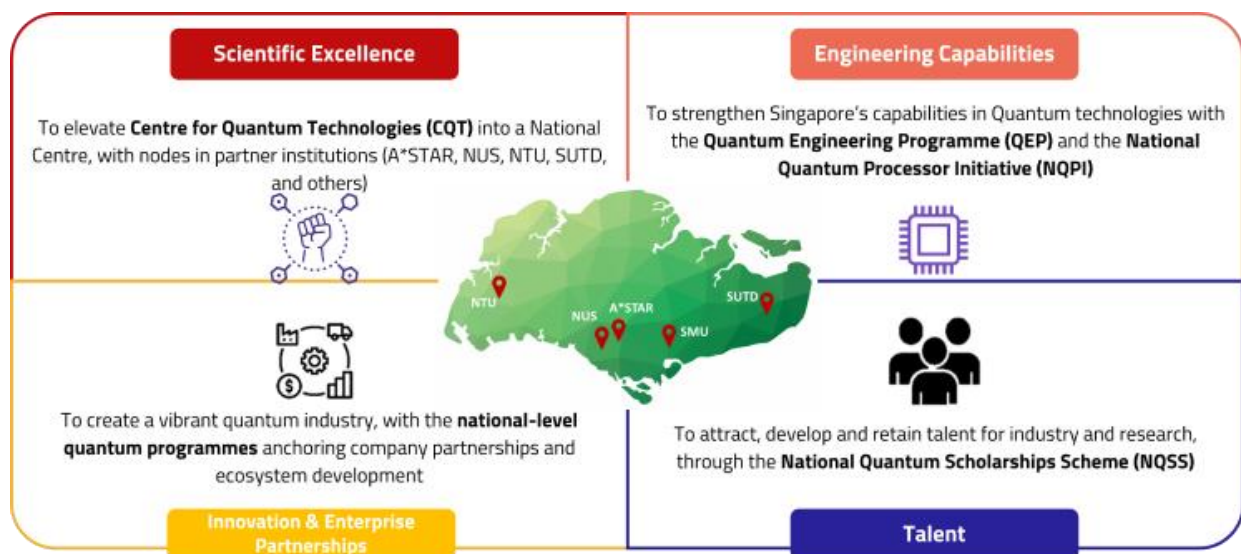


Singapore's strives to become (South East) Asia's Quantum hub

Singapore aims to strengthen itself as a Smart Nation. To ensure that the country, roughly half the size of the province of Utrecht and with limited natural resources, is part of future value chains, the government invests heavily into research and development in a wide range of key-enabling technologies. In comes quantum technology. Last May 2024 the country came out with its first National Quantum Strategy to nurture a local quantum ecosystem and build sovereign quantum capabilities. Doing so enables Singapore to shape and respond to international technology development, pursue strategic partnerships and position itself as future provider in a budding highly strategic value chain. To maintain its **status as the region's leading** innovation and business environment, quantum technology implementation and adoption is also a key factor to safeguard its digital infrastructure and secure national and international connectivity.

Singapore started investing in Quantum Technology early on, with approximately S\$250 million over the last 15 years (approximately €170 million) into setting up the Centre for Quantum Technologies (CQT) hosted at the National University of Singapore (NUS). The focus of CQT is basic research on quantum physics and translation to devices based on quantum phenomena. Noteworthy is the focus on technology development, **with Singapore's general** approach of positioning itself as a living lab- and pilot ground to test emerging technologies, invite (global) talent with funds to do so and programs being application- and result-driven to realize societal and economic value.

Funding for the National Quantum Strategy (NQS) comes from Singapore's national Research, Innovation, and Enterprise 2025 5-year plan, a S\$300 million top up out of a S\$25 billion budget allocated by the National Research Foundation (NRF) in 2020. The strategy, developed and overseen by the National Quantum Office (NQO), comprises of 4 strategic thrusts. Under one of the four thrusts, coined "Engineering Capabilities", NQO will be launching grant calls that specifically focus on critical components and technologies, and application areas in (I) communications and security, (II) processors, computation and simulation, and (III) quantum sensing and metrology. Under the thrust "Scientific Excellence" CQT is set to become a national centre to align its own research agenda and those at partner institutions with these engineering priority areas.



