Assured Position Navigation and Timing

The approach to developing and implementing a UK PNT Strategy

Kevin McLoughlin
Head of Space Security and Resilience
UK Space Agency

The case for a new approach

- It was increasingly clear from UK and other nations studies that **PNT services were critical to our everyday life;** that **we had become critically dependent on them** and that this dependency was set to increase
- It was also clear that the resilience gap in this evolving environment was increasing exponentially as **threats continued to grow and proliferate and our access to diverse, robust and assured services was reducing**
- The overwhelming majority of users depend on GNSS – and in particular GPS – to provide PNT which is increasingly understood to be **a single point of failure for much of our national infrastructure and domestic way of life**
- The UK had a number of programmes under way including **UK GNSS, RETSI, MarRINav, RGNS and many S&T low TRL innovations**, but **no coherence or central coordination** for these initiatives

Mandate

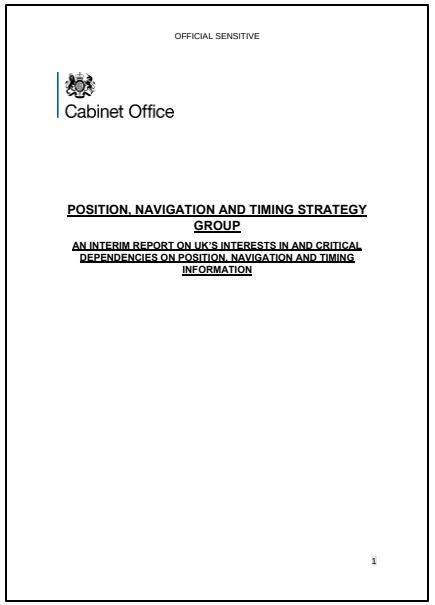
- In November 2019 the National Security Advisor Sir Mark Sedwill asked his then deputy, Madeleine Allessandri, to take ownership of PNT requirements for HMG
- DNSA authorised the convening of a PNT Sponsor Board (which she chairs) and a PNT Strategy Group to provide technical and strategic advice to the Sponsor Board, delivery programmes and OGD

PNT Strategy Group tasks

- Capability Audit – to **determine the UK vulnerabilities, risks and capability *requirements for P, N and T*** services focussing on CNI criticalities (which includes Defence) but also to include non CNI public use of the services.
- Capability analysis – to **determine the veracity and viability of potential solutions to meet the need across the spectrum of use cases** and taking account of the threats/hazards likely to need mitigation.
- PNT Strategy – set out the case for **a holistic, assured and resilient PNT solution including the range of available terrestrial and space based technologies**; focussing on space bases services conduct an assessment of the range of potential solutions that might address the requirement.
- And use these approaches to **work with potential providers to deliver a clear demand for PNT and assess the viability of technical proposals** , as part of the holistic PNT Strategy, in support of the Authority.

Phase 1 – The Interim PNT Report

- 80+ members of the PNT community, user representatives, industry and academia worked in specific groups to deliver:
  - Threats, hazards and risk assessments
  - Use cases, applications and criticality of dependency
  - Assessments of current and future technologies
  - Skills, Education and Training needs to deliver an assured solution
- The Interim Report was delivered in Apr 2020 with several findings and recommendations


OFFICIAL SENSITIVE

Cabinet Office

POSITION, NAVIGATION AND TIMING STRATEGY GROUP

AN INTERIM REPORT ON UK'S INTERESTS IN AND CRITICAL DEPENDENCIES ON POSITION, NAVIGATION AND TIMING INFORMATION

1

Key Findings

- **The UK is critically dependent on PNT** information – principally accessed through Global Navigation Satellite Systems (GNSS), and the US Global Positioning System (GPS) in particular. There is no UK PNT Strategy to manage and monitor the UK's dependencies.

- The UK has **requirements for assured PNT information around the world**.

