Ministry of Foreign Affairs

Special Quantum Technology

Commissioned by the Netherlands Enterprise Agency

>> *Sustainable. Agricultural. Innovative. International.*

QUANTUM TECHNOLOGY

Netherlands Innovation Network

CONNECTING INNOVATION WORLDWIDE

"We aim to put the Netherlands on the map as one unified quantum ecosystem: The quantum world's own Silicon Valley."

Quantum Delta NL

Connecting Innovation Worldwide

FOREWORD

Dear reader,

Welcome to another exciting edition of the Netherlands Innovation Network Theme Special, where we delve into the world of quantum technologies. In this edition, our Innovation Attachés bring you a comprehensive view of the strategies and developments in quantum technologies across the globe.

The quantum realm has long captured the imagination of scientists, visionaries, and innovators. It's a domain where the potential for groundbreaking innovation knows virtually no bounds. The power of quantum technologies lies in the unique properties of quantum mechanics, such as superposition and entanglement, to tackle some of the most complex challenges facing humanity.

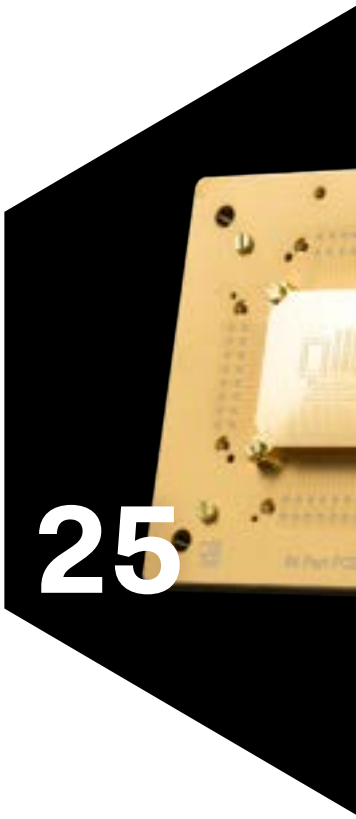
"This edition is testimony to the global nature of innovation and the urgency with which nations are embracing quantum technologies to secure their competitive advantage in the future."

In the pages that follow, you will discover how nations around the world are positioning themselves at the forefront of this quantum revolution. Quantum technologies have the potential to revolutionise a wide array of industries, from computing and communication to healthcare and materials science. The Netherlands has a very strong knowledge base in quantum research. In 2014, QuTech was awarded the status of National Icon and with the National Growth Fund programme Quantum Delta NL (2021-2027) the Netherlands is well-positioned to play a pivotal role in this global quantum ecosystem. But there are still many scientific discoveries needed before we can enjoy technological innovations. Innovation knows no borders and the Netherlands regards international collaboration as key to strengthening and accelerating these developments. We are keen to learn from innovations in other parts of the world and welcome companies and knowledge institutions from abroad to come to the Netherlands to participate in our efforts.

Thank you for being a part of our ongoing exploration of global innovation. Whether you represent a company, a knowledge institution, an academic community or a government department, the Netherlands Innovation Network is here to support your endeavours. I encourage you to reach out to our Attachés at the Netherlands' embassies and consulates for any inquiries or assistance you may require.

Erwin Nijsse
Director General Business Policy and Innovation

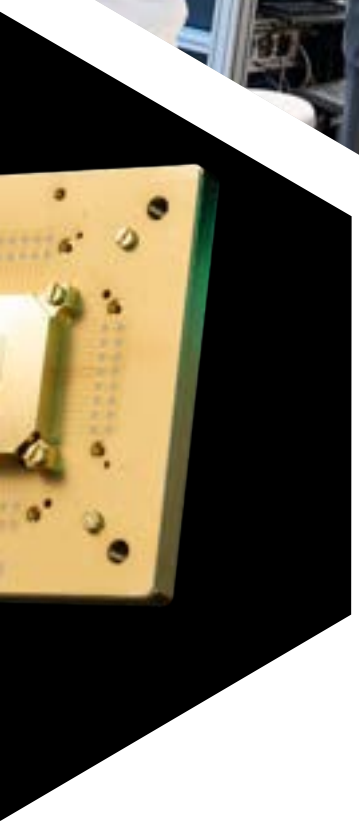
CONTENT




12


18


22




KLM
KLM
35

Quantum Delta NL

A Quantum Ecosystem With(out) Borders

Quantum technology is a burgeoning industry, a dynamic sector brimming with startups that continue to explore their potential. However, in recent years, the market has undergone significant changes. Whereas Dutch companies previously explored the world without limits, we now observe a change: Europe is taking centre stage, and export restrictions and investment screenings are being introduced. Why is that and what consequences does it have for the developments of quantum technology? Quantum Delta NL, discusses the (international) positioning of the quantum market and the consortium's unique approach.

In April 2021, Quantum Delta NL received €615 million from the National Growth Fund. With this money, the fund stimulates advancements on quantum technology in the Netherlands. The aim is long-term economic growth and the creation of more jobs in the Netherlands by strengthening quantum technology within the country. QDNL, as the organisation is abbreviated, adopts a holistic approach and functions as an ecosystem.

The Silicon Valley of the Quantum World

"We aim to put the Netherlands on the map as one unified quantum ecosystem: The quantum world's own Silicon Valley. Size-wise, that region in San Francisco is as vast as the entire Netherlands, so it should be feasible. The idea is to have five hubs spread across the Netherlands: in Delft, Eindhoven, Leiden, Twente, and Amsterdam. Hence the initialism DELTA. Each location has its own strengths. For example, Amsterdam focuses more on software, while Twente is more oriented towards materials. Together with a total of 23 quantum companies, we engage in fundamental research, education, application development, business development, and more."

Ethical Issues

QDNL is based on three technology areas: quantum sensors, quantum networks, and quantum computers. To bring these technologies to market readiness, Quantum operates with four action lines: investment in research and development, business ecosystem development, human capital, and Ethical, Legal, and Societal Aspects (ELSA). "These action lines summarise what we do, focusing on the three technology areas.

Cryostat
Source: Anne Reitsma Fotografie

The latter, the societal aspects of quantum technology, have recently become critical. "How do we ensure that the outcomes of technology meet certain norms and values? We want to work ethically and make a positive contribution to society. We don't want to widen the gap between rich and poor, we want to contribute to sustainable development goals, and safeguarding people's privacy and information. Especially in our geopolitical situation, this is very important."

