Office of the Government Chief Scientific Adviser, Sir Mark Walport

Ministerial Foreword:

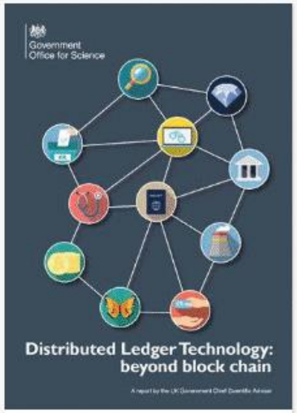
“This review represents a vital step in understanding the UK’s dependency on GNSS and recommends measures to improve our resilience. Importantly, it also recognises that innovation will be key to realising, fully and safely, the economic and societal benefits offered by GNSS.”

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).”

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.



Distributed ledger technology: beyond block chain

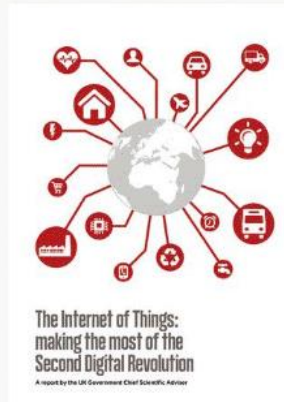
Government Office for Science

Review looking at the future of distributed ledger (or block chain) technology.

FinTech futures: the UK as a world leader in financial technologies

Government Office for Science

Review looking at the future of financial technologies (FinTech) up to 2025.



Internet of things: making the most of the second digital revolution

Government Office for Science

Review exploring how the UK can make best use of the internet of things.

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

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.

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.

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.