



Quantum Technologies for Next-Generation PNT

Post-event report

Executive Summary

The Quantum Technologies for Next-Generation PNT workshop brought together key stakeholders from government, industry, academia, and defence communities to collaboratively identify priority use cases and technical requirements for quantum-enabled Positioning, Navigation, and Timing (PNT). Convened by the Quantum Enabled PNT (QEPNT) Hub in partnership with the Royal Institute of Navigation, this event represented a starting point in the Hub's mission to engage with industry to accelerate the realisation of real-world quantum PNT capabilities.

This meeting directly supported the UK's strategic focus to strengthen PNT resilience, particularly in the face of rapidly growing vulnerabilities associated with Global Navigation Satellite Systems (GNSS) and aligns closely with Quantum Mission 4 which targets PNT.

Key Outcomes:

- **Identified and prioritised** sector-specific quantum PNT use cases across land, sea, air, space and infrastructure domains, for defence and civil use, organised into clear short-, medium-, and long-term development horizons.
- **Confirmed** immediate priorities, emphasising robust quantum-enhanced timing solutions and practical demonstrations of GNSS-independent navigation for sea and air.
- **Highlighted** medium-term commercial and operational opportunities, particularly quantum inertial sensors for rail systems, the role of QPNT in autonomous platform, and logistics management use cases.
- **Articulated** a long-term strategic vision encompassing hybrid quantum-classical navigation systems with the SWaP-C characteristics required for general adoption, next-generation space-deployed quantum clocks, and distributed quantum sensing capabilities for environmental monitoring, civil security and defence.

- **Recognised** shared enabling challenges across domains and sensor technologies, including significant advances required in SWaP-C performance, interoperability and integrability within existing systems-of-systems, accelerated standards development to strengthen UK competitiveness, completion of sovereign supply chains, growth of a quantum-ready workforce, and expanded of operational testbeds for test, validation and assurance.

Next Steps

The domain coverage and breadth of stakeholder representation in this workshop has yielded a uniquely comprehensive look into use cases, linked to technical, commercial and strategic drivers. These outputs will directly shape the QEPNT Hub's forward programme, including towards the development of industry-facing guidance material. It has also revealed the most prioritised use cases and key enablers, for which the QEPNT Hub will be convening special interest groups starting this year across the land, air and sea domains with a view to developing technical roadmaps in these areas, as well as understanding the likelihood of each use case highlighted below becoming a reality, and the quantum advantage each would present.



Context and Purpose

Resilient Positioning, Navigation, and Timing (PNT) capabilities underpin essential operations across the UK. These span critical national infrastructure, transport systems, defence and civil security, the financial sector, and many other aspects of the economy at large. Today, the overwhelming reliance on Global Navigation Satellite Systems (GNSS), such as GPS, exposes critical UK systems to potential disruption from interference, jamming and spoofing – it has become a common, widespread, vulnerability. Quantum technologies offer the potential to significantly mitigate these risks, providing resilient, GNSS-independent, timing and navigation solutions. Not only may these reduce vulnerabilities and thus protect against both the associated societal and economic risks, but also enable new capabilities with strong strategic and commercial drivers.

The UK has identified quantum-enabled PNT as a national priority through Quantum Mission 4, establishing clear targets to build national capability and resilience in response to GNSS vulnerabilities. To tackle this Mission, The UK Hub for Quantum Enabled Position, Navigation, and Timing (QEPNT), funded through Phase III of the UK's National Quantum Technologies Programme, has been set up. Its vision is to deliver quantum technology that will create practical systems for resilient position, navigation & timing (PNT) applications. QEPNT is building up the UK community & ecosystem for quantum-enabled PNT by bringing together experts from academia, industry & Government agencies to deliver the technologies required for national security, critical national infrastructure, aerospace, connected & autonomous vehicles (CAVs), maritime & energy applications.