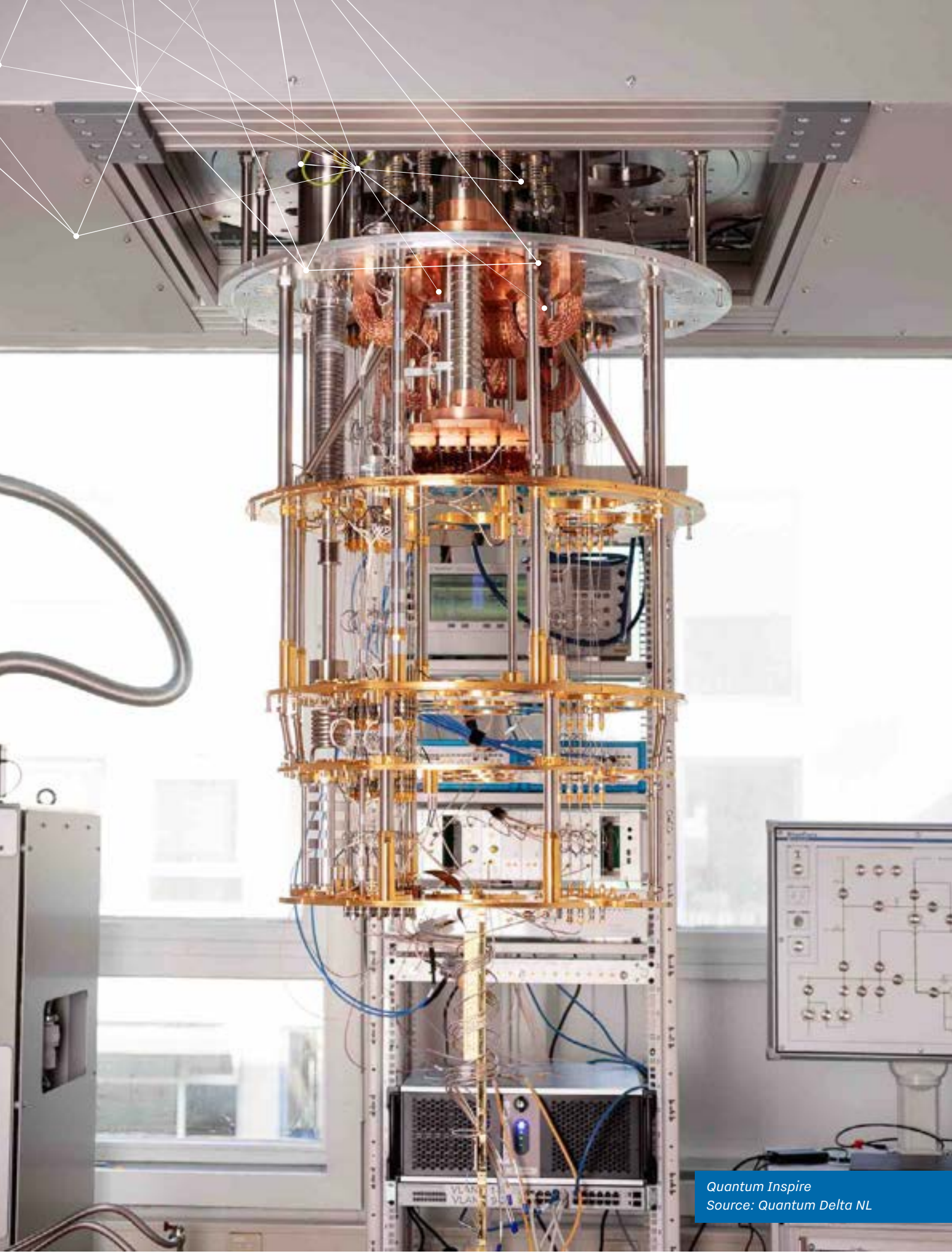
Science With(out) Borders

Up until about five years ago, scientists and quantum tech companies operated under the motto of 'science without borders'. The more collaboration there is globally, the better. "That's different now. We see what's happening in countries like China and Russia. Our technology is strategic and can easily be used to strengthen competitive positions. This makes countries, including ourselves, more cautious in collaborations. On the one hand, we want to maintain international collaboration because it creates a market, allows us to work with the best parties and attract the best talent to the Netherlands. Too many borders suffocate a burgeoning ecosystem. You want to offer scientists the world, that's the fastest way forward. But we also need to be cautious about who we collaborate with and who we bring in. This is a very sensitive issue. That's why we need to introduce certain checks and balances and take measures."

One of those measures relates to the influx of capital and talent from certain countries. "Companies undergo a screening process before they can invest in our quantum tech. We also handle our knowledge sharing carefully. People take their acquired knowledge and experience from the Netherlands back to their home countries, where some governments may call upon them to share and implement what they know. In the Netherlands that's not allowed, but in some other countries it is. Ethically, I find that very challenging: we're forced to consider someone's background and not just what a person brings in terms of capabilities and intentions."

International Cooperation

"Although our ecosystem thrives in the Netherlands, we do really need Europe. Take the manufacturing processes for quantum technology, they are very costly. Enormous investments are needed for various parts of the processes. It's not realistic to think that we'll be able to do all that alone. That's why we also look strategically at what we want to develop here and where another country can take the lead, to participate in partnerships in European programmes. We coordinate this together with the government. The Ministry of Economic Affairs and Climate Policy has discussions about this in Brussels. Of course, sometimes European interests conflict with our Dutch interests. The European game is about give and take."



Quantum Inspire
Source: Quantum Delta NL

“Until about five years ago, quantum tech companies operated under the motto 'science without borders'. The more collaboration there is globally, the better. That's different now.”

Quantum Talent & Learning Centres
Source: Quantum Delta NL

European Collaboration

Quantum Delta NL is active in all European programmes related to quantum technology. They were among the first in Europe, but nowadays most EU member states have a similar programme. "We collaborate with them too. For example, we launched a program with France and Germany, so we can share our ecosystems and Europe doesn't become a patchwork of various initiatives. The more intertwined we are, the stronger we stand, and the less likely it is that we will see companies leaving Europe. But the ecosystem doesn't stop at the European border. Precisely because quantum technology is a young industry, you’re still at a stage where you can shape the value chains and enter global markets. For example, we also have close ties with the United States, Japan, the United Kingdom, and Australia. There's an international collective where thirteen like-minded nations discuss how they can achieve a level playing field."

Collaboration with the Business Community

To involve more companies in the Dutch ecosystem, the organisation has two initiatives: Quantum for Business and the Quantum Application Lab. "The former is a service for companies wanting to learn more about quantum tech. We offer guidance and provide an introduction to the quantum world. The second initiative goes more into depth. Here we help companies in understanding what quantum can mean for their business. Additionally, we have scientific programmes in which quantum experts from the outside can collaborate with us. There is a lot of interest from abroad, including from outside the EU. These companies can benefit greatly from our acquired knowledge and experience, but they are also very valuable to us. For example, the Netherlands excels in quantum internet, hardware components, and algorithms, but there's still room for development in integrated software systems and devices. By mapping out the technology roadmaps and future value chains of quantum technology together with research institutions and companies, we can strategically seek partners who strengthen our ecosystem. We also have two Houses of Quantum, physical spaces where companies can meet and gain access to labs and facilities. If a company wants to establish itself in our quantum ecosystem, this is the place to be."

Focus in the Future

"All in all, the Netherlands has a leading position when it comes to quantum technology. We have a portfolio of companies that we assist in scaling up. We do that by focusing on three points, aligning with the four action lines. First, we invest in facilities such as clean rooms and maker spaces. The companies in our ecosystem are still too small to do everything on their own. Additionally, we encourage the availability of capital. Europe has by far the most startups in quantum technology, but the capital involved pales in comparison to that of, for example, the United States. Quantum tech is still new and uncertain and has a longer time-to-market. European investors take less risk. We encourage this with our own fund Quantum Delta NL Participations and collaborate with other investment funds, such as Invest NL, Invest NL, DeeptechXL, Quantonation, PBI France, and the EIC and EIF.

Lastly, we focus on talent. We want to attract existing talent but also educate new talent. That's why we have talent and learning centers in the five hubs. Young people learn, for example, through practical education, how to build devices in labs. This way, we try to build a workforce that includes people at all levels, not just highly educated scientists. In the first few years, we mainly positioned our programme very much from the inside out. Our ecosystem is now firmly rooted in society. We are now ready to focus more outward and internationalise further."

The US: Determined to Maintain Leadership in Emerging Quantum Technologies

The United States has long been at the forefront of research and development in quantum information sciences and sees quantum technology as an important avenue for maintaining its global technological leadership. The Quantum Technology report of the Netherlands Innovation Network US outlines the US government's national strategy for quantum and highlights some of the major programs and initiatives underway to accelerate progress in this cutting-edge field.

