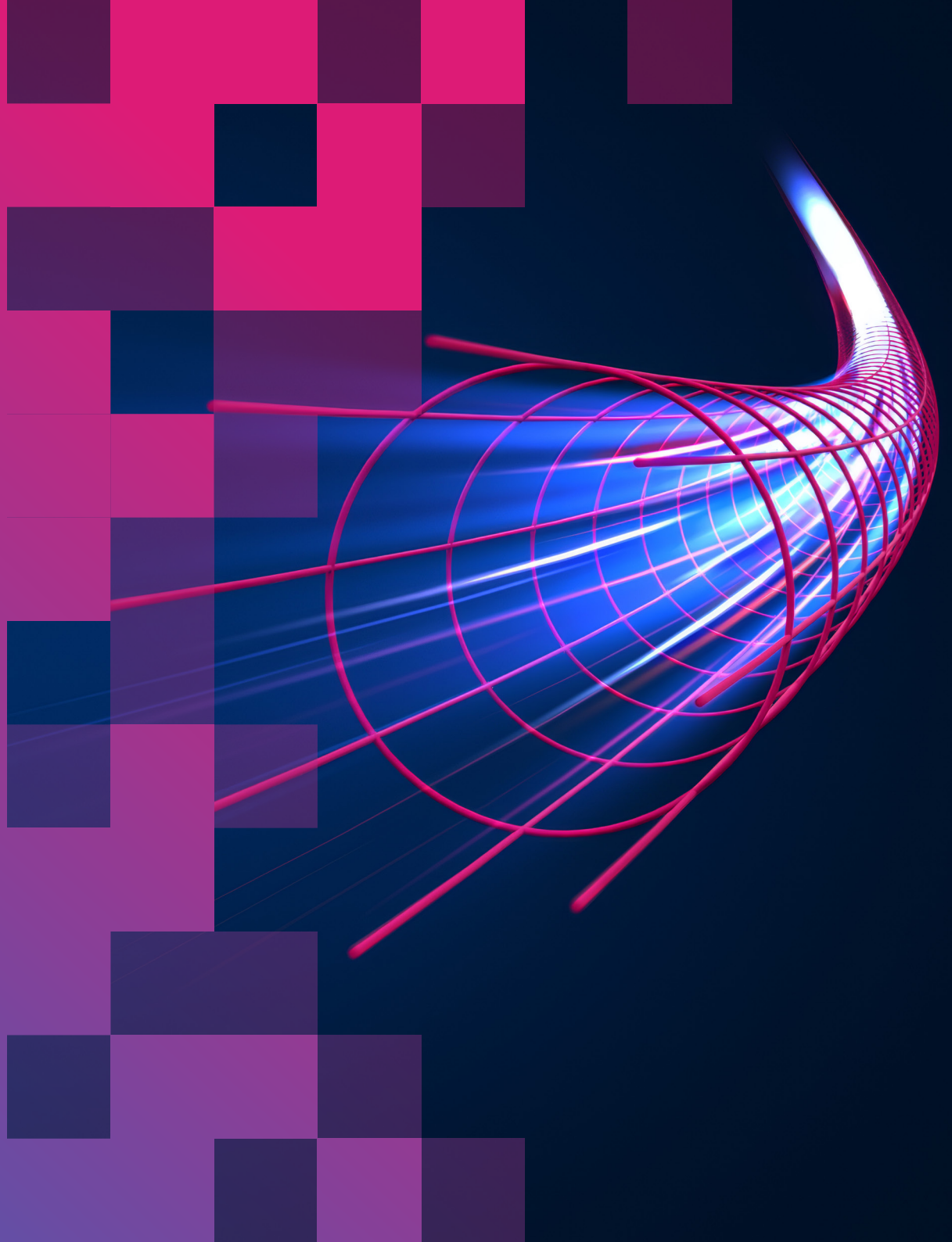
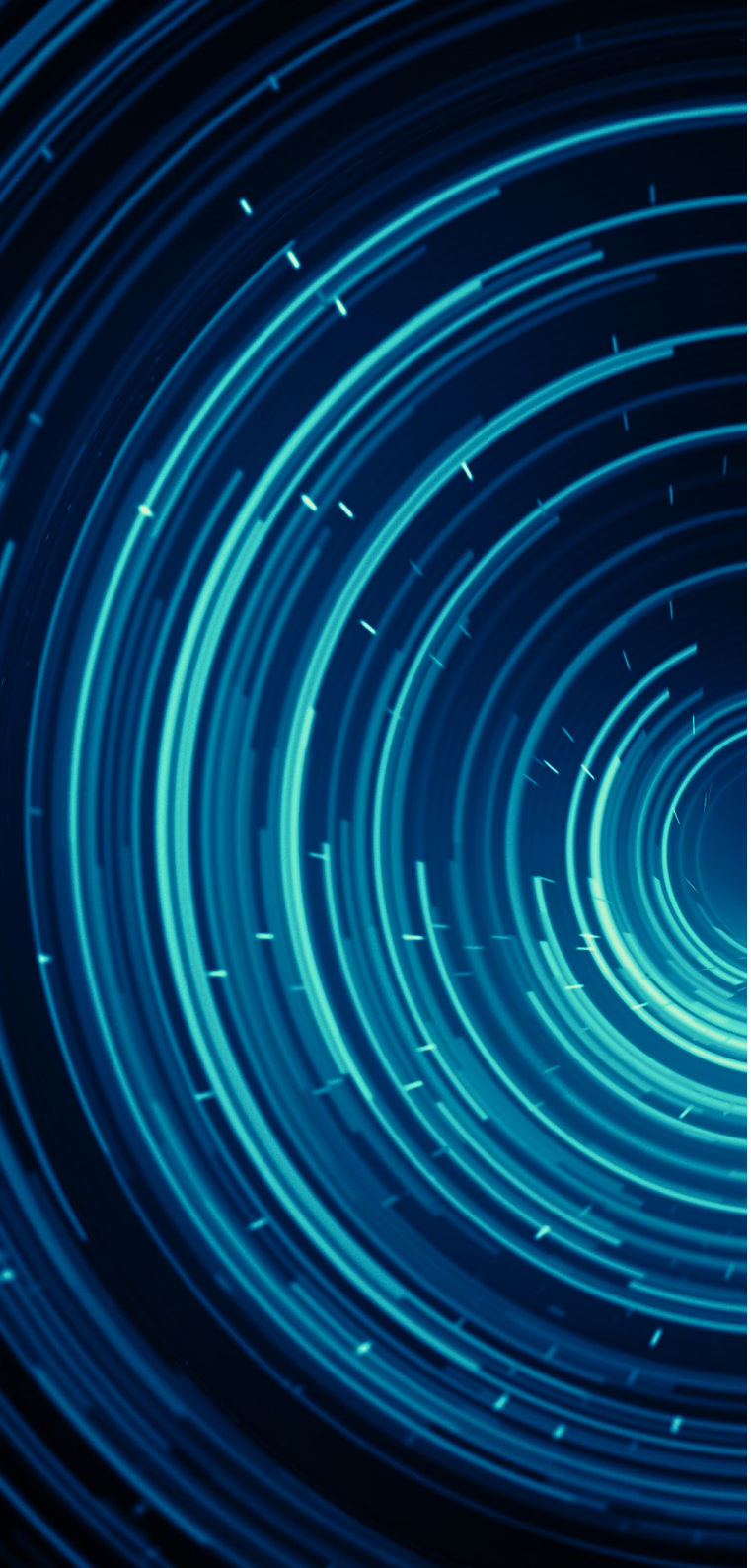
NPL
National Physical Laboratory

National Timing Centre

A UKRI-funded R&D programme 2019 – 2025

End of programme report





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Foreword

Over the past six years, the National Physical Laboratory (NPL) and key partners have been working hard on the National Timing Centre (NTC) programme.

Its aim is to create a resilient timing infrastructure that will reduce the UK's reliance on Global Navigation Satellite Systems (GNSS), providing confidence to all sectors – from banks to energy grids – which rely on stable, accurate timing signals.

In March 2025, the research and development (R&D) phase of the programme concluded, having delivered its key goals. Principally, this has involved designing and testing a world-first secure and resilient time scale – known as the Resilient Enhanced Time Scale Infrastructure, or RETSI – across two geographically distributed sites.

The design is for a four-site RETSI. As part of the R&D phase of the programme, NPL has built and linked two sites and tested the highest-risk aspects of the technology and design, derisking full design implementation across the future sites. As it has developed, the programme has supported timing innovators and created training opportunities.