"4 Strategic Thrusts", National Quantum Office 2024

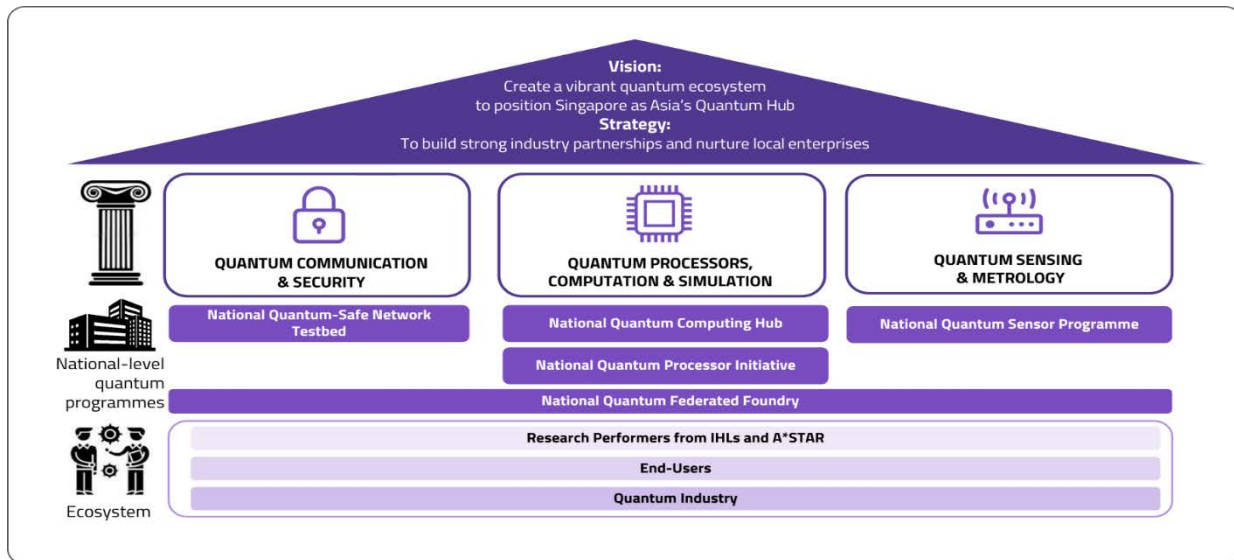
Funding flows through the NQS (through RIE2025), external grants and Ministry of Education (MOE) support directly to the CQT, research groups at other Institutes of Higher Learning such as Nanyang Technological University (NTU), and the country's two major research programs: the national Quantum

Engineering Program (QEP) and the Quantum Technologies for Engineering Programme. The latter is a research program specific to A*STAR's **Institute of Materials Research and Engineering** and aims to establish long term capabilities in using quantum sensors and phenomena for new concept devices and materials. The goal of the national QEP is to leverage quantum technologies to solve real-world problems and drive translation. The R&D programme is supported by the NRF (budget spanning 2018 to 2025), is overseen by the National Quantum Office at A*STAR, and hosted at NUS. QEP provides research grants for 2-3 year projects (in some cases over a longer period of time), and builds a quantum ecosystem of researchers in quantum communication & security, quantum processors, computation & simulation, and quantum sensing & metrology together with industry partners. By linking engineering capabilities in device fabrication, imaging, system design and communication, the program focusses on the commercialization of quantum cryptography, ground-basis time network, enhanced imaging and sensing technology and advanced manufacturing capability. Under QEP three national platforms were launched in 2022:

1. National Quantum Computing Hub (NQCH) - to develops quantum computing capabilities and explore applications through industry collaborations;
2. National Quantum Fabless Foundry (NQFF) - to supports micro- and nanofabrication techniques for quantum devices and enabling technologies;
3. National Quantum-Safe Network (NQSN) - conducts nationwide trials of quantum-safe communication technologies that aim to enhance network security for critical infrastructure.