While the private sector is playing a large role in driving quantum development, the 2018 National Quantum Initiative Act established a coordinated federal response to boost quantum R&D. Funding has since doubled across government agencies like the Department of Energy, National Science Foundation, and intelligence community. Over $877 million has been requested for quantum research in the 2022 federal budget alone.

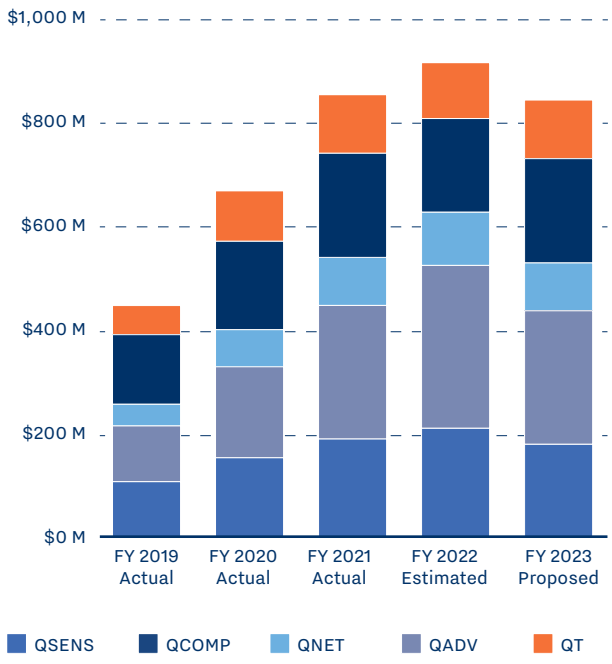
Four federal bodies are tasked with coordinating this interagency effort. The Subcommittee on Quantum Information Science aims to align research objectives, while the Subcommittee on Economic and Security Implications ensures implications are understood across national security agencies. An advisory committee comprised of industry, academia and government experts provides strategic guidance. Daily coordination is handled by the National Quantum Coordination Office.

Key program areas receiving funding include quantum metrology and sensing, quantum computing, quantum networking, and using quantum technologies to advance fundamental science. The largest investment currently goes to quantum computing initiatives, reflecting its prominence as a strategic technology. Research spans simulation, algorithms, and hybrid quantum-classical systems.

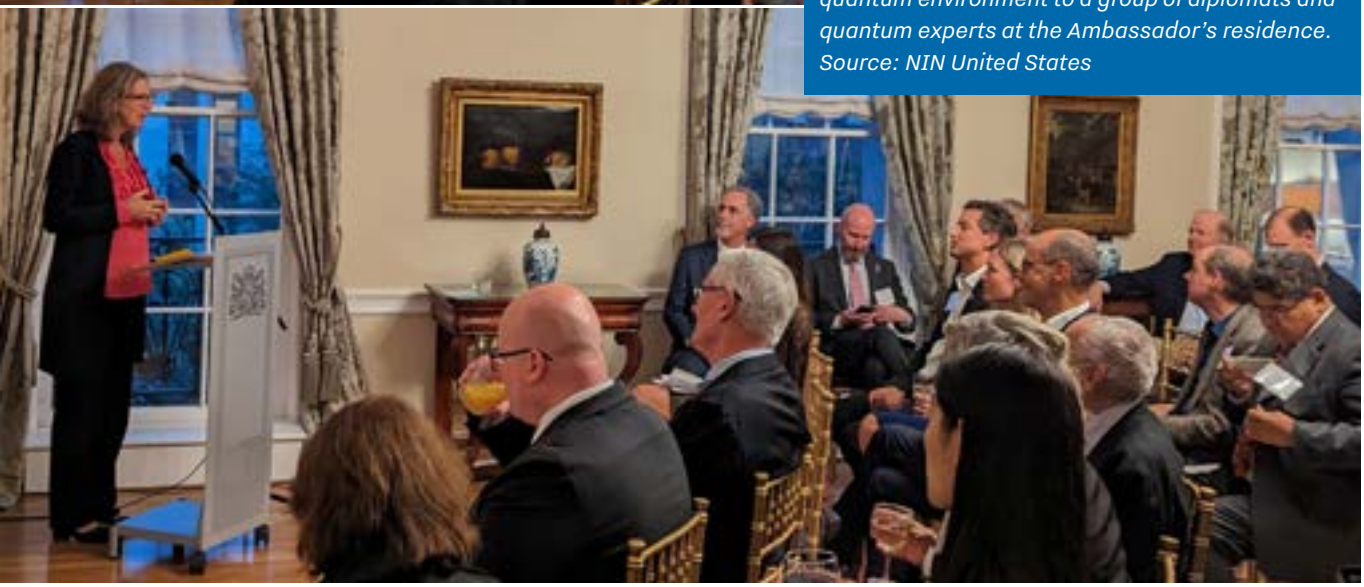
While the US leads in many areas of quantum research output, developing technical skills and a robust domestic workforce will be crucial for long-term success. Through the National Quantum Initiative Act, the government is aiming to help grow a diverse, skilled quantum workforce over the next decade that can fulfill growing demand across industry and laboratories. International talent is also seen as important for driving further progress.

> "The federal government's passage of major new technology legislation is expected to provide a further boost."

U.S. QIS R&D BREAKOUT BY PCA



Quantum World Congres, September 2023. Freeke Heijman for Quantum Delta NL and Ambassador Birgitta Tazelaar speaking on the NL quantum environment to a group of diplomats and quantum experts at the Ambassador's residence. Source: NIN United States



To accelerate commercialization, the strategy calls for deepening public-private partnerships and identifying high-impact applications. Industries eager to explore quantum opportunities range from aerospace to healthcare to logistics. Collaborations are already underway between tech giants, national labs, and startups to explore applications in fields like quantum chemistry, drug discovery and materials design.

The establishment of numerous government-backed quantum research hubs around the country is also helping to build vibrant regional innovation ecosystems. centers in Illinois, Colorado, Washington DC and Massachusetts anchor large consortia of academic, industry and government partners. Conferences and trade groups work to facilitate connections across these communities.

While investment has slowed this year due to economic headwinds, the federal government's passage of major new technology legislation like the CHIPS and Science Act is expected to provide a further boost. Billions in research funding will support activities like standardized infrastructure, expanded access to computing resources, and growing the quantum-ready STEM workforce pipeline.

As new nations begin developing their own quantum programs, the US strategy emphasizes maintaining international cooperation on research priorities while protecting economic and national security interests. Looking ahead, fully realizing the promise of quantum information science will require sustained investment and coordination across both public and private sectors.

The United States appears committed to playing a leading role in this emerging high-tech revolution.

Netherlands Innovation Network United States
Sean Silbert, Senior Advisor for Innovation, Technology and Science
sean.silbert@minbuza.nl

Leading the Way Towards a Quantum Future

Japan is an important player in the area of quantum technology, and a leader in translating technology into applications for society. The country has a pro-active government policy that places quantum as a key element in its future vision for social transformations in energy, life science, digitalization and others. Providers and users of quantum related solutions are working together towards such future. Industry and research organizations are collaborating in multiple programs and joint testbeds to develop quantum computers based on advanced software and precision hardware. Importance is placed on new industries and startups, innovation hubs and the development of human resources through public-private partnerships.

This article will shortly introduce different quantum technology-related programs in Japan, including the national quantum strategy (Cabinet Office), Q-Leap (MEXT), Moonshot Goal 6 (JST), RQC (RIKEN), G-QuAT (METI and AIST) and Q-Star (business consortium led by Toshiba). These programs show the country's high (fun-damental) research level, well developed cooperation between companies and research institutes, proactive government policies with long term objectives, strong focus on real-life benefits and applications, as well as excellent environment for international collaboration.