Plans for a five-year follow-on programme are being developed, as of April 2025, to complete the work to deliver a resilient national time scale. NPL has been working closely with government to develop a longer-term programme, designed to meet the Positioning, Navigation and Timing (PNT) framework through fully implementing RETSI, including further onward distribution and ensuring a UK supply chain can be developed in line with the framework.

This report starts by looking at what the NTC is and the value of resilient national timing to industry, government, and UK innovators, providing a summary of the programme's value and reason for being (Part 1).

It then provides a summary of what has been achieved to date, during the R&D phase, covering the three core objectives of the R&D programme: resilience, innovation and skills (Part 2). This looks at the development of RETSI and covers the establishment of three Time and Frequency Innovation Nodes at the University of Strathclyde, Cranfield University and the University of Surrey, which support UK innovation through the dissemination of UTC(NPL) traceable timing signals to innovators. It also outlines the training and skills programmes the NTC has developed to raise the UK's timing expertise.

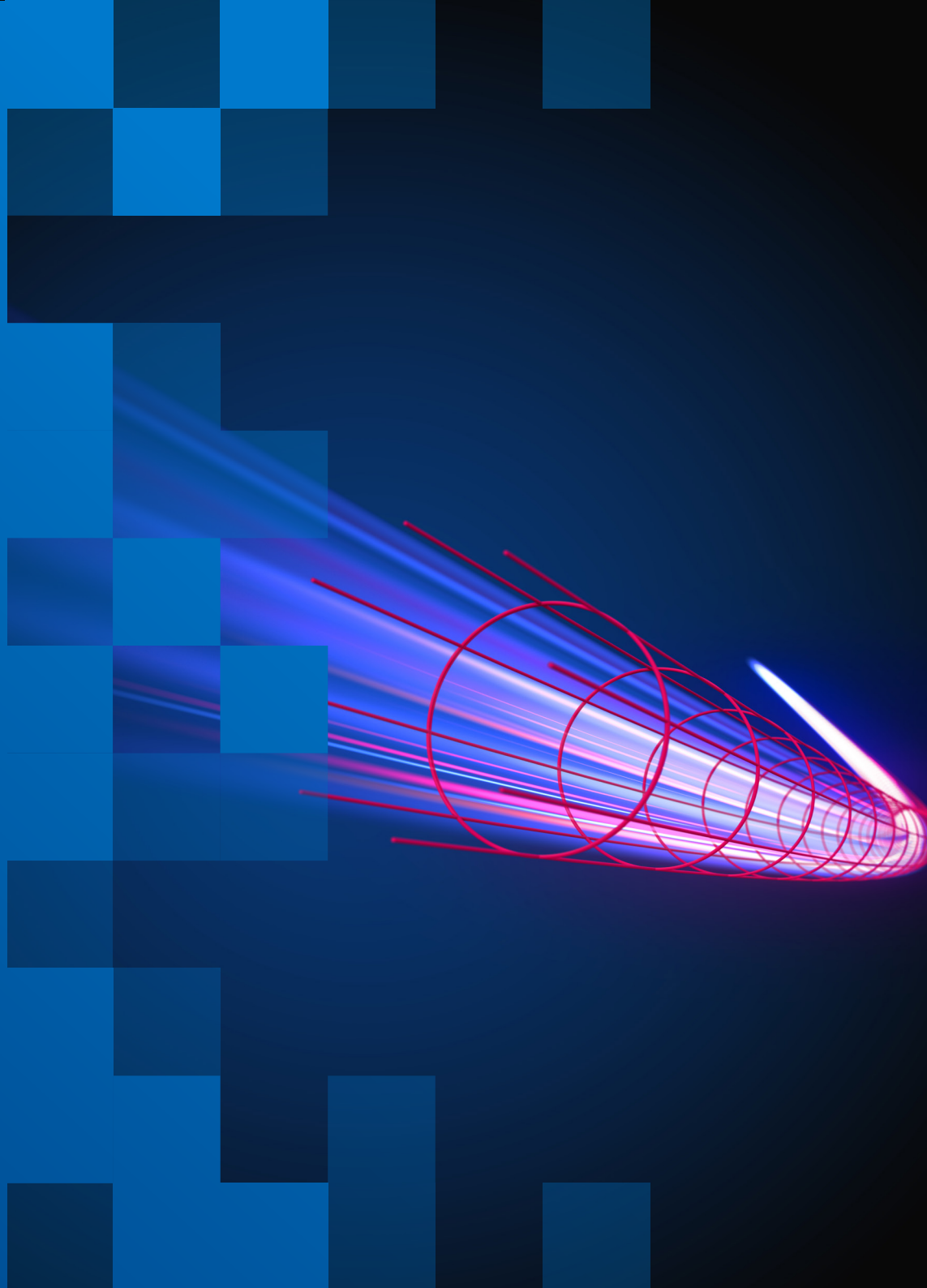
Finally, the report considers the wider benefit the NTC programme is delivering for timing in the UK, helping inform government policy, boost business, and demonstrate UK leadership, through supply chain development and engagement with the UK government, industry, academia, and the public at large (Part 3).

Acknowledgements

We would like to sincerely thank the Department of Science, Innovation and Technology (DSIT), Innovate UK, Ministry of Defence (MoD) and GCHQ for their valued support and partnership throughout the National Timing Centre (NTC) R&D programme.

Introduction:

Why timing matters



Why timing matters

Although few notice it, the modern world runs to time with incredible precision. Thousands of financial trades are executed every second, which must be timestamped to the microsecond – and accurate to within 100 microseconds (better for high frequency trading) – so they can be audited with accuracy. The quality of mobile video calls requires networks to accurately timestamp every data packet, to ensure integrity as they move between networks and countries. Electrical grids need detailed timing data on their phase and power to detect faults and reroute around them – with risks of blackouts and damage to equipment if things go wrong. The list goes on.

New technologies such as 5G and autonomous vehicles will mean the UK economy is ever more reliant on timing signals.

Organisations use external time signals – which are traceable to UTC (Coordinated Universal Time), the internationally agreed time standard – to continuously sync their own internal clocks. This is critical not just for their own timekeeping, but to ensure diverse networks of organisations and assets are all using the same time scale, to provide synchronisation, and clarity with regard to sequence and causality.

These time signals originate in terrestrial time scale laboratories and are then disseminated via the satellite constellations of GNSS; however, these satellites are vulnerable to disruption from solar storms, jamming and spoofing, and the UK has no direct control over these signals. Any failure in GNSS would jeopardise critical systems and could impact the UK economy by over £1 billion per day[1].

Ground-based atomic clocks do not face these risks and therefore offer greater security. The UK's time scale, UTC(NPL), is managed and disseminated by NPL, which maintains a suite of highly stable atomic clocks that are constantly compared with other clocks in the global UTC network. The time scale is disseminated via radio signals (MSF transmission) from the Anthorn Radio Station in Cumbria, over the internet using Network Time Protocol (NTP), and directly to industry over fibre-optic networks – via a service called **NPL**Time®.

This risk of timing signal failure has long been recognised and has become more pressing in recent years. The 2020 National Risk Register[2] noted that a severe space weather event could compromise many technologies for days or weeks and encouraged businesses to engage with the NTC to boost resilience. Since then, the need for resilience has only grown. There has been an increase in our reliance on digital communications, which rely on time and synchronisation. Then came the escalation of conflicts in Ukraine and the Middle East, and with them an increase in jamming and spoofing of GNSS signals – in late 2024, 1,500 flights per day were spoofed, according to an OPSGroup report[3]. As of 2023, PNT has been identified as a standalone risk in the UK Risk Register[4]. These have all further highlighted the need for a National Timing Centre.

The UK Government – past and present – has recognised the importance of timing and risks of GNSS reliance. In 2023, the previous government published a Framework for Greater Position, Navigation and Timing Resilience, which the new government has recommitted to. This is a 10-point plan for timing resilience in the UK, including establishing a National Positioning, Navigation and Timing Office, developing a PNT crisis plan, and a variety of measures to develop and deploy resilient timing technologies.