These 3 existing programs are part of the **NQS thrust "Engineering Capabilities"** along with two more recently announced national programmes:

1. National Quantum Sensor Programme (NQSP): to translate critical components and technologies for positioning, navigation and timing, remote sensing, biomedical and MedTech applications;
2. National Quantum Processor Initiative (NQPI): to design and develop quantum processor using trapped ions and neutral atom arrays.



"Innovation & Enterprise Partnerships", National Quantum Office 2024

Singapore's quantum public and private ecosystem closely collaborates in these national platforms. Consortia typically include government partners such as the Infocomm Media Development Authority (IMDA), local industry (SMEs and (majority) state owned companies) and international partnerships with renowned research institutes and industry. In addition to these platforms, Singapore there is also some interesting start-up and private investment activity. A recent example is Horizon Quantum Computing, which makes a software layer to compile conventional code to quantum algorithms, raising US \$18.1

million (approximately €17 million) in Series A funding. Other noteworthy start-ups include S-Fifteen Instruments, which manufactures quantum control instruments, Atomionics, which focuses on applications for quantum sensing, SpeQtral, working on space-based quantum communication, AngelQ, which builds architecture-agnostic quantum software for company deployment, and Entropica Labs, which develops quantum optimisation models, algorithms, and techniques. These companies are all either CQT or NUS spin-offs, or start-ups founded by staff and alumni and many of them receive investments from government holdings and funds.

Quantum sensing strives under Defense guidance

Since 2019 Singapore's Defence Science Organization (DSO) has taken more active role in the nation's initiatives to cultivate capabilities and a knowledge base in quantum technologies. An example is its participation together with HTX (Homeland Science and **Technology Agency**) **in the nation's efforts to** build a national quantum-safe network for experience building and commercial testing. DSO seems particularly interested in quantum sensor technologies for navigation and surveillance: cold atoms inertial sensors (CAIS) and superconducting quantum interference filters (SQIFS). DSO is established as the centre of R&D for the Singapore Armed Forces, and receives direct funding from the Ministry of Defence through its innovation fund.

Cap Vista Pte Ltd is the **strategic investment arm in Singapore's defense ecosystem. Beyond** investment capital, it provides advice to further develop start-ups to meet Singapore's defense and security needs. The Singaporean quantum sensing start-up Atomionics is part of Cap Vista's **portfolio**. Philippe Bouyer, member of the Quantum Delta board of directors, noted that the company under DSO guidance made real technological progress during the pandemic. Atomionics focuses on resource exploration and navigation through cold atom interferometry.

Quantum risks and opportunities for the Singapore financial sector

Last February 2024, the Monetary Authority of Singapore (MAS) published an Advisory outlining the cyber risks arising from quantum computing, and highlighting mitigating PQC and OKD measures local financial institutions ought to consider. It followed up by launching a S\$100 million quantum track under its Financial Sector Technology and Innovation Grant Scheme. Under the scheme financial institutes can receive funding support for quantum projects and capability building related to both risks as opportunities. Several partnerships were announced, focusing on secure quantum key distribution solution experimentation between a consortia of 7 local banks, and a Post-Quantum Encryption (PQC) partnership between the French central bank and MAS. The Singapore FinTech Festival, a flagship event **co-organized by MAS, returned the same year with "Roadmap to AI & Quantum" as its main theme.**

Singapore balances sovereign capability building with commercially procuring them – using the national platforms to pursue strategic partnerships with public and private (international) entities. Thales and QEP have partnered up to develop and test quantum security and quantum sensors for industry use. SingTel works together with CQT to develop quantum key distribution for Singtel's fibre network, and T-Systems Singapore and ST Engineering are working with NUS on standards and technical requirements for quantum security technologies. Last April 2023 Tektronix Inc signed an MoU with QEP to collaborate in providing technical advice and input on instrumentation and operation practices in the NOFF platform.