Jointly organised by the QEPNT Hub and the Royal Institute of Navigation, this workshop aimed to introduce the QEPNT's goals and workstreams to senior PNT industry stakeholders from government, industry, academia, and defence. Leveraging the collective expertise of the attending stakeholders, afternoon workshop sessions identified and validated quantum PNT use cases across key operational sectors and defined the enabling conditions necessary for their successful adoption.

Session 1: Priority Use Cases

The first workshop session analysed priority use cases for quantum-enabled PNT. Participants collaboratively identified and prioritised quantum-enabled PNT use cases, structured across sector domains such as Land, Air, Sea, Space, CNI, and high-dependency sectors such as finance and energy. These use cases were also aligned to short-, medium-, and long-term development horizons, characterising both the technical challenge and the maturity of the need and the commercial opportunity. The session revealed new PNT use cases and brought additional clarity to known ones by better capturing their drivers as well as wider gaps.



Short-term (1–3 years):

A clear immediate priority was retrofittable quantum-enhanced clocks to strengthen resilience of critical national infrastructure, support timestamping and synchronisation for the financial sector, support terrestrial PNT signal broadcast, enable tight synchronisation of radar arrays including to support air traffic control in congested environments, and in general reduce reliance on GPS time. Early quantum optical clocks are already commercially available, targeting the high-end caesium reference market, with gaps mainly around assurance of these devices to enable procurement.

Alongside timing-focused use cases, participants highlighted near-term opportunities around improvements to integrity of navigation for civil aviation, quantum illumination for search and rescue, agriculture and logistics tracking, and sub-sea maritime use cases where GNSS is necessarily unavailable such as seabed infrastructure inspections.

Medium-term (3–7 years):

Discussions emphasised broader adoption of quantum inertial navigation systems (INS) as an enabler for PNT resilience in this timeframe, particularly within the rail sector, urban transportation and logistics networks, where position certainty is important to capacity management and signalling limits utilisation. Autonomy was identified as a major driver; autonomous systems require high levels of PNT integrity, resilience and performance, combined with robust communication links for teaming and command, which points to a demand for integrated quantum timing, sensing and navigation capabilities.

Participants noted that while the operational need for GNSS-resilient navigation exists today, realising these use cases will require more mature, fully integrated systems. Deployment will be influenced by integration challenges, assurance requirements, and sector-specific regulation, with high-value platforms expected to see early uptake ahead of cost reductions necessary for wider adoption. It was also acknowledged that this is a competitive domain, and in environments where signals are available (i.e. not sub-surface or subterranean), alternative solutions such as eLoran and LEO-based PNT will present strong options.

Lastly, the integration of quantum-enhanced LiDAR for navigation and mapping in complex and feature poor environments, such as urban canyons, underground, or underwater, was recognised as a realistic capability development in this timeframe. There were clear advantages in using single-photon LiDAR over its classical counterpart noted, mainly in the ability to resolve features more precisely, the potential for accurate imaging through obscurants, and greater distances at which systems could be used. Initial deployment will likely be areas such as the marine sector for pipeline inspection and ocean floor mapping before miniaturised systems can be realised and used in consumer products, such as CAVs.



Long-term (7+ years):

Long-term opportunities focused on transformational capabilities enabled by fully mature quantum PNT systems. Chief among these was the deployment of hybrid quantum-classical navigation systems capable of providing persistent, high-integrity, and very-high accuracy positioning in all environments – independent of external signals. Equally significant was the expectation of far lower SWaP-C systems, enabling integration into mass-market platforms and supporting wider utilisation, with quantum PNT becoming an embedded feature of mainstream infrastructure and platforms.

Participants also emphasised the potential from advances in networked and synchronised sensors, including entangled sensor arrays which might represent the next leading edge in performance. Space-qualified quantum sensors were also seen to reach maturity in this timeframe, with the demand for high-performance low-SWaP space-based clocks driving those systems forward first. This would impact space-based mapping and monitoring, next-generation space-based PNT, and space situational awareness.

Together, this session defined priority applications, their drivers, and the conditions under which quantum PNT can deliver operational, commercial and strategic value. Detailed listings of all identified use cases, categorised by sector and horizon, are provided in **Annex A**.