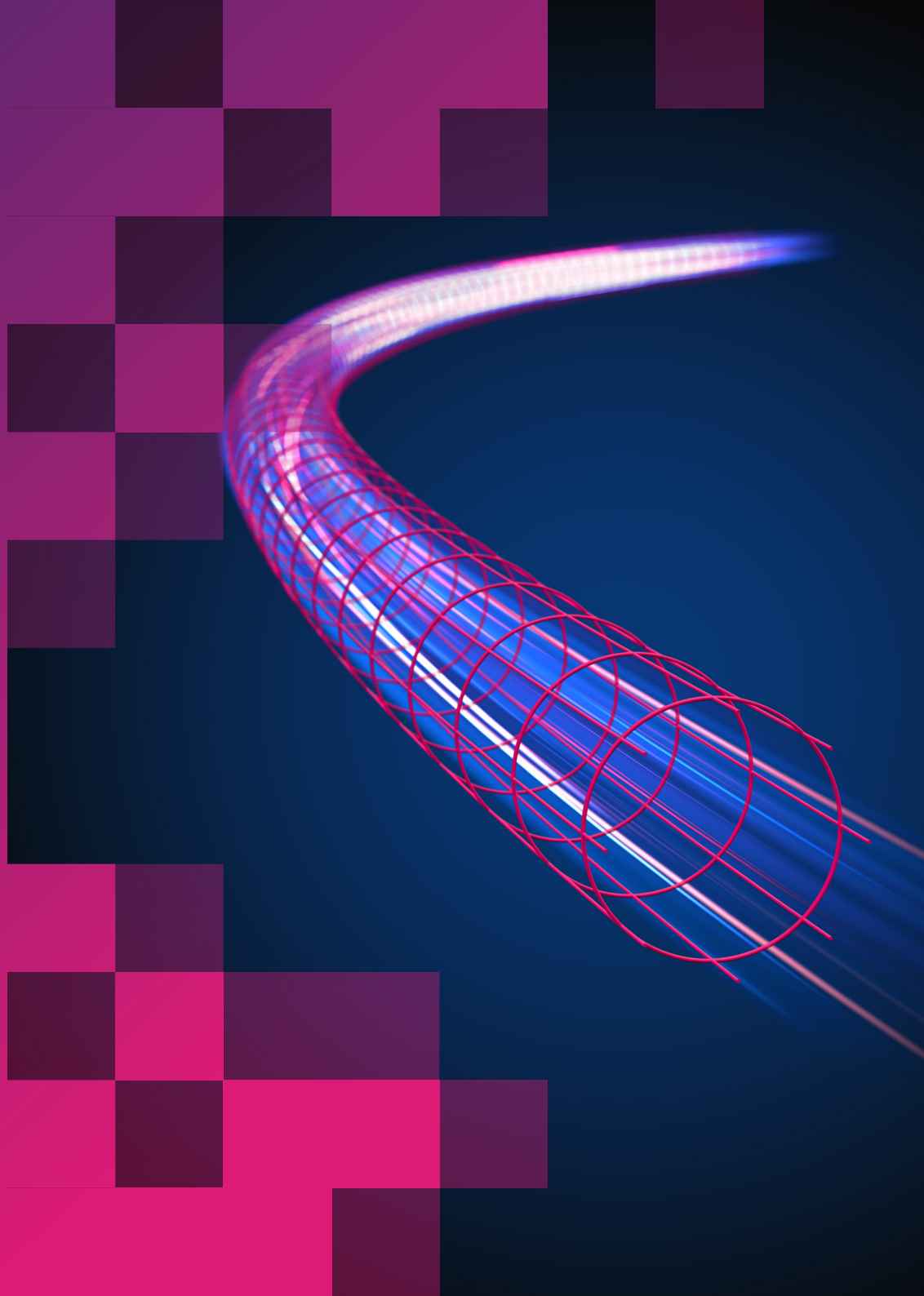
A key strand of the framework was establishing the National Timing Centre and investing £62.7m to March 2025 in funding its R&D phase – announced in 2020 and led by NPL. Continued support for the NTC is a key tenet of the framework, and the NTC will play a role in informing policy and supporting all other elements within it.

The NTC programme aims to develop sovereign, resilient, terrestrial and high-quality timing for the UK. As it does so, it will support timing innovation and skills across the UK to develop secure time dissemination technologies and maintain and strengthen the UK as a global leader in timing.

In this report we will discuss the NTC's value to the UK, and what has been achieved in the R&D phase.

Part 1:

The NTC programme – aims and benefits



Programme goals

In this section we lay out the three goals of the NTC, set at the start of the programme. These goals continue to guide our work across the programme:

① Resilience

The first goal of the programme is to design and implement a new geographically distributed UK time scale, which will provide industry with a robust alternative to GNSS for timing signals, and multi-site resilience should one site fail. Time should ultimately become a utility – like power or water – delivered where it is needed on demand. This 'future-proof' timing ecosystem will support existing industries, as well as emerging technologies identified in the Industrial Strategy, such as autonomous vehicles, smart cities, and quantum.

Ultimately, the NTC aims to create a next-generation time scale that could one day support GNSS as a primary source of time with an assured, sovereign time signal.

② Innovation

Reliable timing signals are critical for boosting UK innovation in advanced timing technologies for industries such as quantum computing and 5G. Indeed, the timing network itself will depend on a robust supply chain of time and frequency technologies. Right now some are in short supply, making national timing infrastructure over-reliant on a small group of suppliers, not all of which are in countries with favourable export policies.

So, the second goal of the programme is to establish and scale homegrown timing and frequency innovation, create a UK supply chain that supports timing and the sectors that rely on it, and attract timing innovators to the UK.

This will be achieved by creating three Time and Frequency Innovation Nodes based at university hubs, providing UK timing innovators with access to state-of-the-art infrastructure, trusted time signals, and expertise – enabling startups and researchers to develop, test, and scale new time-dependent technologies with confidence.

③ Skills

The network will need access to skills to maintain and update it, and to work at its new supply chain companies. Therefore, the third NTC goal is to nurture timing and frequency skills across the UK by providing training and creating new jobs, ensuring we have the skills to support the new atomic clock network, and the innovators who hope to benefit from it.

Who benefits from the NTC?

A resilient sovereign, ground-based time signal would improve the efficiency of digital systems, boost resilience, cut costs, strengthen audit and authentication, and unlock innovation – supporting industries, innovators and the UK economy.

Industry

A wide range of industries rely on resilient time signals and would suffer financial and security consequences if those signals were lost.

Finance

Banks rely on time stamps for trade. Loss of accurate time signals could require them to pause trading or receive fines for regulatory noncompliance.

Telecommunications

The importance of time for synchronisation grew with 4G and is even more important for 5G and 6G networks. Ultra-precise and resilient timing is essential for synchronising dense 5G cell deployments, reducing latency, and maintaining seamless data transmission across networks.

Energy

Power grids rely on accurate time signals to synchronise sensors and switch operations across vast networks, ensuring grid stability, fault detection, and efficient energy distribution.

Maritime

Ships and ports depend on precise timing for navigation, collision avoidance, and secure communication between onboard systems and coastal infrastructure.

Broadcasting

TV and radio broadcasters use accurate time to synchronise content, ensure seamless switching between feeds, and maintain regulatory compliance for logging and transmission.

Autonomous vehicles

Autonomous vehicles will require highly accurate time signals for real-time decision-making and coordination with roadside infrastructure.

Defence

Military systems require resilient time for encrypted communications, coordinated operations, and the reliable functioning of autonomous vehicles and weapons systems in GPS-denied environments.

Data Centres

Data centres are the physical backbone that support and enable the digital economy and provide the technical infrastructure for sectors like finance, telecoms, transport, and energy. Applications like transaction ordering (finance), data integrity across distributed databases (enterprise), low-latency synchronisation (5G), and data stream alignment for real-time processing (Artificial Intelligence) all rely on highly accurate timing signals used to synchronise servers within data centres.

Timing innovators

The UK has a strong network of specialist timing and frequency companies, and many global timing and synchronisation companies have UK bases. Such companies stand to benefit from access to reliable timing signals to develop and test their innovations through the three partner universities. Potential beneficiaries include those developing:

New clocks

Time signals will support research and development for a broad range of new clocks: from tiny chip-scale atomic clocks, providing accurate timing in portable applications, to boundary-breaking, next-generation optical and quantum clocks that seek to provide even greater accuracy, and therefore open up new possibilities, beyond those of the atomic clocks available today.

Time distribution technologies

The NTC will support the development of new technologies for securely disseminating time signals to users over fibre and free space and will itself utilise many of these technologies as they emerge.

Quantum technologies

Ultra-stable and traceable time signals will be needed to study and test quantum sensors and networks, laying the foundation for future quantum communication and computing infrastructure.

The time and frequency workforce

Individuals

Access to NTC training programmes, funded PhDs and collaboration hubs will provide individuals with the timing skills required to support this evolving field.

Companies

Training courses for experts and non-experts will help companies understand and mitigate risks from timing signals.

