***"Omnisense and Locata may be preferred for localised applications that require high levels of accuracy"***

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The Contribution of UK Public Funding

- *"GNSS is characterised by a number of market failures that mean that there is a strong economic case for government intervention."*

- *"This includes large benefits for society that are estimated to be between £4 and £5 per £1 of public investment."*

- *"The UK's … downstream investments [in GNSS] since 2000 have … unlocked significant benefits to end-users and the rest of the society that would have been lost without UK funding."*

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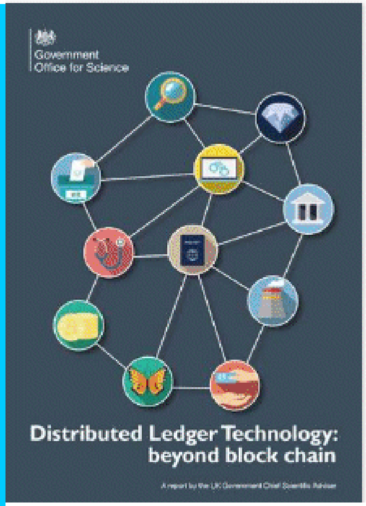
Office of the Government Chief Scientific Adviser, Sir Mark Walport

Aims: "*… to lay out the breadth, scale and implications of our reliance on 'the invisible utility' mainly in terms of existing critical national infrastructure (CNI).*"

Ministerial Foreword: ***"This review represents a vital step in understanding the UK's dependency on GNSS and recommends measures to improve our resilience. Importantly, it also recognises that innovation will be key to realising, fully and safely, the economic and societal benefits offered by GNSS."***

Blackett Reviews

The Government Chief Scientific Advisor (GCSA) has established a process for government to engage with academia and industry to answer specific scientific and/or technical questions primarily in the security domain. These Blackett Reviews provide fresh, multi-disciplinary thinking in a specific area. In each review, a small panel of 10-12 experts is tasked with answering a well defined question or set of questions of relevance to a challenging technical problem.



Patrick Maynard Stuart Blackett, Baron Blackett OM CH PRS[1] (18 November 1897 – 13 July 1974) was an English experimental physicist known for his work on cloud chambers, cosmic rays, and paleomagnetism, winning the Nobel Prize for Physics in 1948.[4] He also made a major contribution in World War II advising on military strategy and developing operational research.

Patrick Blackett, ca. 1950

https://issuu.com/go-science/stacks/6fffc9d084dc4b45bd49bd11fde756c1

Recommendations summarised:

1. CNI operators to review and report on their reliance on GNSS. Cabinet Office to assess overall dependence of CNI on GNSS.

2. Add loss or compromise of GNSS-derived PNT to National Risk Assessment, not just as a dimension of space weather.

3. In allocating radio spectrum to new services and applications, address the risk of interference to GNSS-dependent users, including CNI.

4. Review the legality of the sale, ownership and use of devices and software to cause deliberate interference to GNSS receivers or signals.

5. Assess the need to monitor interference of GNSS at key sites such as ports and share the data with government

6. Employ GNSS-independent back-up systems.

7. Cross-government PNT Working Group to report to Cabinet Office on ways to improve national resilience.

Recommendations summarised:

8. Government to facilitate as those procuring GNSS equipment for CNI specify performance standards.

9. Map PNT testing facilities and explore how industry and critical services can better access them.

10. Leverage UK academic and industrial expertise in time and geo-location, increasing coordination among existing centres of excellence.

Mitigations by sector

Sector	Mitigations
Telecoms	The first line of defence is **resilient architecture** with diverse network routing to high stability atomic clocks in the core of the network and localised **holdover** at the edge. In the future multiple sources of time will be required for 4G/5G services. Back-up to GNSS would be a **terrestrial radio system**. If UTC traceability is required **time by fibre** could be considered at key locations.
Finance	The **multi-constellation receivers** used today experience common GNSS vulnerabilities, and their different UTC sources hamper traceability. **Holdover** devices provide mitigation, but errors increase with time. **Time by fibre** offers traceability to UTC. Some organisations are considering a **terrestrial radio system**.
Energy	As with telecoms, better **holdover** with atomic clocks is one option, along with GNSS based Precision Time Protocol (Chapter1). GNSS **integrity monitoring**, or a **terrestrial radio system** back-up, would improve timing resilience. National grid is also considering **time by fibre**.
Emergency Services	Emergency services would benefit from **multi-frequency and multi-constellation receivers** with backup navigation from **inertial navigation** and **terrestrial radio systems**. Emergency service operators' on-screen maps could allow manual shifting of vehicle positions.