The vast number of these recent activities in Japan give various excellent opportunities for Dutch-Japanese cooperation over the whole value chain, and indeed several cooperations are ongoing. This article ends with activities by the Netherlands Embassy in Tokyo to further identify and realize such opportunities.

Kyoto University, and PhotonDelta signed a Memorandum of Understanding to further strengthen their cooperation in the field of integrated photonics. Source: Aki Takematsu

National Strategy

Japan is making significant strides in the field of quantum technology. In April 2023, the Japanese government published the Strategy of Quantum Future Industry Development. This strategy outlines a vision for a future society with quantum-based applications, focusing on research, vision, and industry collaboration.

Research is a key component of the strategy, building on the innovation strategy of 2020 to prioritize areas such as quantum computers, sensors, communication, cryp-tography, and international innovation hubs. The vision is centered around societal impact, economic security, and growth opportunities for Japanese industries in areas like mobility, finance, energy, and health. The industry is actively involved through support mechanisms for collaboration, start-ups, human resource development, public-private partnerships, standardization, and innovation hubs.

Q-leap

One of the key programs supporting quantum technology development in Japan is the Q-Leap program, overseen by the Ministry of Education, Science, Culture, Sport, Science and Technology (MEXT). This program, running from 2018 to 2027, focuses on quantum computers, quantum metrology & sensing, and next-generation laser technology. It also includes a Human Resource Development Program to nurture future leaders in quantum technologies.

Moonshot Goal

Another ambitious initiative is the Moonshot Goal 6 research program, coordinated by the Japan Science and Technology Agency (JST). This program aims to develop a fault-tolerant quantum computer by 2050 by focusing on hardware, networks, and software components. The program has set milestones to achieve an intermediate quantum computer with error correction by 2030 and a final universal fault-tolerant quantum computer by 2050.

The current phase of the Moonshot Goal 6 program involves twelve projects with a focus on various aspects of quantum technology development, including quantum computing, quantum interfaces, large-scale quantum hardware, and quantum error correction systems. These projects aim to achieve significant breakthroughs in quantum technology by increasing the number of physical qubits and developing scalable technologies for quantum computers.

The program has yielded promising research results in areas such as photonics, semiconductors, and software, with publications in renowned journals like Nature and Applied Physics Letters.

The program director, Prof. Masahiro Kitagawa of Osaka University, emphasizes the importance of international collaboration in achieving the program's goals and highlights the collaboration with leading research institutions like QuTech in the Netherlands.

RIKEN and Quantum Innovation Hubs

RIKEN, the national research institute, plays a central role in quantum-related activities in Japan through the RIKEN Center for Quantum Computing (RQC) and the network of Quantum Technology Innovation Hubs (QIH). RQC recently released Japan's first domestically produced quantum computer, positioning Japan alongside the US and Europe in quantum technology development. The QIH network consists of various innovation hubs focusing on quantum computing, quantum sensing, quantum communications, and quantum materials.

G-QuAT (AIST)

G-QuAT, established at AIST in July 2023, is a global research and development center focusing on quantum-AI technology. This center aims to explore practical use cases that combine quantum computing and classical computing technologies, with a special focus on increasing the number of qubits for quantum devices. The centre is running testbeds together with industry partners and has an annual budget of about €200 million.

Q-Star

Q-Star, a business consortium with 84 members, is actively working on developing use cases for quantum technology across various industries such as finance, mobility, and chemistry. The consortium aims to contribute to Japan's position as a quantum technology innovation nation and has signed agreements with international counterparts to grow the global quantum industry.

Opportunities for Collaboration

The vast amount of Japanese activities described above give many opportunities for the Netherlands. As part of its role and activities to develop bilateral cooperation in the field of quantum technology, the Netherlands Embassy in Tokyo is in close contact with all programs described in this article. Since 2021, these activities are integrated with those for semiconductors, photonics and nanotechnology (sometimes jointly referred to as ‘deeptech’). This is because of the many crossovers in topics and the fact that Japanese organizations are often active in all of these areas and also integrate related strategies and policies.

Therefore, the approach towards Japan is executed in close cooperation with Quantum Delta NL, Photon Delta NL, Hightech NL, national and regional governments, as well as the Dutch business and science community. Until summer 2023, the activities were broad and explorative, ranging from fundamental research to commercial applications and policies. In order to give updates and introductions about Dutch and Japanese programs, policies, stakeholders, we organized multiple online webinars and lab tours, on-site roadshows and exhibitions, Innovation Missions and matchmaking events, etc. In total between fifty and sixty Dutch organizations have joined these activities. Bilateral agreements were signed between governments, industries and academia, recognizing each other as important players and partners.

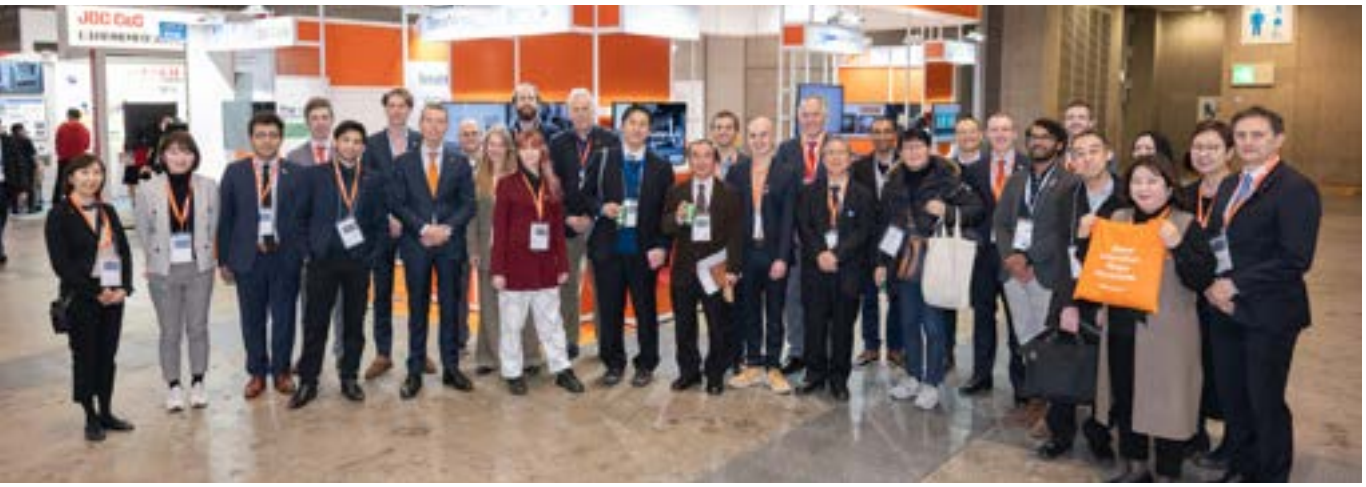
A number of bilateral cooperations are ongoing, such as the QuTech-Fujitsu joint project to develop a blueprint for a scalable quantum computer based on optically linked spin qubits, includes quantum algorithms with error correction codes. New opportunities for research cooperation are for example given by the JST Aspire program of the Japanese government.

In order to define a relevant multi-annual program, from September 2023 a Dutch stakeholder committee started with the aim to narrow down topics and activities that contribute to strategically connect both countries in the field. A recent activity was an incoming public-private delegation from Japan to the Netherlands at the beginning of 2024. There is still a lot of work ahead!