International timekeeping

Regulators

The NTC will advise regulators on best practices in timekeeping, ensuring standards are understood and implemented consistently across the economy.

UTC

Once fully operational, the network will contribute data to the Bureau International des Poids et Mesures (BIPM), helping formulate and maintain UTC.

The UK economy

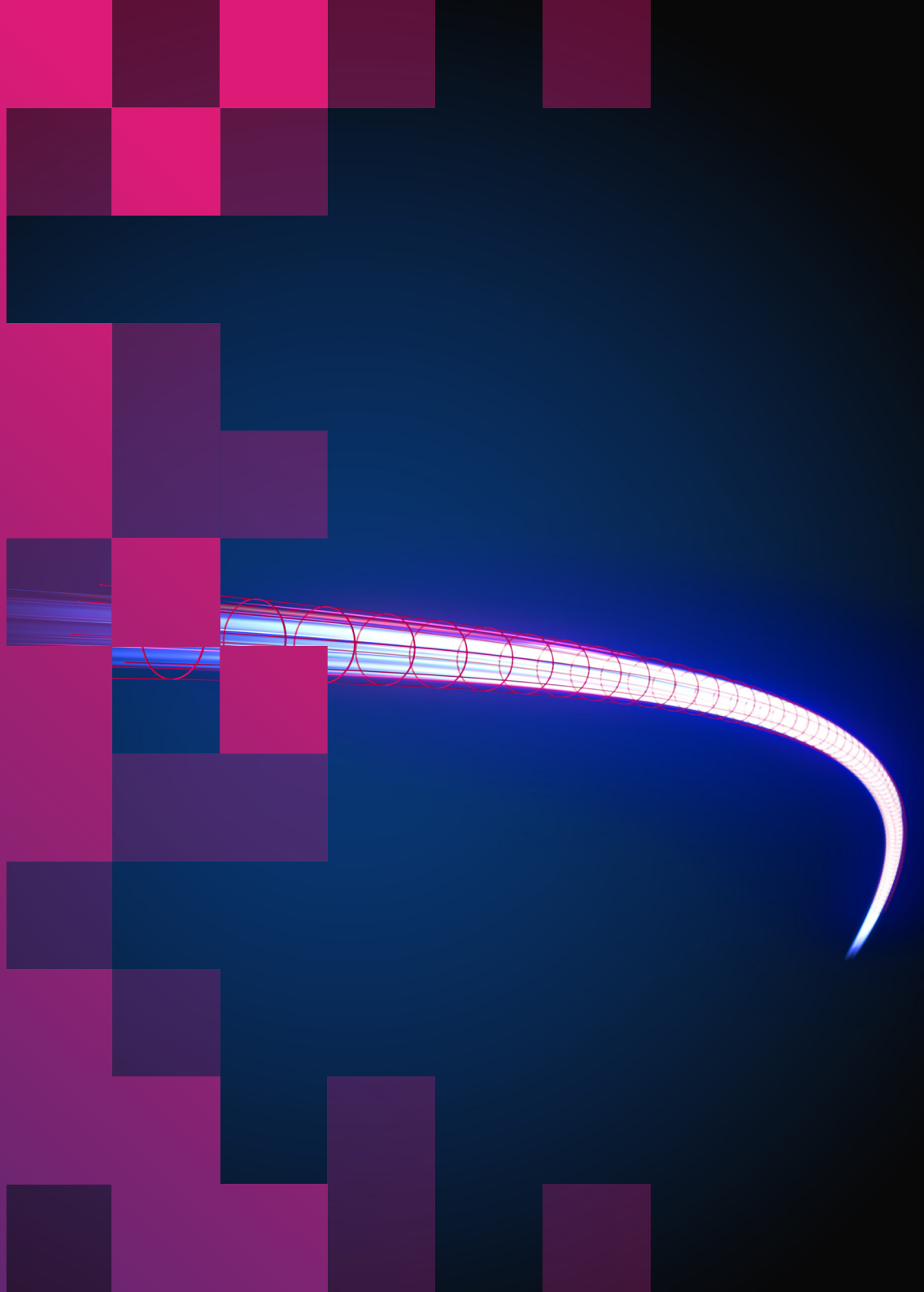
All of this activity is expected to support businesses to operate more reliably and efficiently, reduce risk, eliminate cost in the event of timing failures, spur innovation and create jobs.

An economic analysis was conducted at the start of the programme; however, it does not reflect the revised scope, costs, or delivery timelines of the programme. An independent end-of-programme evaluation is underway and is being carried out by London Economics. This study is expected to conclude in Q1 2026 and will provide fresh estimates of the programme's impacts, independent of the initial economic analysis.

In an interim assessment, one channel of economic benefit has been estimated using Innovate UK grants data, specifically examining the relationship between public sector R&D spend and the subsequent private sector R&D spend. Innovate UK Call 1 successfully funded seventeen projects. The total cost of these projects was around £2.87 million, of which about £1.94 million was funded via Innovate UK grants. The remaining £0.93 million was borne by the private companies. Therefore, every £1 of public R&D spending (via Innovate UK) led to £0.48 in private spending. This gives us a starting point for the private sector R&D leverage for the programme. This number may be treated as a lower bound, since it captures only the money spent by the private firms on these grants. However, we can expect them to undertake further R&D that builds on the successful grant projects.

Part 2:

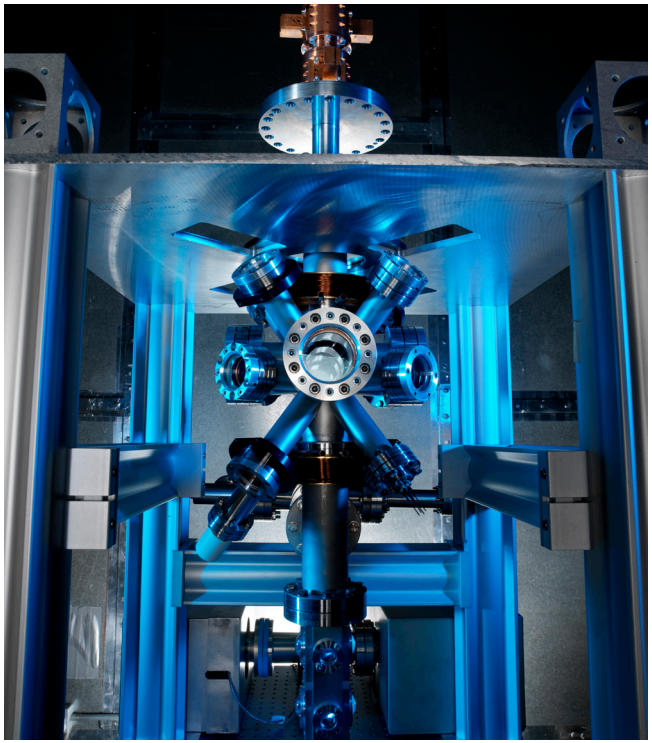
What we have done to create the NTC: The story so far



Creating the NTC

To build this new resilient UK national timing infrastructure, we needed to deliver on our three goals: build the NTC's Resilient Enhanced Time Scale Infrastructure (RETSI) sites; use the new timing capabilities to support UK innovation; and develop skills in timing and frequency.

In this section, we report on what has been delivered across all three during the initial R&D phase which ran from April 2019 to the end of March 2025.



1. Building a resilient UK time network

To meet the first aim of resilience, we have designed RETSI as the foundation of the NTC programme. This involved defining the requirements for the system, which includes four sites to host the atomic clocks that maintain the time scale. We have future-proofed clock configuration and connections between the sites using modern techniques for future security.

These setups have been implemented on two geographically separate sites so far. The sites are linked by an optical fibre cable and a dedicated two-way satellite link. We have procured equipment including hydrogen masers, and managed installation of two brand new caesium fountain (CsF) clocks at the sites.

This was followed by rigorous testing and validation, which will ensure the new infrastructure becomes a resilient time scale once fully implemented in the future.

Having proven the setup and worked through the challenges, the full infrastructure can now be delivered with much greater confidence under a future programme.

In addition, a pre-production environment has been built at NPL – a functionally equivalent version of a three-site RETSI system – for testing the deployment of software, integration of hardware and overall system integration before deployment of any technologies onto the production systems. This ensures risk is mitigated and expedites testing before entering the live systems.

What makes up the RETSI sites and pre-production environment?