- **Threats and Hazards** with the potential to disrupt the UK's access to PNT information **are increasingly diverse, prolific and capable.**

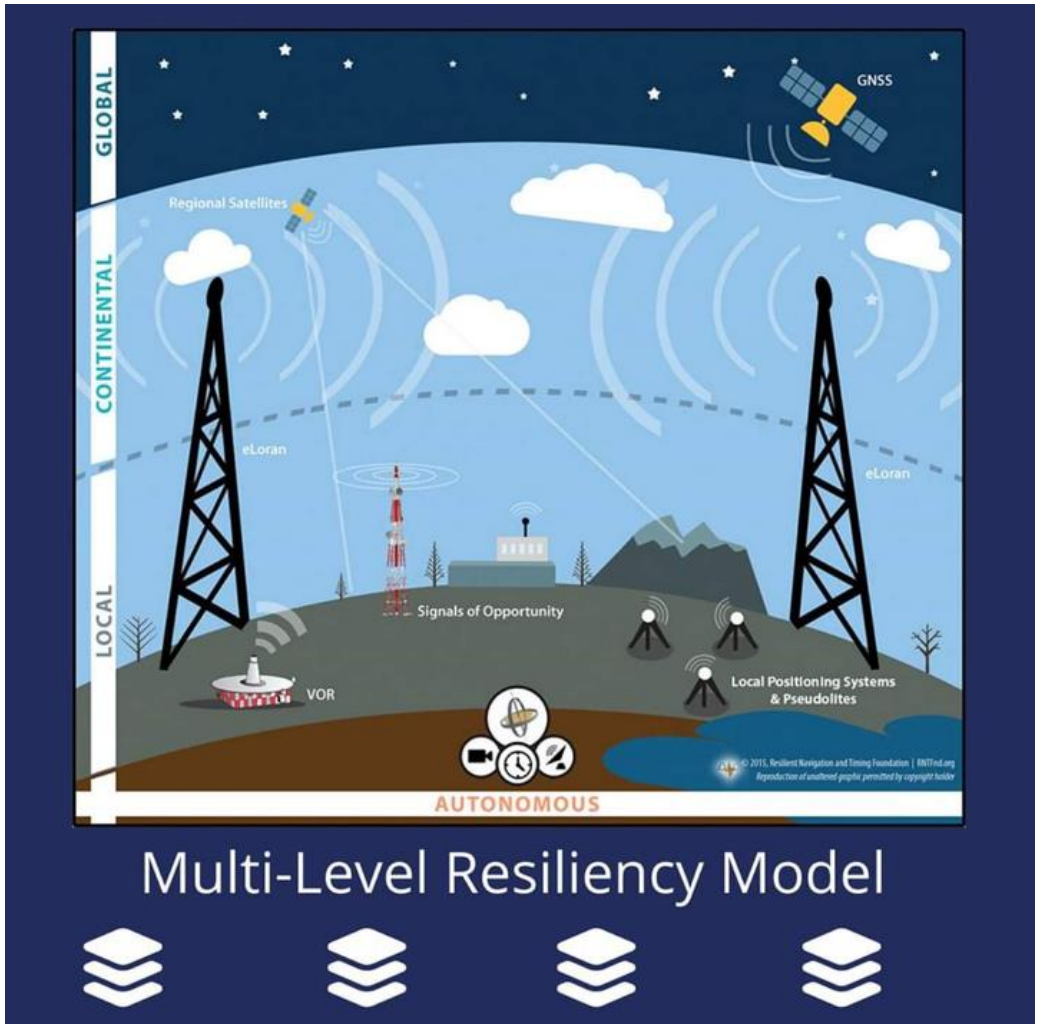
- **Solutions** to the UK's PNT requirements **must be diverse, adopting a 'system of systems' approach with a holistic mix of technologies (terrestrial and space-based)**. No single technology is likely to deliver enough resilience for critical users of PNT information.

- However, there is a **range of technologies available now or in development** which could meet some of the UK's near-term requirements for assured PNT.

- There **remains a low level of understanding about the dependencies on, and risks to, PNT in many UK sectors**. There is a risk that users are not aware of the vulnerabilities they have to disruption.