Both Telecom provider Singtel and a consortium made up from state-owned SPtel and start-up SpeQtral **were jointly appointed last November 2023 to build Singapore's first National Quantum-Safe Network Plus (NQSN+).** NQSN+ will support multiple network operators to deploy quantum-safe networks nationwide, so that businesses can have easy access to quantum-safe solutions to safeguard their critical data and explore different use-cases across industries. When completed, NQSN+ will be an interoperable network fortified with quantum encryption capabilities for critical government and commercial applications.



Singapore houses regional offices, procures services and conducts R&D with the dominant players in the cloud computing industry, working with both USA and China based cloud providers. The USA based cloud providers, IBM, Microsoft and AWS, additionally develop and offer access to quantum cloud services, research and training. All three have partnerships with Singaporean government, university or business entities.

Opportunities for international collaboration and SG – NL niches

As Singapore tends to be interested in trialling applied innovations in real-life or emulated settings for computing and communication, there are opportunities for collaboration in the field of supporting quantum modules, for instance those being offered by the Delft start-ups. In this light, the ImpaQT proposition of these start-ups is relevant, offering a full range of supporting quantum modules. Dutch modules and trialling solutions for testing and checking networks could be a match with the national testbed NQSN+ initiative. Additionally, forces could be joined to develop, produce and trial hardware for this testbed, as well develop and drive protocols and standards. Together with the two other national quantum platforms, NQCH and NQFF, NQSN lends itself naturally for (international) collaboration. Through the NQFF platform joint hardware component development may be explored, while the NQCH platform would fit collaboration on middleware- and use-case development. The NQPI targets to develop quantum processors with focus on platforms of trapped ions and neutral atom arrays. Targeted grant calls for photonics and control electronics components are expected in the near future which could be interesting for the Dutch photonics ecosystem.

Singapore is actively pursuing forums and partnerships that will enable it to drive international and local standardisation of quantum-safe communication technologies. At the International Telecommunication Union, Singapore and Japan are co-leading the standardisation of the Quantum Key Distribution (QKD) protocol framework. It also signed an MoU with South-Korea's **NIA to increase bilateral cooperation**. Start-up SpeQtral, one of the two partners building the NQSN+ platform, recently started a collaboration with Toshiba Digital Solutions to bring QKD solutions to the wider region. With the Dutch strong expertise in small satellite engineering, collaboration with SpeQtral and CQT on commercial space-based QKD might prove an interesting area to explore cross-over. As QKD technology matures and might become **more widely adopted, and given Singapore's investments in this technology** and testbed, Dutch offerings in Public Key Infrastructure and Management could become increasingly interesting for Singapore.

Singapore participates as member in the Quantum Economic Development Consortium (QED-C), which **was established with support from the U.S. Department of Commerce's National Institute of Standards and Technology (NIST)**. The NIST is a key driver in specifying standards for PQC algorithms. Though CQT does work on post-quantum cryptography (PQC) and it is included as a software-approach in NQSN+, Dutch experts noted that the Netherlands has more groundwork in this area of communication and quantum-safe technology that we could share our expertise and services on. Government officials between the two countries have been sharing best practices on PQC migration, tooling and policies.

Both Netherlands and Singapore can learn from each other how quantum applications can be advanced to higher TRLs and implemented to contribute to societal challenges and industry adoption. The Centrum Wiskunde & Informatica (CWI) and NTU, **Singapore's largest quantum theory** university research group, have a long-standing partnership in cryptography. In order to bring this (academic) collaboration and the Netherlands Singapore government-to-government digitalisation collaboration together, cross-border triple helix collaboration could come together to develop use cases and applications in, for example, the areas of quantum finance, quantum chemistry (e.g. drug discovery and development) and combinatorial optimisation (e.g. logistics).

Find Singapore's National Quantum Strategy [here](#).

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