2
new caesium fountain primary standards

30
racks of equipment

400+
km of optical fibre

1000+
pieces of equipment including advanced measurement tools and hydrogen masers

6000+
coaxial cables

2. Time and Frequency Innovation Nodes: building a UK-based supply chain

To support the second aim of the NTC – providing a launchpad for UK-based innovation in time and frequency technologies – three Time and Frequency Innovation Nodes have been established in partnership with Cranfield, Strathclyde, and Surrey universities. The aim of these nodes is to foster innovation across UK industries by providing research and development support for diverse sectors such as telecommunications, transport, energy and finance, and across their supply chains.

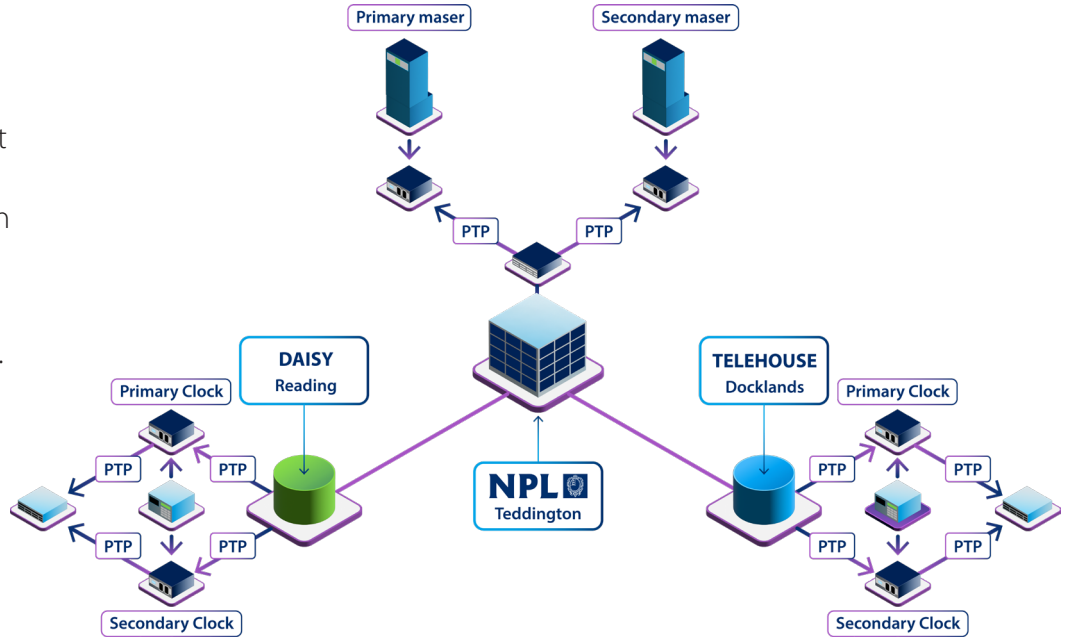
The nodes at these universities receive reference time signals traceable to UTC(NPL), directly from NPL – a service which will continue and become more resilient once the RETSI network is complete.

The three Innovation Nodes act as regional hubs where businesses, researchers, and public-sector organisations can access, test, and develop new technologies – such as smart grids, 5G, and autonomous systems – that depend on high-precision, resilient time signals. Innovators can plug their hardware in and access timing signals for testing or R&D, spurring innovation in UK time and frequency technologies and boosting the UK supply chain.

Each node has unique setups designed around different forms of timing dissemination, to provide a broad range of capabilities for timing innovators. And each is focused around supporting particular industries, aligned to local opportunities.

In addition to the innovation nodes, NPL operates two service nodes in London and Reading, which provide continuous, assured timing signals over dedicated fibre optic cables. These are currently used primarily for distribution of **NPL**Time® to the financial sector. Through Innovate UK funding calls, organisations across the UK were able to access funding nationally, selecting the nodes that best met their access requirements.

RETSI will one day feed into both innovation and service nodes, and it is hoped will provide a catalyst to expand service nodes across the country.



*NPL's existing **NPL**Time® service already offers industry a time signal over fibre that is traceable to UTC(NPL).*

The Time and Frequency Innovation Nodes

Node at Cranfield University: PTP (Precision Time Protocol)

NPL's Innovation Node at Cranfield University supports local innovation in aviation, autonomous transport and smart cities.

Cranfield receives a time signal by a fibre link from NPL, which feeds a commercially available Timeserver. This distributes signals to local systems using PTP, a network protocol used to synchronise clocks across devices in a communication network, enabling GNSS-independent time distribution for research and digital infrastructure testing.

Node at the University of Surrey: White Rabbit

The University of Surrey supports local expertise in developing future communications, providing signals to Surrey's 5/6G Innovation Centre for use in telecoms research.

Surrey's Innovation Node delivers White Rabbit timing signals – a high-precision timing protocol, pioneered by CERN, that combines Ethernet and PTP to synchronise devices over fibre-optic networks with sub-nanosecond accuracy.

Node at the University of Strathclyde: GPS Common View

The University of Strathclyde has a particular focus on supporting quantum, photonics, fintech back office and energy sectors, where the university has leading research and an ecosystem of innovative companies.

A highly accurate caesium clock keeps local time. It synchronises with UTC(NPL) using GPS Common View – a method well suited to time transfer at a distance (Strathclyde is the furthest node from NPL). This involves comparing the measurement of GPS signals received at the node against those received at NPL. If any difference is found, NPL calculates a small adjustment and sends it back to the node to correct the clock.

The node at the University of Strathclyde has also been expanded to provide optical frequency metrology capability. This expansion was funded through the NPL Quantum Programme, in collaboration with the NTC programme. It allows users to test and verify their optical references, such as the deployable optical atomic clocks being developed by the UK Hub for Quantum Enabled Position, Navigation & Timing, with full traceability to NPL's standards.

Case studies: How innovators are using the nodes

During their development, the three node sites have supported UK companies with projects that contribute to resilient time, frequency and synchronisation. Innovate UK provided £6.7 million for feasibility studies and demonstration projects to this end.

In total, 26 projects were supported under the fund to enable the development of new products and services. Five included access to traceable timing signals and five received technical consultancy from NPL. We highlight three below.

Resilient time signals for autonomous systems

Innovate UK–funded collaboration enables drones and autonomous vehicles to receive secure, resilient timing signals

Autonomous drones are increasingly valuable for tasks like surveying hazardous sites and repairing hard-to-reach infrastructure. To navigate, coordinate and operate safely, they depend on precise, reliable timing signals – currently provided by GNSS.

From 2023, iQuila, Quantum Dice, and Cranfield University came together under an Innovate UK competition on resilient timing, which included access to the Time and Frequency Innovation Node at Cranfield. The project developed a "last-mile" system to transmit traceable, over-the-air time signals from fixed infrastructure to drones – and between drones themselves. Though demonstrated with a single drone and two ground terminals, the solution is applicable to a wide range of autonomous systems and digital infrastructure.

iQuila, the project lead, adapted its Software Defined Network (SDN) to distribute timing signals via wired, wireless, Wi-Fi, or 4G/5G connections. The SDN packages the time data and transmits it like standard network traffic, dynamically allocating bandwidth and maintaining signal quality in changing environments.

To secure dissemination, Quantum Dice's Quantum Random Number Generator (QRNG) was integrated into the network. Its patented DISC™ protocol verifies randomness in real time, ensuring encryption keys are truly unpredictable and providing protection beyond classical methods.

Cranfield's Time and Frequency Innovation Node receives NPL-traceable signals via fibre, aligned with UTC – the global time standard. These were used to develop, test, and validate the wireless dissemination system against UTC(NPL).

The project culminated in a live demonstration where an autonomous drone maintained precise, secure timing even in conditions that disrupted GNSS, proving the potential for resilient, UK-owned time delivery across future autonomous systems.

George Dunlop, Founder of Quantum Dice, said of the project, "The coming together of iQuila's connectivity and Quantum Dice's verifiable quantum randomness enabled us to build a trusted foundation for secure time dissemination – creating a solution greater than the sum of its parts, and demonstrating the kind of innovation only possible through collaboration."

"By working with Cranfield and the National Timing Centre, we've taken an innovative idea to a commercial product that strengthens resilience for industry, government, and the UK economy," adds David Sweet, CEO of iQuila.

Resilient time signals for the electricity grids

A new architecture demonstrates transmitting NPL-traceable time signals to electricity substations using radio transmitters

Electricity grid operators must constantly balance power flow between generators and consumers. They rely on time-stamped voltage and current measurements from substations to monitor supply and demand and coordinate rapid fault responses. When a power line fails, sensors and switches must act in unison – which depends on access to a shared, precisely synchronised clock. Today, these time signals mostly come from atomic clocks on GNSS satellites.