System of Systems Concept

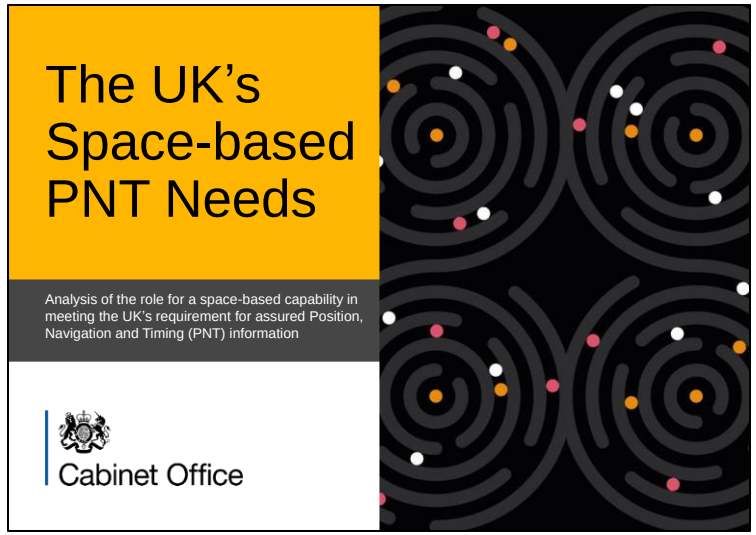
- A system of systems approach means developing a suite of different technologies that provide PNT information to users without single points of failure or common modes of failure.
- For example, the loss of the terrestrial communications networks should not lead to the loss of services for users as other technologies should work independently.
- **The space component can consist of a variety of diverse approaches making use of a variety of novel architecture approaches. It should form an integrated, mutually supporting system with the terrestrial component.**
- The system of systems needs to be underpinned by an assured timing source. The National Timing Centre (NTC) could provide this source, providing the national time scale into the terrestrial and space components.

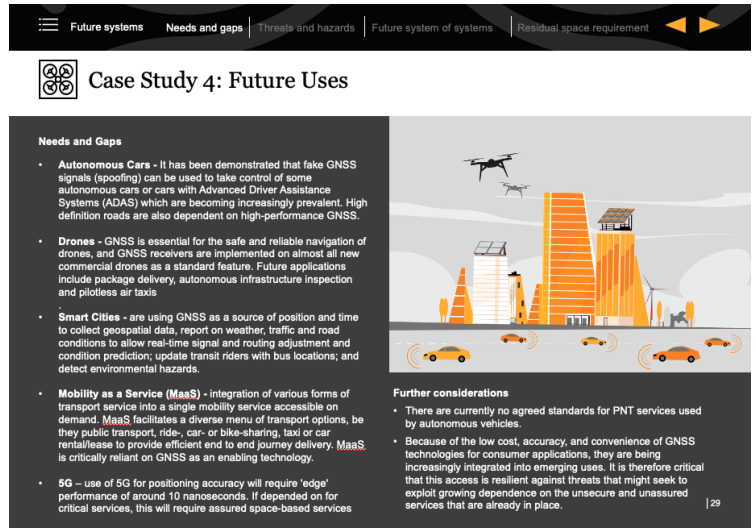


The graphic above illustrates the MaRINav programme's conceptualisation of a system of systems approach.

Subsequent work

- The Business Secretary then asked the PNT Strategy Group to focus our effort on the specific case for a space-based component to form part of the overall Assured PNT solution
- A further study, which made assumptions about the availability of terrestrial solutions to focus on the drivers for a space component reported in July 2020.





The Evidence

- Throughout these studies the Strategy Group has built a comprehensive evidence base of use cases and applications across all sectors
- This has been tested and validated by sector leads to determine the criticality of those use cases and the current and future mitigation plans should the primary source be lost or degraded
- A comprehensive set of Reasonable Worst Case Scenarios, based on threats and hazards, has been used as the handrail to understand the likelihood and impact (scale and duration) of realising these risks