Sector	Mitigations
Road	Research is underway to identify **signals of opportunity** with high positioning accuracy, independent of GNSS. **Composite or hybrid navigation** can be used in GNSS outage areas. An alternative, intelligent urban positioning, matches the shadows of buildings to 3D maps Interference can be mitigated using the same detection techniques as for aviation. **Terrestrial radio systems** have been successfully demonstrated on land.
Rail	**Space weather forecasting** will help mitigate ionospheric effects. GNSS positions can be validated using accelerometers, gyroscopes, odometers and trackside radio beacons. **Detection**, in the form of a dedicated trackside augmentation network, could pick up ionospheric anomalies and interference. **Terrestrial radio systems** have been successfully demonstrated.
Maritime	Ships must carry a GNSS-based electronic positioning/navigation system. The only back-ups may be visual navigation and radar. Harbour and coastal authorities are interested in **detection** of interference using local GNSS monitoring systems. At sea and in ports eLoran meets international standards.
Aviation	**Multi-frequency receivers**, improved **space weather forecasting** and **differential GNSS** using Extended GBAS would help mitigate ionospheric effects. A system of interference **detection** stations would mitigate interference and jamming. A **terrestrial radio system** back-up would maximise safety.

It is important to the UK Government therefore that an alternative to these satellite systems, which does not suffer from the same vulnerabilities, is established. Your letter and report notes that Enhanced Loran (eLoran), being a technologically dissimilar system, provides just such a resilient alternative to satellite systems. The UK Government is therefore supportive of any progress towards initiating and maintaining an operational eLoran network that can provide position, navigation and timing services and will lend support where appropriate to aid its establishment and continued use.

Cabinet Office

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Dr Ruth McKernan CBE
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(SENT VIA EMAIL)

17 July 2017

Dear Dr McKernan

Re. Publication of 'Economic impact to the UK of a disruption to GNSS' report

I write to thank you for your letter of the 28th June highlighting the recent study from Innovate UK and others into the economic impact to the UK of a disruption to Global Navigation and Satellite Systems (GNSS), available on the GOV.UK website here.

I share your interest and concern regarding this issue and thank you for pursuing this important work. As Minister with responsibility for the resilience of the UK's infrastructure, I am acutely aware that a disruption to satellite systems would affect the running of critical services. A broad range of sectors in the UK including the power grid, telecommunications networks, financial services, private and public transport including the maritime sector, emergency services and the military rely on this capability.

It is important to the UK Government therefore that an alternative to these satellite systems, which does not suffer from the same vulnerabilities, is established. Your letter and report notes that Enhanced Loran (eLoran), being a technologically dissimilar system, provides just such a resilient alternative to satellite systems. The UK Government is therefore supportive of any progress towards initiating and maintaining an operational eLoran network that can provide position, navigation and timing services and will lend support where appropriate to aid its establishment and continued use.

I understand that an in-depth UK Government review into the reliance of the UK's Critical National Infrastructure on satellite systems is due to be published shortly. This review will make an important contribution towards informing the UK Government's understanding of resilience to GNSS disruption.

I am copying this letter to the Government Chief Scientific Adviser and the Deputy National Security Adviser. A copy of this letter will also be published on the GOV.UK website.

Yours sincerely

Caroline Nokes

CAROLINE NOKES MP

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/677738/January_2018_Annex_B_-_MfGRE_to_Innovate_UK_re_eLoran__1___1_.pdf

So … what happens now (if anything)?

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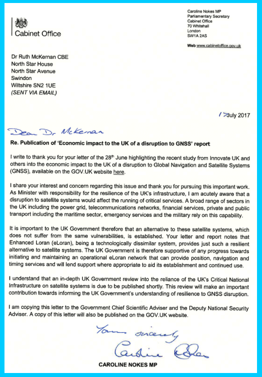

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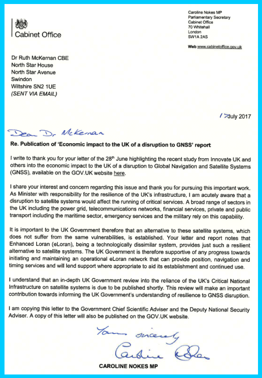

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Blackett Revue Implementation Group (BRIG)

- Reports to the National Security Council
- Chaired by Cabinet Office
- Senior policy advisers from government departments
- Meets at 6-week intervals
- Has already met twice
- Deals with the "How?" and the "Who?"

PNT Technical Group

- Technical input and policy advice for the BRIG
- Government, industry and academia

"There is a lot of commitment in the Cabinet Office to do things"

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