The Innovate UK-funded NTOL (NPL Time Over eLoran) project, led by Chronos Technology and the University of Strathclyde, demonstrated how time signals traceable to UTC(NPL) could be broadcast over radio waves, using one of the UK's eLoran transmitters. Electricity substations served as the demonstration case for how such signals could be received and used in practice.

The eLoran transmitter broadcasts high-power, low-frequency radio waves that are difficult to jam and can penetrate buildings – meaning it could add a valuable layer of resilience when combined with GNSS.

The team used a satellite link to compare Strathclyde's clock to the eLoran transmitter's clocks, with a correction then sent to the eLoran clocks to anchor them to NPL's time. Whilst satellites were used to calibrate the eLoran clocks, those clocks are accurate enough to maintain reliable time during a temporary loss of the satellite link.

Tests at Strathclyde's Power Networks Demonstration Centre (PNDC) confirmed that substations equipped with eLoran receivers could receive eLoran time signals, and use them to synchronise monitoring and protection systems as accurately as satellite based approaches.

The project thereby proved an end-to-end timing chain capable of delivering trusted, NPL-traceable time to industry via eLoran.

Calum Dalmeny, Technical Director at Chronos, says, "We have shown that we can adapt and integrate existing technologies to deliver a resilient UK timing signal to critical industries. This was made possible thanks to the NPL traceable time signals at the Strathclyde Innovation Node as well as the power and timing expertise at Strathclyde and NPL."

Resilience for a stable net-zero grid

The move to net-zero presents challenges for electricity grid operators, due to irregular wind and solar generation coupled with increased demand from electric vehicles and heat pumps.

Energy start-up Sygensys is developing demand management and energy storage solutions to help ensure a consistent and resilient electricity supply. Its technologies require high-quality, time-synchronised measurements in many locations across the grid. Existing solutions typically use GPS as a timing reference, which can be subject to disruption, such as from space weather.

Under an Innovate UK project, Sygensys worked with NPL and the University of Surrey's Innovation Node to investigate the performance of commercial timing receivers used across the grid. The project confirmed that such receivers vary in a way which wasn't obvious from regular measurements, but which was revealed through the ultra-precise Innovation Node timing signals. Over time, this variance could have a considerable undesirable impact on Sygensys and its customers.

By conducting this evaluation, Sygensys had confidence that they understood the limitations of commercial timing receivers, and confirmed those limitations came from the receivers and not the measurement equipment they were using. Through further research, they were able to identify alternative mechanisms for generating the precise timing signals they need, which still make the most of off-the-shelf products.

This means they can scale their technology without resorting to expensive specialist equipment. That opens the door to a wide customer base across all renewable energy generators, rather than just large electricity grid operators.

Thanks in part to this work, Sygensys has now progressed from an early feasibility study to a fully functional demonstrator which offers synchronised measurement, the foundation for a stable net-zero power grid. This has led to trials on micro generation sites using thousands of units in the UK, a significant US collaboration, and plans for rapid business expansion.

Andrew Larkins, CEO of Sygensys, said, "The collaboration with NPL and the University of Surrey is enabling us to realise our ambitions of creating a solution using multiple techniques for measurement, which is essential both for resilience, and for the levels of accuracy we need to offer services to generator and grid operators of all sizes."

3. Skills and training development: closing the timing skills gap

Finally, the NTC is tackling the skills shortage in precision timing head-on, training the next generation of engineers and timing system developers. Through apprenticeships, postgraduate research, and continuing professional development courses, it is helping UK talent get hands-on experience with tomorrow's timing technologies – creating high-value jobs and ensuring the UK has the expertise to lead in timing technologies for years to come.

Defining the skills gap

In 2020, a skills assessment was undertaken by NPL colleagues, involving over 100 people working in the Time, Frequency and Synchronisation (TFS) industry. It found that organisations find it difficult to recruit people with specialist skills and experience in TFS. It identified a number of skills gaps including satellite TFS and GPS vulnerabilities, optical fibre TFS, network time protocols, and security in time dissemination.

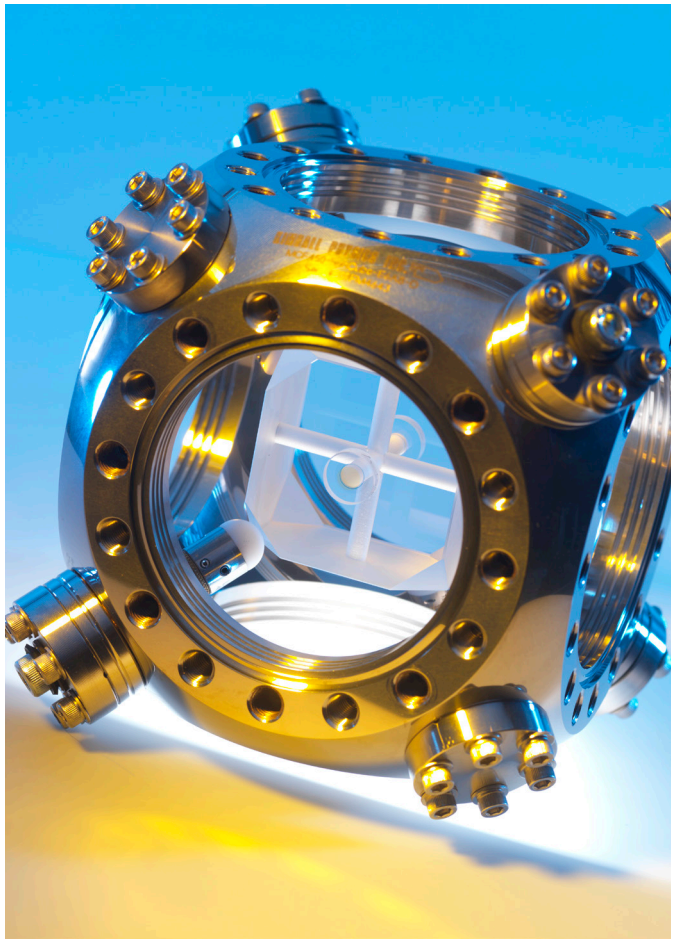
This assessment led to a blueprint, outlining what is required to deliver the requisite TFS skills. Some of its key recommendations included:

- Embed TFS in STEM university curricula and apprenticeships, upskill the existing workforce through clear career-spanning training pathways
- Develop a Range of TFS training products from basic awareness (including via e-learning) to advanced applications

Interested parties can contact the NTC programme team on ntcreports@npl.co.uk to see the full report.

An Ipsos study in June 2023, commissioned by NPL, conducted in-depth interviews with TFS professionals. All agreed that there is a large TFS skills gap in the industry. Recruiting STEM graduates is a challenge, and awareness of TFS as a career path is low. Many who have the requisite knowledge are over the age of 50, meaning companies face an imminent loss of knowledge in the area.

The survey also found that more generalist skills in TFS would benefit wider teams within these organisations and the TFS professionals welcomed the idea of courses in the fundamentals of time and frequency metrology for non-specialists.



Delivering skills and training

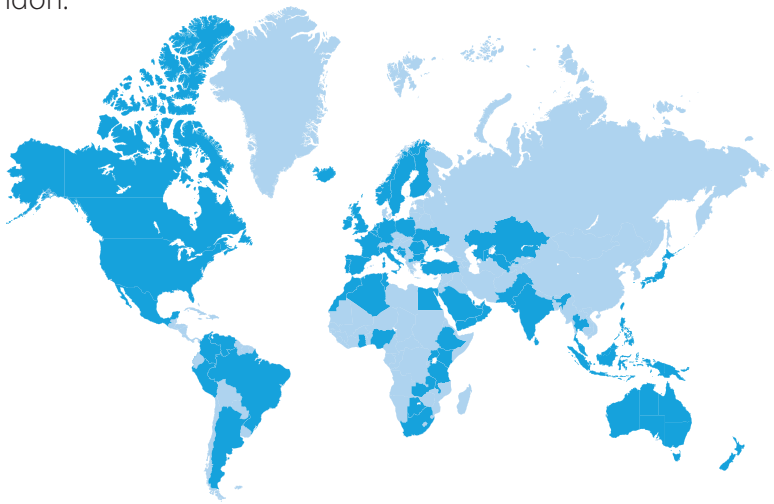
To proactively develop the skills needed, the NTC has developed training and provided support for time and frequency at various levels.

Online introductory courses:

Two online courses[6] have been developed by the NTC programme: an Introduction to Time and Frequency Measurement, and an Introduction to Clock Performance. Both are one-day courses, offered at no charge, which aim to equip the next generation of specialists. They are suitable for anyone interested in the subject, from students to entry-level scientists and engineers, and professionals in many different industry sectors for which time and frequency play a role.