Use Cases

Sector	Use Case	Description	2020 PACE				Resilience RAG Veracity of Backup 2020	Degree of dependence on space based PNT	2035 Future Tech PACE				Future RAG Resilience	Deduction
			Primary Source	Alternate Source	Contingency	Emergency			Primary	Alternate	Contingency	Emergency	Veracity of Backup (What Good could look like) 2035	So What? How to get from 2020 to 2035?
Maritime	Oceanic Voyage Phase	Ocean navigation is that phase in which a ship is beyond the continental shelf (200 m in depth), and more than 50 NM from land, in waters where position fixing by visual and/or radar reference to land or to fixed or floating aids to navigation is not practical or avilable. Ocean navigation is sufficiently far from land masses so that the hazards of shallow water and of collision are comparatively small, which also affords longer position fixing intervals.	GPS L1, compass, augmented by SBAS (EGNOS V2 in service from 2022)	Celestial (sextant) and Dead Reckoning (DR) by gyrocompass, speed log as well by manual estimation.	Inertial navigation, however, not for merchant but only mainly limited to naval vessels	Manual celestial, with visual and radar, if possible, close to land.	Yellow	Yellow	Multi Constellation, Multi-Frequency GNSS with SBAS and Maritime-RAIM or diverse space based PNT (SOOP etc)	Commercial PNT (eg orolia) from space and/or Terrestrial PNT (eLoran (limited to c.1,000 Nautical Miles)/SOOP etc)	Terrestrial PNT where able	Automatic, by electronic equipment using celestial means and sources. Database matching and mapping with saved/stored positions	Yellow	Resilience gap: - terrestrial/oceanic coverage for positioning applications (non-space) - Data fusion receivers for hybrid operation - Full maritime SBAS and maritime RAIM capabilities - Precision shipborne sensors such as INS, gravity and magnetometers sensor-mappir - Detailed, precise and dynamic gravity maps - Full multi-constellation GNSS receivers Requirement: - Resilient multi-source assured global positioning to <10m (95%) depending on geo-spatial application - higher precision resilient positioning in coastal and port operations phases (to <5m depending on application) - resilient positioning reporting and situational awareness - low drift/degradation sensor sytsems Options to address gap: - assured eLoran deployment for UK and overseas territories (c.f. GLA OT document) - hybrid multi-gnss and terrestrial receivers for improved resilience, (multi-positioning capable) - advanced sensor suites for improved dead reckoning - resilent electronic RF (radio frequency) satellite and terristrial systems-based comm for situational awareness/mapping
Maritime	Maritime: Maritime Autonomous Surface Ships (MASS) and Unmanned Surface Vessels (USV)	Early implementations will be manned, partially manned-automatic/autonoumous, and/or remotely monitored operation and control centres. Position Accuracy requirement is better than 5 m (95% probability rating). Compliance with existing international regulations, or equivalences thereto, would imply operations limited to coastal State jurisdictional areas (UNCLOS inland waters, baselines, 12 nautical mile territorial waters). Due to absence of human intervention, such systems are totally dependent on PNT	GPS L1 which at a later date may be integrated with Beacon DGNSS and/or SBAS, radar, lidar, sonar, and optical and IR cameras. Fused sensor solution including LIDAR relative positioning Remote	Visual and digital sensing and collision/allision avoidance - although in a very limited sense and close to coastal waters only. Remote optical sensing/ IR sensor/ HD cameras - although in			Red	Red	Multi Constellation, Multi-Frequency GNSS with SBAS and Maritime-RAIM.	Hybrid system-of-systems	Graceful degradation of performance using subset of the components of the hybrid system-of-systems	Dead Reckoning and visual bearings if possible Database matching using magnetometry and/or gravity (Viability of this is amber) in combination with current or future IMUs (e.g. MEMS, quantum) - onve	Yellow	- VDES/R-mode systems, maritime RAIM and maritime focussed SBAS - alternate space based (i.e. not a "me too" GNSS) for signal/frequency/resilience div redundancy with assured component - improved on [or off] board data processing systems Immediate investment assessment: - deployment of eLoran "like" system infrastructure for UK and OT and MF (medium frequency) like DGPS services - investigate international coorperation for a wider network - investment in improved on board sensing systems (INU's, gravity/magnetic sensing - investment in hybrid receivers - analysis/investment of alternate space-based approaches to deliver global assured - investigation into viability of VDES/R-Mode terrestrial systems

- Maritime Use Cases

Approach/Methodology

Step 1 – Identify the sectors and working groups

- The study focused on the 13 Critical National Infrastructure sectors and the risks and vulnerabilities to the primary and back-up sources to PNT in these sectors.
- Due to time constraints, the study focused on four CNI sectors – communications, transport, energy and defence – selected for their high degree of dependence on PNT information, interdependence with other sectors, and ability to provide an appropriate cross-section of potential risks and impacts applicable, broadly, to the other sectors