Session 2: Technical Requirements

The second workshop session explored the enabling conditions necessary for quantum PNT technologies to achieve operational deployment at scale. Discussions focused on the practical constraints, integration challenges, and systemic considerations that are shaping the transition from laboratory systems to real-world products. Five cross-cutting requirement areas emerged, each necessary to ensuring quantum PNT solutions are operationally effective and commercially viable.

Size, Weight, Power, and Cost (SWaP-C):

Participants identified SWaP-C as the most significant technical constraint across platforms. Whilst large platforms, such as fixed infrastructure or naval vessels, can accommodate rack-sized systems with bespoke integration requirements, smaller mobile platforms demand compact, low-power designs that conform to stricter platform design constraints. Cost is a defining factor, with quantum components and sub-system assemblies (laser, photonics, vacuum, etc.) having high base-line costs and not yet benefiting from economies of scale. There is also a significant engineering and assembly cost to systems, which will be reduced through more integrated designs. Achieving reductions in physical footprint and cost is essential for adoption beyond specialist platforms.



Scalability and Supply Chains:

Establishing a robust and sovereign supply chain was highlighted as a prerequisite for both strategic resilience and industrial scale-up. The current reliance on specialist, low volume, component manufacturing presents a bottleneck for production. Developing scalable manufacturing processes for key components, standardising designs across applications where possible, and creating a stable domestic supply of critical materials and components were seen as essential steps toward ensuring strategic capability.

Interoperability and Standards:

Participants stressed the importance of common technical standards and interfaces to facilitate integration into existing systems-of-systems. Defence and aerospace platforms will require NATO-compatible solutions, while transport and infrastructure applications will depend on adherence to civil certification regimes. These standards may need updating to be compatible with, or specify requirements for, quantum systems. There is also a need to mature new quantum standards, which includes a sovereign commercial imperative to ensure the voice of UK industry is well represented in standards development.

Technical Requirements:

The session underscored that technical performance is not defined by accuracy alone, availability, continuity, and integrity are equally important. These parameters are not the development focus of most current systems and need to be matured alongside accuracy (or stability). They may influence fundamental technical design decisions, and significant engineering and test effort is required to measure and understand these, which will be necessary for system assurance and procurement readiness. New systems will also place a burden on the complementary system-of-systems into which they integrate, and particular attention is needed on sensor and data fusion.

Quantum Systems Engineering:

Ease of deployment, maintenance, and operation emerged as essential non-performance attributes for systems. Participants emphasised the importance of line-replaceable components, minimal user intervention, and system resilience to environmental factors. For military users, solutions should offer functionally familiar behaviour, delivering enhanced capability without increasing operator burden or complexity. Long life cycles, typically 20–25 years in infrastructure and aerospace, will demand extensible designs that can accommodate incremental technology upgrades and that are realistically maintainable over the service life. Advances in Quantum Systems Engineering are needed to deliver integrable, certifiable products with repeatable performance that meet assurance and lifecycle requirements.



Collectively, these discussions reinforced that technical innovation alone will not deliver operational and commercial impact. Progress across multiple areas, including SWaP-C, supply chain resilience, standards development, and quantum systems engineering, is essential to realise the full potential of quantum-enabled PNT, ensuring trusted, interoperable, and scalable solutions that deliver significant capability enhancements across the breadth of use cases identified.

Next Steps:

Community events:

Both QEPNT Hub and RIN will be hosting several events to support the drive towards the commercialisation of quantum PNT. Upcoming events include:

- **Quantum Technology for Innovation in Automotive Electronics**, jointly hosted by QEPNT and the Automotive Electronic Systems Innovation Network (AESIN) to explore Quantum PNT in the automotive industry.
 - 18th September, ZF Automotive UK Solihull. Register here: <https://www.ticketsource.co.uk/quantic/t-krkqlqx>
- **Quantum PNT: the Benefits and Business Case**, a one-day conference hosted by RIN connecting quantum developers with business leaders and decision makers in the PNT sector.
 - 23rd September, Institute of Physics, London. Register here: <https://rin.org.uk/events/eventdetails.aspx?id=1962092>

If you would like to be kept up to date about all QEPNT events, please sign up to our mailing list at <https://qepnt.org/signup/>.