The courses have collectively been taken over 2,500 times, by people from 19 countries. They have been used to support new starters and upskill the existing workforce.

A training course on PNT was developed and delivered in collaboration with the Royal Institute of Navigation (RIN) in 2024. It formed part of the RIN's Space Applications Learning Hub (SALHUB) online PNT training course on 25 November and was subsequently delivered in person on 15 January 2025 in London.



Countries where NPL's time and frequency training courses have been taken

Training and upskilling

Through the programme, a number of work and training opportunities have been created in time and frequency, including:

Funding **two PhD students and 12 graduates** to perform original research into new timing technologies

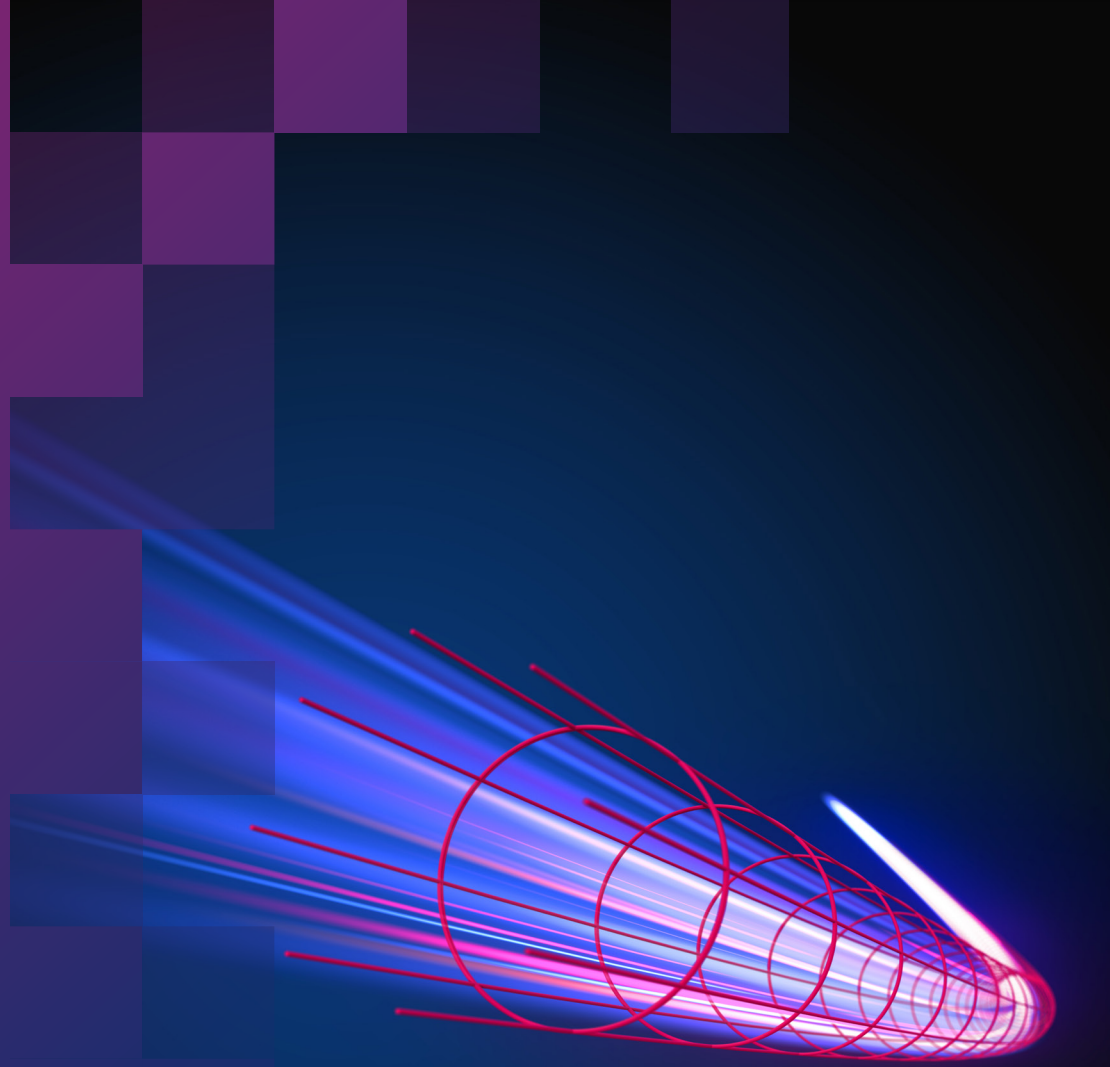
Upskilling **31 people** within the technical team through work shadowing, tutorials, technical training courses and by attending relevant conferences

Hosting secondments with partner organisations including AWE and Ofcom to support the NTC infrastructure development and help timing experts broaden their skillsets and understanding of industries that use time signals

Upskilling **45 contractors** who worked on the programme in time and frequency

Part 3:

Supporting the UK timing community through engagement and outreach



Part 3: Supporting the UK timing community through engagement and outreach

As part of the R&D phase of the NTC programme, significant effort has been put into outreach and engagement to ensure relevant partners benefit from the programme and start to raise awareness among time-using industries of this future capability. This has ensured the activity of the programme and associated work at NPL has also contributed to a wider benefit to the UK timing ecosystem, which will support the next phase of the NTC programme and feed into its broader goals.

Partnerships

- The NTC is working in collaboration with the European Space Agency's (ESA's) Navigation Innovation Support Programme (NAVISP) and the UK Space Agency to develop the next generation of Positioning, Navigation and Timing technologies.
- Our **NPL**Time **Access®** service offers users a time signal over fibre-optic links that is traceable to UTC(NPL) and entirely independent from GNSS. The service can be accessed from the two NPL service nodes located at the following data centres: Telehouse in the Docklands area of London and Daisy in Reading. The **NPL**Time **Access®** service is based on the initial longstanding timing service for the financial industry and provides an opportunity for users to partner directly with NPL to easily access the signal for their own timing needs or to develop assured timing services for their customers. It is attracting interest from a wide range of industries, including Innovation Node users, and its use is often referenced as a key enabler in timing project proposals, notably for applications to NAVISP. Aquis Exchange, Vorboss and JISC are currently using the **NPL**Time® service on a commercial basis, and we are engaging on Proofs of Concept (POCs) with Vodafone, Three, Virgin Media/O2, NESO, Safran/Equinix and Net Insight.
- In September 2023, NPL signed a Memorandum of Understanding (MoU) with satellite internet company, OneWeb, to work together on PNT capabilities in space, including to collaborate on OneWeb Gen 2 PNT system time scale design and NPL certification of OneWeb's Gen 1 Timing service.

Public and business engagement

We have run events to spur interest and understanding of time and its challenges. For example:

- As part of the Lord Mayor's "Connect to Prosper" initiative, we placed atomic clocks on the 61st floor of 22 Bishopsgate, the tallest building in the City of London, and at ground level at NPL to demonstrate Einstein's theory of general relativity – showing that time passes slightly faster at higher altitudes. This collaborative demonstration revealed a measurable time gain of 100±30 nanoseconds on the higher clock, compared to the ground level clock – in other words, the clock would need to spend around one million years on the 61st floor to see one-second difference between the clocks. Promoted during British Science Week, this initiative raised awareness of NPL's expertise in time and frequency and its role in developing next-generation atomic clocks to ensure precise and synchronised timekeeping, which UK industry and society rely on. It created interest among schoolchildren in STEM and topics such as timing.
- NPL presented the Royal Museums Greenwich with an atomic clock to celebrate the relationship between the two organisations, both of which play an influential role in how the world tells time. The atomic clock will extend the museum's longstanding exhibit on Harrison's Clocks, the original precision navigation devices, to give visitors a vision of the next-generation clocks that are supporting navigation (amongst other things) into the future.
- The London Stock Exchange hosted the NTC Steering Committee (pictured) to mark progress on enhancing the UK's timing resilience. Discussions focused on future capabilities, regulatory compliance, and ensuring long-term resilience for industries dependent on precise time synchronisation.

Events

Innovation Node launches:

Our Time and Frequency Innovation Nodes were launched through events aimed at engaging local timing companies, time-signal users and other stakeholders.

University of Strathclyde – March 2024

The first Innovation Node at the University of Strathclyde was launched on 13 March 2024 as part of a two-day programme that showcased the work delivered by NPL, and the capabilities in quantum and timing available to Scottish industry.