Step 2 – Define the assessment framework and conduct analysis

- The analysis drew on established methodology processes used elsewhere in government; notably the National Risk Assessment and Criticality Assessment methodologies used by CCS; the Capability Audit approach used by the MOD; and the PACE (primary, alternate, contingency, emergency) categorisation employed in communications and resilience planning.
- To assess the vulnerability of sectors, granular use cases were developed which could be mapped against current technologies and future technologies, and stress tested against Reasonable Worst-Case Scenarios (RWCS).

Step 3 – Independent deep dives on GNSS dependence

- The use cases were RAYG assessed according to their reliance on GNSS and the performance of the backups or holdover systems they had in place.
- Use cases were subsequently tested against five RWCS, encompassing key threat and hazard vectors as identified by SMEs in a series of workshops. This testing exposed core areas of risk where neither the primary source nor the backups and holdover systems were resilient to a selection of the most likely threats and hazards.

Key findings – Overall Resilience

125 use cases were investigated and findings were endorsed by subject matter experts across the UK

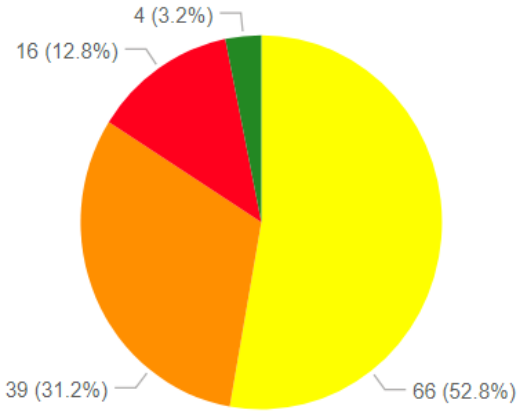
This analysis showed that there is inadequate resilience against PNT at this time. However, by employing a hybrid mix of technologies which includes a space based component that this risk can be considerably reduced.

This aligns with the current approach of the US, China, Russia, and the EU.

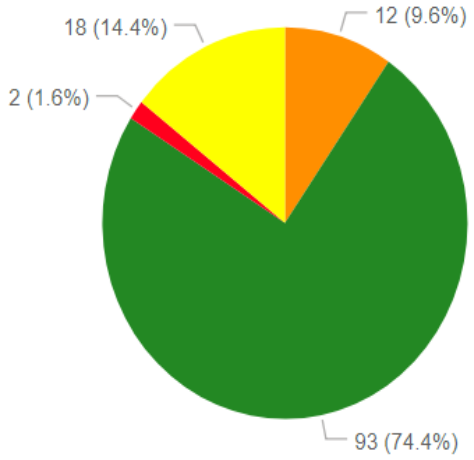
RAYG Score Definitions

- Green - Will continue to Meet the performance criteria without any significant impact to service delivery over time.
- Yellow - Meets the performance criteria without any initial impact to service delivery; however, degrades over time
- Amber - Meets the minimum performance criteria to deliver the service; however, will immediately impact on cost, efficiency.
- Red - Does not meet the performance criteria and thus unable to deliver the service.

Current Resilience RAG Values (2020)