Roadmapping and technical engagement:

Following on from this event, QEPNT will convene a series of special interest groups beginning in late 2025/early 2026. Initial focuses will be on developing technical roadmaps for land, air, and sea-based PNT technologies, aligned with QEPNT's program of work, with a view to expand to other key sectors, including space, communications, energy, and critical national infrastructure. Please contact Steffan.Gwyn@Glasgow.ac.uk if you are interested in contributing to our SIGs and technical roadmapping activities.

Additionally, QEPNT Hub are planning to deploy technologies on a variety of platforms in field trials, to support the acceleration of the development of these technologies into commercial products.



Skills, training, and outreach:

There are several opportunities to engage with QEPNT Hub around the development of the talent pipeline in quantum technology. This includes collaborative PhD studentships across the Hub's programme of work, and we are currently drafting projects for students starting in Autumn 2026. The Hub also has a secondment scheme, and can support mobility between the Hub and external organisations for a short period of time to exchange knowledge and develop collaborations between research groups and industry and government. For more information or to express interest in this, please contact Steffan Gwyn.



Annex A: Priority Use Case Tables

Land		
Short	Medium	Long
Logistics Management	Single-photon LiDAR with CAVs	Hybrid quantum-classical INS
Battlefield navigation and situational awareness	Quantum Inertial Sensors for rail sector	Consumer vehicles with GNSS denial mitigation systems
First/last mile logistics	LiDAR for Urban Canyons/indoor	Positioning of underground public transport
Food – logistics support	OPM Biosensing	Smart vehicles/associated management
Animal herding/tracking	Mobility-as-a-service	Disaster response – asset/people identification and tracking
	Rail signalling – local positioning	Synchronised timing across transport network
	Smart cities	
	Vehicle-to-X	
	Infrastructure monitoring	
	Underground navigation	

Air		
Short	Medium	Long
Bounding integrity for airport approaches	Hybrid systems for GNSS denied aircraft	Assured PNT for GNSS denied UAVs
Jamming mitigation	Baggage handling vehicles in fog	Formation flying for drones/air force
Enhanced access to remote airfields	Future air defence systems	Future ATC – asset tracking
Remote deliveries	Drone detection around airfields	Quantum radar/distributed timing
Find/fix/track/target/assess	Incoming missile detection at long distance	Next-generation fighter jets
Resilient navigation		
Defence-based drone systems		



Sea		
Short	Medium	Long
Collision avoidance	Commercial Quantum Inertial Sensors	Low-SWaP-C navigation systems
Inspection of pipelines	Timing for Submarines	UUV constellations
Water quality monitoring	Passive interrogation of cargo	Bathymetry
Resilient Ship-Shore communications	Untethered underwater drones at a distance	Merchant ship navigation using crowdsourced maps
Surveying using remote platforms	Beyond-line-of-sight-communications	
Tethered underwater drones	Underwater object identification/inspection	
Map Matching	Geofencing	
Quantum Illumination for search & rescue		
Oil & Gas exploration		
Environmental monitoring		

Other		
Short	Medium	Long
Clocks for satellite-based augmentation systems	Satellite attitude control	Space weather monitoring
Space-qualified clocks at low SWaP-C and high performance	Space-deployed clocks for next generation GNSS	Radiation monitoring in space
LiDAR for Space-to-Space comms	LiDAR for robotics	Unified global environmental sensing
Agricultural monitoring	National Grid resilience	Consumer devices
Financial transaction timing synchronisation	GPS timing distribution using fibre networks	Cyber system synchronisation
	Earthquake monitoring	Predicting natural disasters
Resilience and future-proofing of telecoms	Animal/crop health monitoring	
Power grid synchronisation		