Cranfield University – October 2024

On 15 October 2024, Cranfield University officially launched its Time and Frequency Innovation Node. Attended by 60 industry and academic stakeholders, the event featured presentations highlighting advancements in resilient UK time distribution and the node's capabilities.

University of Surrey – June 2025

The final launch in the series of NPL Innovation Nodes took place on 3 June 2025 at the University of Surrey's 5G Innovation Centre. This event highlighted the university's contribution to the NTC programme and demonstrated the node's potential for driving business innovation. Attendees had the opportunity to explore the facility, engage with experts, and learn about its role in the UK's emerging national timing infrastructure.

National Timing Community Engagement Forum, March 2025

On 10 March 2025, NPL hosted the inaugural National Timing Community Engagement Forum in collaboration with the Defence Science and Technology Laboratory (Dstl), and supported by the National Positioning, Navigation and Timing Office (PNTO) in the Department for Science, Innovation and Technology (DSIT) and the RIN.

The forum brought together over 100 industry stakeholders in the UK timing sector to discuss strategies for addressing national challenges and identifying policy priorities for the UK's digital infrastructure.

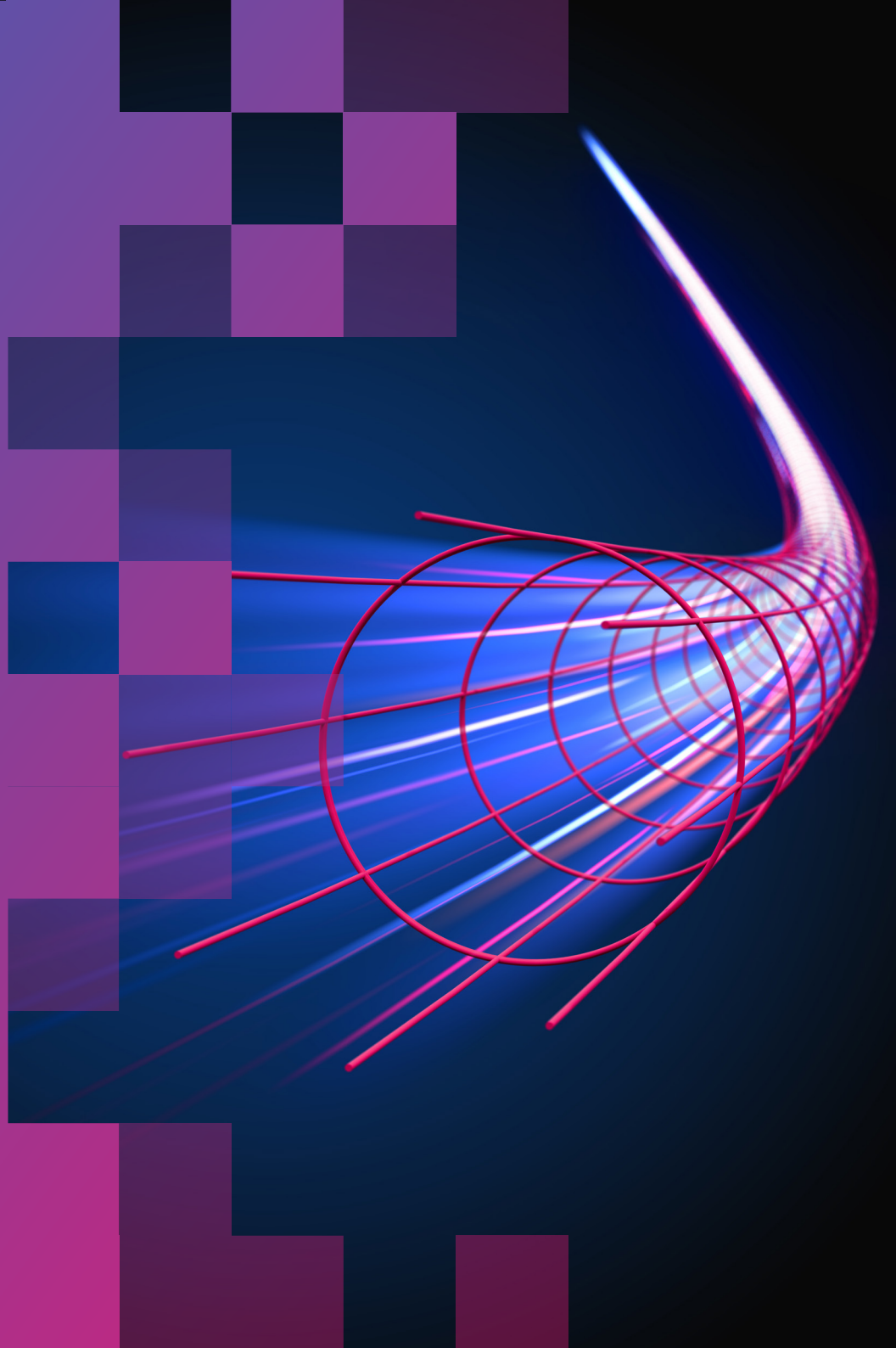
Several SMEs and startup companies presented their timing product and service innovations and unique value propositions, including Calnex Solutions, Chronos Technology, CPI TMD, GMV, Hoptroff London Ltd, IQD Frequency Products and iQuila Ltd.

This was the first in a planned series of collaborative timing events led by national laboratories and government, which highlighted the importance of a resilient time element within the UK PNT framework. Subsequent events are being organised to continue addressing timing community priorities.

Awareness raising and public leadership

As the NTC has taken shape, NPL has regularly offered a public voice on the importance of timing, sharing news, updates and thought leadership through our own channels and the media. Our efforts are aimed at helping users understand the importance of resilient timing and the capabilities available to them to deliver it, and to show the leadership the UK is taking in addressing this critical challenge.

Conclusion and future outlook



What's next for the NTC programme?

Having successfully designed and tested RETSI across two geographically distributed sites during the R&D phase of the NTC programme, NPL is developing plans for a five-year delivery phase, as of April 2025, guided by a 10-year vision for future development.

This will include completing the four RETSI sites core structure, designing the distribution architecture, and managing and delivering the build.

The programme will move to real world value, providing traceable and resilient signals across UK digital infrastructure, initially in priority sectors such as energy, telecoms, finance, and defence. These will be available via multiple methods, including eLoran (a low frequency radio transmission).

In essence, the UK will soon benefit from a national, robust, multi-route timing service that supports key sectors – even if satellite timing like GPS fails. Assured timing signals to the UK will be an enabler for industry to innovate and deliver exciting new solutions, much as GPS did, but with the added layer of security and sovereign control over signals. This world-leading innovation will enable the UK's timing source to be more secure, resilient and innovative, making the country more prosperous as a global leader in the timing technologies that underpin the modern digital world.

Glossary

BIPM	Bureau International des Poids et Mesures
CsF	Caesium Fountain Clock
DISC™	Device Independent Self-Certification
DSIT	Department for Science, Innovation and Technology
Dstl	Defence Science and Technology Laboratory
ESA	European Space Agency
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
MSF	Radio Time Signal - the UK's national longwave time signal broadcast from Anthorn
NAVISP	Navigation Innovation Support Programme
NPL	National Physical Laboratory
NTC	National Timing Centre
NTOL	NPL Time Over eLoran
NTP	Network Time Protocol
PNDC	Power Networks Demonstration Centre
PNT	Positioning, Navigation and Timing
PNTO	National Positioning, Navigation and Timing Office
PTP	Precision Time Protocol
QRNG	Quantum Random Number Generator
R&D	Research and Development
RETSI	Resilient Enhanced Time Scale Infrastructure
RIN	Royal Institute of Navigation
SDN	Software Defined Network
TFS	Time, Frequency and Synchronisation
UKRI	UK Research and Innovation
UTC	Coordinated Universal Time
UTC(NPL)	UK national time scale, managed and disseminated by NPL

1 The economic impact on the UK of a disruption to GNSS
2 https://assets.publishing.service.gov.uk/media/6001b2688fa8f55f6978561a/6.6920_CO_CCS_s_National_Risk_Register_2020_11-1-21-FINAL.pdf
3 https://ops.group/blog/gps-spoofing-final-report/
4 https://assets.publishing.service.gov.uk/media/67b5f85732b2aab18314bbe4/National_Risk_Register_2025.pdf
5 https://www.gov.uk/government/news/critical-services-to-be-better-protected-from-satellite-data-disruptions-through-new-position-navigation-and-timing-framework
6 https://training.npl.co.uk/courses/?_sft_product_cat=6_quantumandtimeandfrequency&_sfm__regular_price=0+1700

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