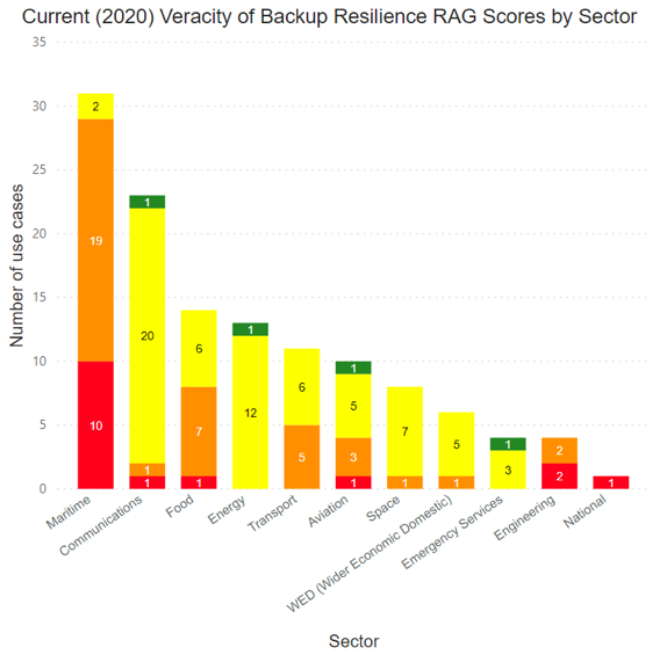


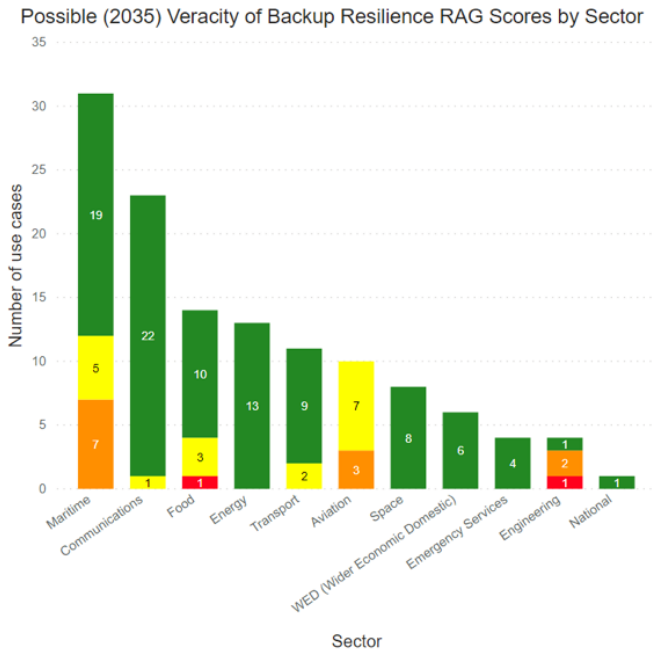
Possible Resilience RAG Values (2035)



Key findings – Breakdown by Sector

The chart below illustrate that application of a hybrid technology solution significantly reduces the risks across the various sector with Maritime, Aviation and Engineering needing further solutions to improve resilience.





RAYG Score Definitions

- Green - Will continue to Meet the performance criteria without any significant impact to service delivery over time.
- Yellow - Meets the performance criteria without any initial impact to service delivery; however, degrades over time
- Amber - Meets the minimum performance criteria to deliver the service; however, will immediately impact on cost, efficiency.
- Red - Does not meet the performance criteria and thus unable to deliver the service.

Key Conclusions

- **There is sufficiently strong evidence to demonstrate the need for a space component** to meet critical use cases in the sectors assessed which cannot be serviced adequately by a terrestrial component.
- The **resilience gap in this evolving environment is increasing exponentially** as the threats continue to grow and proliferate, there are increasing demands for ever higher performance standards and wider use of space enabled services generally.
- In order to address the needs of the user community, **continuing the analysis of innovative space and terrestrial technology solutions to inform a UK PNT Strategy would give decision makers the benefit of a wide range of delivery options.**
- **A system of systems approach**, combining the performance of multi-layered terrestrial and space components with the ability to deliver redundancy and diversity, **remains the only clear way to achieve an appropriate level of cross sector resilience.**
- The **degree of resilience required** and the ability of solutions to meet that, **varies by sector and use case**.

Phase 2

- Deliver the PNT Strategy by Dec 2020
- Deliver the endorsed UK Assured PNT Requirements by Dec 2020
- Develop a system of systems integration plan and a technology acceleration and insertion plan

Approach

- PNT Strategy Group teams:
  - PNT Strategy development
  - Requirements Definition (System of Systems)
  - Integration and Technical requirements
  - Skills, Education and Training
  - Legislation, Regulation and Standards
  - Threats, hazards and risks
- Working much more closely in this phase with HMG delivery programmes, industry and user community [Phase 1 maintained a ‘solution agnostic’ approach to use case evidence gathering]

End