In conclusion, Japan is at the forefront of quantum technology development, with ambitious programs and initiatives driving innovation in the field. With a strong focus on research, collaboration, and industry partnerships, Japan is poised to make significant advancements in quantum technology and solidify its position as a global leader in the quantum industry.

See for more information:
www.rvo.nl/onderwerpen/buitenlandnetwerk/ia-netwerk/japan#publicaties

Netherlands Innovation Network Japan
Mihoko Ishii, Innovation Advisor
mihoko@hollandinnovation.jp



Quantum technology was a topic for several missions, expos and other activities in Japan.
Source: Aki Takematsu, NIN Japan

CANADA

€ 1.36 BILLION

UK

€ 2.15 BILLION

US

€ 3.04 BILLION

EU

€ 6.21 BILLION

GOVERNMENT FUNDING IN QUANTUM TECH 2023

- **CANADA** € 1.36 billion
- **US** € 3.04 billion
- **EU** € 6.21 billion
- **UK** € 2.15 billion
- **GERMANY** € 5.32 billion
- **FRANCE** € 2.05 billion
- **ISRAEL** € 362.3 million
- **QATAR** € 8.4 million
- **RUSSIA** € 661.9 million
- **CHINA** € 21.2 billion

Source: Global Quantum Intelligence LLC

SWEDEN

€ 136.4 MILLION

RUSSIA

€ 661.9 MILLION

JAPAN

€ 1.53 TRILLION

CHINA

€ 21.2 BILLION

QATAR

€ 8.4 MILLION

TAIWAN

€ 238.6 MILLION

AUSTRALIA

€ 82.6 MILLION

NEW ZEALAND

€ 30.9 MILLION

- > **SOUTH KOREA** € 44.2 million
- > **JAPAN** € 1.53 trillion
- > **TAIWAN** € 238.6 million
- > **AUSTRALIA** € 82.6 million
- > **NEW ZEALAND** € 30.9 million
- > **NETHERLANDS** € 774.3 million
- > **SWEDEN** € 136.4 million
- > **FINLAND** € 72.2 million
- > **DENMARK** € 28.8 million
- > **IRELAND** € 11.5 million

Growing Quantum Ties: Sweden and the Netherlands

The Scandinavian Quantum Legacy

Scandinavia has played a pioneering role in the development of quantum science, with Danish Niels Bohr being a founding father in quantum mechanics. Today, this legacy continues through various institutions and national initiatives in Sweden, positioning the country as a leader in quantum technology. Sweden, alongside Denmark and Finland, has established a strong foothold in quantum research, supported by both academic and industrial sectors. The Swedish ecosystem is heavily invested in quantum computing, sensing and communication technologies, and efforts are supported by the Swedish government and large private foundations such as the investments of the Wallenberg family, one of Sweden's leading industrial and entrepreneurial families. Moreover, collaborations with international players, including the Netherlands, are critical to the further advancement of these technologies.

Wallenberg Center for Quantum Technology (WACQT)

At the heart of Sweden's quantum ambitions lies the Wallenberg Center for Quantum Technology (WACQT), a major Private Public initiative housed at Chalmers University. Funded by the Knut and Alice Wallenberg Foundation with SEK 1 billion (€90 million), WACQT's primary goal is to build a 100-qubit quantum computer. This 12-year project also aims to develop Swedish expertise in quantum computing. While the long-term goal is to develop a scalable quantum computer that could surpass classical supercomputers, WACQT also emphasizes collaboration with industry partners and international institutions. Among these partners is Qblox, a Dutch scale-up company specializing in quantum control stacks. Qblox has partnered with WACQT to support the Swedish quantum computing efforts with modular control systems that can be scaled for larger quantum machines. This cooperation was confirmed in the presence of Carl XVI Gustaf, King of Sweden, in a Memorandum of Understanding during the recent Swedish Royal Technology Mission to the Netherlands. This partnership is another example of the growing ties between Sweden and the Netherlands in the field of quantum research.

Swedish Leadership in Quantum Sensing and Computing

Beyond quantum computing, Sweden is also at the forefront of quantum sensing and communication technologies. Karolinska Institute, KTH, and Lund University are leading institutions in these fields. Quantum sensing, in particular, offers Sweden a unique opportunity in fields like healthcare and environmental science. Research at Lund University focuses on creating sensitive measurement instruments that can revolutionize industries ranging from medicine to geology.

QSIP

An important enabler of these efforts is the Swedish government-funded Quantum Science and Innovation Program (QSIP), which coordinates quantum research across academia and industry. QSIP is vital in bringing together companies like Volvo and Ericsson with academic institutions to explore quantum applications in communications, logistics, and more. To date, QSIP has fostered several successful spin-offs, with nine Swedish quantum start-ups now operating in the ecosystem. The recently held QSIP Annual Meeting showcased the country's growing role in this global revolution.

Sweden has a strong position in the early application of quantum technology in three main areas, Life Sciences and Health, as well as in industrial applications in the automotive and telecoms industries.

Quantum's Role in Life Sciences

One of the most exciting applications of quantum technology is in life sciences. In this domain, Swedish company Elekta has taken a leading role. Elekta, in partnership with the Quantum Application Lab (QAL) in

Carl XVI Gustaf King of Sweden visits Quantum Delta during the Swedish Royal Technology Mission (RTM) to the Netherlands in May 2024. Source: Erik Cronberg

"Sweden has established a strong foothold in quantum research."

Amsterdam, is exploring how quantum algorithms can improve the processing of medical imaging data. The project focuses on using quantum computing to speed up complex data processing tasks in MRI scanning, which could lead to more efficient and accurate cancer treatment. This partnership highlights the tangible benefits of Dutch-Swedish collaboration in applying quantum technology to healthcare.

Automotive

Sweden's robust industrial sector, particularly the automotive industry, is also looking to capitalize on quantum technology. Volvo is actively researching quantum applications to optimize logistics and improve secure communications within its supply chain. As a member of QSIP, Volvo A.B. is a key player in the push to commercialize quantum solutions in Swedish industry.

Telecommunication

Ericsson, the renowned Swedish telecom company, is investigating how hybrid classical quantum centers will work in the future. 6G will rely heavily on edge computing, meaning that 6G devices will no longer compute data but send them over a quantum-protected connection to a data center, where, depending on the tasks, some will be performed by quantum computers and others by classical computers.

Strengthening Dutch-Swedish Collaboration

As Sweden continues to push forward in quantum technology, collaborations with key international partners like the Netherlands will be essential. The Netherlands Innovation Network Sweden serve as facilitators of these partnerships, monitoring and enabling joint projects that drive innovation in both countries. In particular, we see collaboration opportunities in quantum applications in LSH, industrial applications and in deep tech start-ups. For policymakers and researchers in the Netherlands, these growing ties represent a fertile ground for future collaborations in quantum computing, sensing, and industrial applications. To learn more about the quantum ecosystem in Sweden or to explore collaboration opportunities, the Netherlands Innovation Network Sweden or the organizations below are your points of reference.

For more information, check out the following links:
Wallenberg Center for Quantum Technology (WACQT)
Quantum Application Lab (QAL)
QSIP
QSIP Annual Quantum Day
Quantum Delta
Qblox

Netherlands Innovation Network Sweden
John Dekker, Innovation Counsellor
john.dekker@minbuza.nl

India Invests Strategically in the Future of Quantum

In January 2024, India announced it is investing $740 million over an eight-year span for its national quantum mission.
Source: AdobeStock

Recognizing that quantum technologies are crucial to its future competitiveness, India has increased investments and programs related to quantum in recent years. With ambitions to become a world leader in this emerging field, the country is actively working to build its quantum ecosystem by focusing on research, skills development and commercializing quantum solutions. Some of the key initiatives in India include the National Quantum Mission launched in 2020, which aims to invest about $1 billion over the next decade in developing fundamental science, enabling technological development and strengthening human and infrastructural resources. The goal of the mission is to transform quantum research into market-ready products and services.

An incomplete list of academic and research institutes where theoretical and experimental research in quantum computation is carried out.

- Bose Institute - Kolkata
- The Harish-Chandra Research Institute (HRI) - Allahbad
- IISER Mohali
- IISER Pune
- IISER Thiruvananthapuram
- IIT Chennai
- IIT Kanpur
- IIT Mumbai
- IIT Hyderabad
- IIIT Hyderabad
- The Institute of Mathematical Sciences - Chennai
- Indian Statistical Institute (ISI) - Kolkata
- Physical Research Laboratory (PRL) - Ahmedabad
- Raman Research Institute (RRI) - Bangalore
- SN Bose Centre - Kolkata
- Tata Institute of Fundamental Research (TIFR)
- University of Calcutta - Kolkata

Leading the effort is the Department of Science and Technology (DST), which established the pioneering Quantum-Enabled Science and Technology (QuEST) program to support early experimental research. Several other ministries are also involved, demonstrating high-level coordination among various stakeholders.

Quantum Computing

On the institutional front, a number of universities and national laboratories are making progress in quantum computing research. The Indian Institute of Science in Bangalore focuses on quantum algorithms and information theory. The Institutes of Technology in Madras and other cities also have active programs. Now that the academic foundation is in place, India is working to improve cooperation between universities, companies and startups.

To this end, new centres such as the Quantum Computing Applications Lab through a MeitY-AWS collaboration and the I-HUB Quantum Technology Foundation, supported by DST and several research

> “Going global will be important for India if it wants to become a major quantum player.”

groups, have been set up recently. Defense laboratories are also getting involved: the Defense Institute of Advanced Technology and the Center for Development of Advanced Computing are collaborating on the development of quantum technology.

Indian companies, both large and small, are also engaged in this emerging field. IT giants such as Infosys, TCS and Wipro are exploring quantum applications and launching training programs. Startups in the quantum domain are making progress with indigenous intellectual property in areas such as quantum communications, photonics and computing platforms.

Strategic Partners

Going global will be important for India if it wants to become a major quantum player. There is already cooperation between Indian and Dutch players, given their existing strategic partnership in science and innovation. Possible openings for closer cooperation include skills and mobility programs, joint R&D in quantum communications and computing, collaboration in the growing 'quantum photonics' sector due to shared strengths in this area, and setting up innovation missions linking the two ecosystems.

Netherlands Innovation Network India
Dhoya Snijders, Innovation Counsellor
dhoya.snijders@minbuza.nl

France's Ambitions for Europe Match Those of the Netherlands

France has ambitious plans to become a frontrunner in the development of quantum technology. With billions invested in research, startups, and strategic partnerships, the country is positioning itself to play a key role in the rapidly growing quantum sector.

On April 12, 2023, during President Macron's state visit to the Netherlands, the innovation pact between France and the Netherlands was signed. During a roundtable discussion, in the presence of His Royal Highness Willem-Alexander, both President Macron and Minister Micky Adriaansens underlined the importance of cross-border cooperation in maintaining and strengthening the technological leadership position in deep technology.
Source: Universiteit van Amsterdam / Freek van den Bergh

Building a Quantum Powerhouse

In 2021, French President Emmanuel Macron kickstarted a €1.8 billion "quantum plan" spanning five years. The goal is to build a thriving quantum ecosystem with 30,000 new jobs created by 2030. Massive government funding supports research at leading institutes like CEA and CNRS while nurturing the thriving startup scene. Over a dozen quantum companies have emerged, with Flagships like Pasqal developing programmable quantum simulators and Alice & Bob working on fault-tolerant qubits. Strategic collaborations with investors and industrial players like Thales and Airbus are also driving progress.

A Bilateral Benchmark

France has recognized that pooling resources with like-minded partners amplifies impact. In 2021 it cemented the world's first bilateral quantum cooperation with the Netherlands. Both countries committed over €2 billion to joint research, entrepreneurship and policy alignment. This paved the way for an even broader trilateral accord including Germany in 2022. By coordinating strengths across borders, the alliance aims to accelerate progress and compete globally.

A Hub of Quantum Talent

With its large education and skills initiative, France is growing the workforce needed to realize its quantum vision. It aims to train over 5,000 professionals by 2025, including doubling the number of graduate students. Promoting accessibility, key figures like Nobel Laureate Alain Aspect and Quantonation founder Christophe Jurczak support commercialization and mentor new players. Along with major research centers, this virtuous cycle of skills and jobs underpins France's emergence as a quantum talent powerhouse.

Pushing the Frontiers of Research

Excellence in fundamental quantum physics and computing has long positioned France as an R&D leader. Breakthroughs at CEA and other institutes underpin today's quantum revolution. Now large-scale PEPR

> “The goal is to build a thriving quantum ecosystem with 30,000 new jobs created by 2030.”

research programs directly support frontier work pushing the boundaries. For instance, advances from groups like X at the École Polytechnique could enable France to deliver on its goal of developing prototype universal quantum computers before 2025. If successful, this would grant it first-mover advantage in the high-stakes race for quantum supremacy.

Driving Quantum-Enabled Innovation

With its quantum plan fully integrated into the wider €54 billion France 2030 strategy, the country is primed to harness transformative applications. Industrial players like Airbus, TotalEnergies and Thales are already exploring uses in optimization, materials science and beyond. The influx of startups will also commercialize quantum solutions across sectors like healthcare, energy, manufacturing and cybersecurity. If it realizes this full innovation potential, France could establish global leadership across the quantum value chain for decades to come.

In Summary

Through ambitious national strategies, strategic partnerships and world-class research institutions, France is emerging as a quantum force to be reckoned with globally. With continued support, the country is well-positioned to achieve prime objectives like developing prototype universal quantum computers ahead of schedule. Long-term, its aim is to establish a competitive quantum industry and reinforce technological sovereignty in key future technologies. France, if working with European partners, can succeed in building a European quantum economy with global impact.

Netherlands Innovation Network France
Stefan Koreneef, Innovation Counsellor
par-ia@minbuza.nl

The OrangeQS team assembling the OrangeQS MAX. Source: Titia Hahne

Testing Quantum Chips: An Essential Link in the Quantum Chain

Orange Quantum Systems steps in where major quantum chip manufacturers leave a gap: in the chip testing phase. Adriaan Rol, along with his team, develops systems for testing quantum chips, making the startup a notable international player. Recently, it launched the world's first industry-scale quantum chip test machine.

The first customer is Finnish-German quantum computer builder IQM. They achieved this milestone with a €2.5 million EIC grant, on top of investments by VC's CottonWood Technology Fund, QDNL Participations and the regional economic development agency InnovationQuarter.

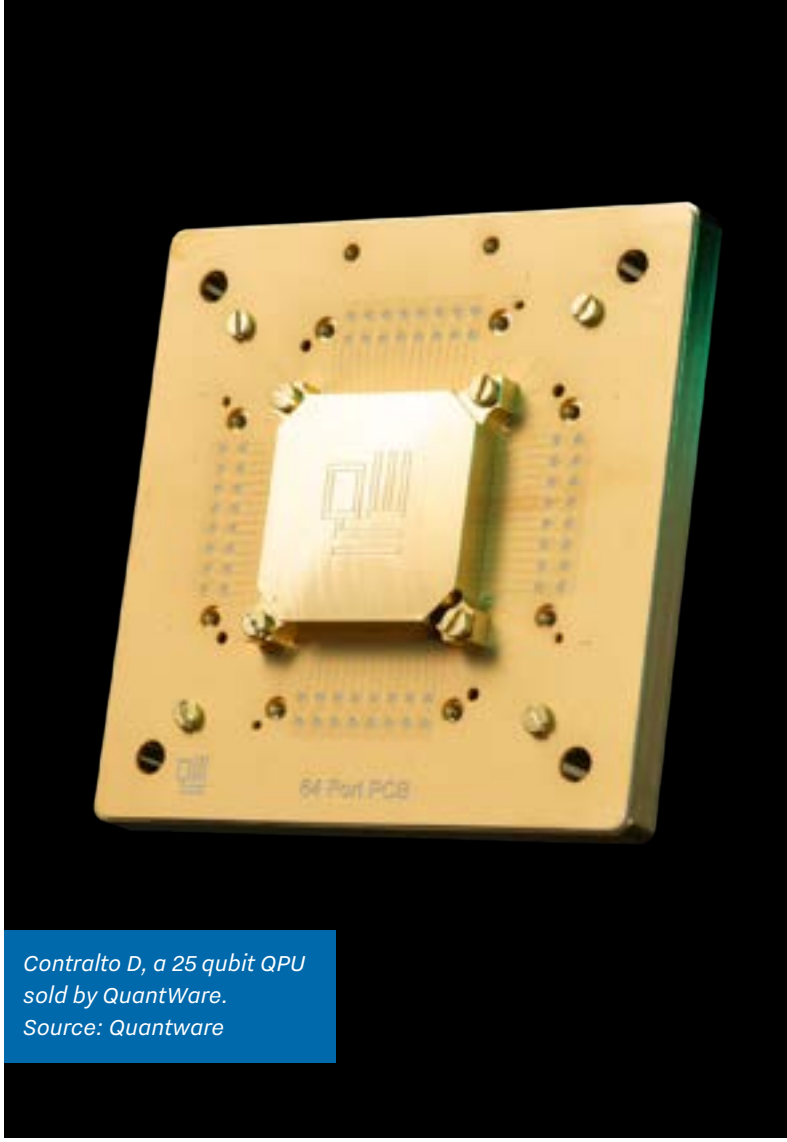
With this €2.5 million grant, the EIC aims to stimulate innovative technology that can put Europe on the map. "Developments in quantum technology are progressing rapidly worldwide, and we are keeping pace with them. Quantum computers have tremendous potential, but the chips need significant improvement to be commercially viable. The quality of the individual quantum bits (qubits) of the chips needs to improve, and their quantity must increase. The more qubits, the more computing power. Our solutions provide insights into this: how well does the chip work, and where are further improvements possible? To observe these quantum effects, the chip is cooled in an advanced refrigerator to 20 millikelvin and then tested using a specially built quantum chip testing machine. In November 2024, we launched the OrangeQS MAX, the first system capable of testing quantum chips with more than 150 qubits on an industrial scale. At the moment, we are deploying the system to the quantum chip fabrication site of our launching customer and Finnish-German quantum computer builder IQM."

Orange Quantum Systems collaborates extensively with other Dutch parties and suppliers. "Our refrigerators come from a Dutch company, as do our control electronics and cables. Most of our value chain is here in the Netherlands. That's unique in the world. We're a true trading nation and know how to weave ourselves into everything by cleverly addressing critical components in the quantum chain. Like what we do with our testing systems. We are the first and only company in the world to develop and sell them. That adds value to the Dutch economy and the position of our country and Europe as a whole."

Adriaan Rol
Executive director and founder
Orange Quantum Systems

Matthijs Rijlaarsdam
CEO QuantWare

The Essential Piece for Quantum Computers



Contralto D, a 25 qubit QPU sold by QuantWare. Source: Quantware

What do you do when you want to accelerate the development of quantum computers? You specialise in one crucial component of the quantum process, decided QuantWare. Now, about three and a half years after its founding, the startup is the world's only specialist in quantum chip production. Together with his team, CEO Matthijs Rijlaarsdam is working on their mission to accelerate the advent of the quantum computer.

In other words, they aim to ensure that we reach the point where quantum computers start doing something useful as quickly as possible. "Quantum computers currently are not big enough to do economically relevant calculations. Despite billions of investment, none of the leading players have the scaling technology you require to make these chips of a size that they will change the world of compute. We are developing VIO, which does unlock this. By specialising, you can much quicker develop such a complex technology. We build up a global customers base (19 countries and counting) very quicky after we started, and we have now started rolling VIO out to initial launching customers. When we make VIO more mainstream in the coming years, you will really see the field accelerate."

QuantWare is part of the ecosystem of Quantum Delta NL, where they receive significant support. They have partnerships with other tech companies worldwide, predominantly in the US. "We are able to attract the world's best talent to QuantWare. That is really the key differentiator: the exceedingly rare minds we have in our team!"

Singapore Strives to Become (South East) Asia's Quantum Hub

Innovation mission visit to satellite-based QKD startup SpeQtral. Source: SpeQtral

Singapore is making significant investments in quantum technology to strengthen its position as a Smart Nation and ensure its future earning potential and international relevance. With limited natural resources, the country is focusing on applied research and development in key-enabling technologies, including quantum technology. By investing in quantum technology, Singapore aims to be part of the global quantum ecosystem and create a highly strategic value chain.

The Centre for Quantum Technologies (CQT) at the National University of Singapore (NUS) has been at the forefront of Singapore's quantum research efforts. Over the last 15 years, approximately SG $250 million (€170 million) has been invested in the establishment of CQT. Singapore's strategy is to position itself as a living lab and pilot ground for emerging technologies, attracting global talent and focusing on application-driven research to quickly realise economic value.

Quantum computing and communications are part of Singapore's national Research, Innovation, and Enterprise 2025 5-year plan, with a budget of SG$26 billion (€16 billion) allocated by the National Research Foundation (NRF). The plan emphasises quantum communication and key distribution, sensing and imaging, and algorithms as areas of focus. The CQT, celebrating its 15th anniversary in 2022, is set to become a national centre by 2024 and align its research agenda with Singapore's national quantum strategy.

Funding for quantum research in Singapore comes from external grants, the Ministry of Education (MOE) support, and the NRF RIE2025 budgets. The funding supports not only CQT but also research groups at other Institutes of Higher Learning and two major research programmes: the national Quantum Engineering Program (QEP) and the Quantum Technologies for Engineering Programme. These programmes aim to leverage quantum technologies to solve real-world problems and build a quantum ecosystem of researchers and industry partners.

Singapore's quantum ecosystem includes collaborations with both local and international partners. Several start-ups in Singapore are active in the field of quantum technology, focusing on applications such as quantum sensing, quantum control instruments, space-based quantum communication, quantum software, and quantum optimisation. Many of these start-ups receive investments from government holdings and funds.

Singapore's Defence Science Organization (DSO) has also taken an active role in cultivating capabilities and knowledge in quantum technologies, particularly in quantum sensor technologies for navigation and surveillance. DSO receives direct funding from the Ministry of Defence and collaborates with HTX (Homeland Science and Technology Agency) in building a national quantum-safe network.

Singapore's quantum public and private ecosystem collaborate through platforms such as the National Quantum Computing Hub (NQCH), the National Quantum Fabless Foundry (NQFF), and the National Quantum-Safe Network (NQSN). These platforms involve

“Singapore aims to strengthen its position as a Smart Nation.”

government partners, local industry, and international partnerships with renowned research institutes and companies.

The launch of Singapore's National Quantum Safe Network (NQSN) in 2022 marked a significant mile-stone in the country's efforts to develop quantum-safe communications technologies. The Infocomm Media Development Authority (IMDA) has announced the NQSN Plus (NQSN+) platform, which will support multiple network operators in deploying quantum-safe networks nationwide. The platform aims to provide businesses with easy access to quantum-safe solutions to safeguard their critical data and explore different use-cases across industries.

IMDA is also working on standardisation in quantum-safe technologies and has signed collaborations with international partners to drive standardisation efforts. Singapore and Japan are co-leading the standardisation of the Quantum Key Distribution protocol framework at the International Telecommunication Union, and an MoU has been signed with South Korea's NIA to increase bilateral cooperation.

There are opportunities for collaboration between Singapore and the Netherlands in the field of quantum technology. Singapore's interest in trialing applied innovations aligns with the expertise and offerings of Dutch start-ups in quantum modules. Coloperation can also focus on hardware development, protocols, and standards for the national testbed and commercial space-based quantum communication. Both countries can learn from each other's experiences in advancing quantum applications and implementing them to address societal challenges and drive industry adoption.

In conclusion, Singapore's investments in quantum technology aim to strengthen its position as a Smart Nation and secure its future earning potential. The country's focus on applied research and development, collaboration with local and international partners, and the establishment of quantum platforms demonstrate its commitment to becoming a quantum hub in Southeast Asia.

This article provides a glimpse into Singapore’s efforts to become a quantum hub and highlights the potential for collaboration with the Netherlands. To read the full article, click *here*.

Netherlands Innovation Network Singapore
Astrid Seegers, Head of Innovation
José Snoep, Advisor for Innovation, Technology and Science
SIN-IA@minbuza.nl

QUANTUM COMPUTING

IMPACT ON APPLICATIONS AND INDUSTRIES

CHEMISTRY

CRYPTOGRAPHY

MACHINE LEARNING

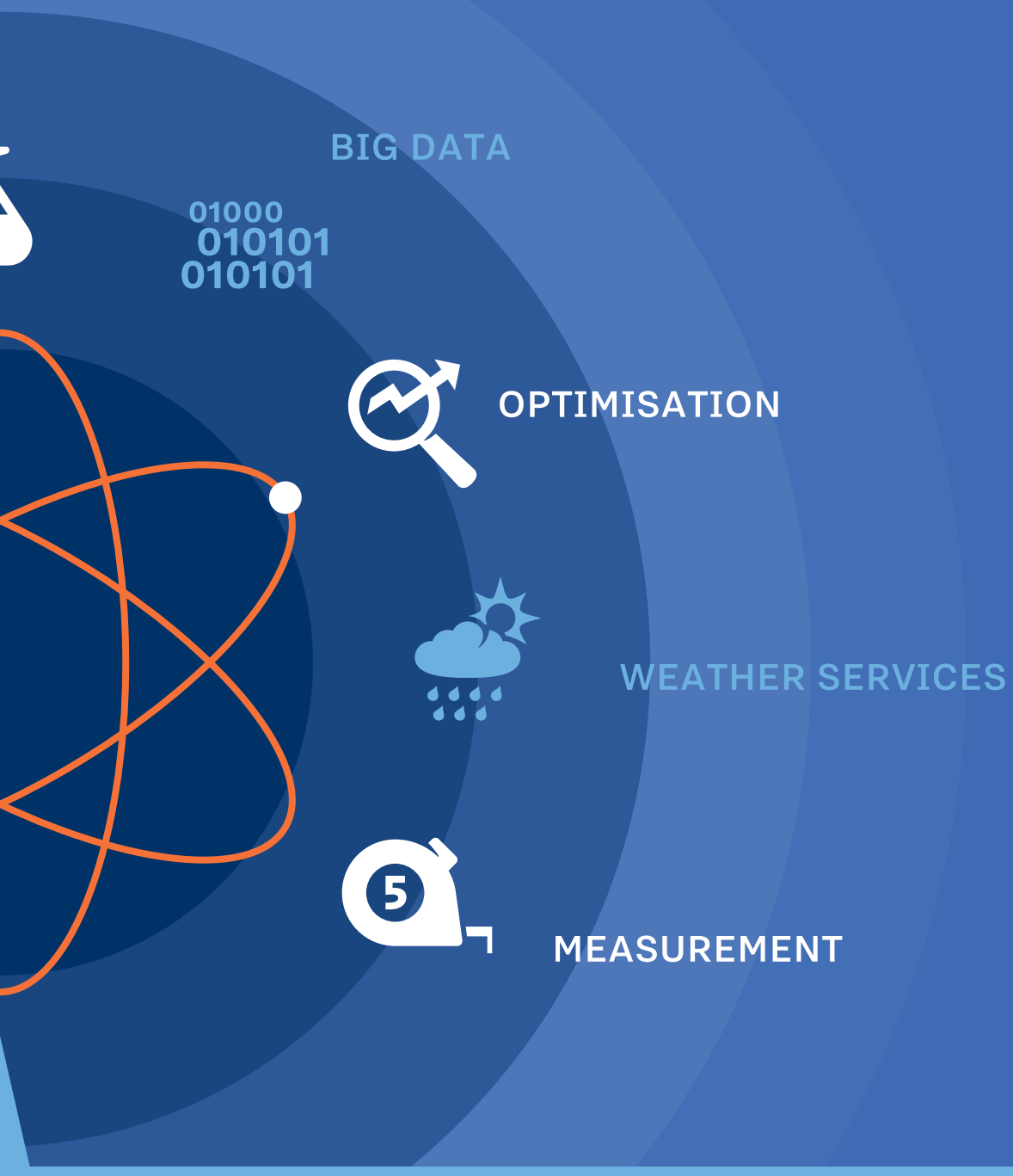
MATERIALS SCIENCE

GOVERNMENT
e.g. Support deep cryptoanalysis of critical data

PHARMACEUTICALS
e.g. Develop new drugs and treatments

TELECOMMUNICATIONS
e.g. Enable secure communications across networks

TRAVEL & TRANSPORTATION
e.g. Design new vehicles and transport systems



MANUFACTURING & INDUSTRY
e.g. Develop new materials and processes

FINANCIAL SERVICES
e.g. Predict market trends and risks

Development of Quantum Technologies in Taiwan

Kick-off meeting of the project 'Hybrid integrated photonic components for optical quantum computing', funded by NSTC and NWO in Taiwan, June 2023
Source: NIN Taiwan

Taiwan is making significant strides in the development of quantum technologies, positioning itself as a leader in the field. The Taiwan government plans to invest NT $8 billion ($288.2 million) from 2022 to 2026 to create an industry cooperation platform for quantum technology. This investment aims to propel Taiwan to the forefront of new-generation quantum technology competitors and create the next semiconductor miracle.

To accelerate the development of quantum computing, a research team comprising 72 experts and 24 enterprises has been formed. This cross-departmental task force, known as the Quantum National Team, consists of Academia Sinica, the National Science and Technology Council (NSTC), and the Ministry of Economic Affairs (MOEA). The team focuses on quantum devices, algorithms, computing, and communication.

Academia Sinica will establish a quantum research base in Shalun, Tainan, with a focus on constructing a quantum experimental building and core facilities. The Ministry of Economic Affairs, through its subsidiary ITRI, will develop low-temperature control circuit processes and key components. The goal is to connect these core quantum technology developments to the industrial sector through collaboration with industry-academia-research teams.

Strengths of Taiwan in the Global Quantum Ecosystem

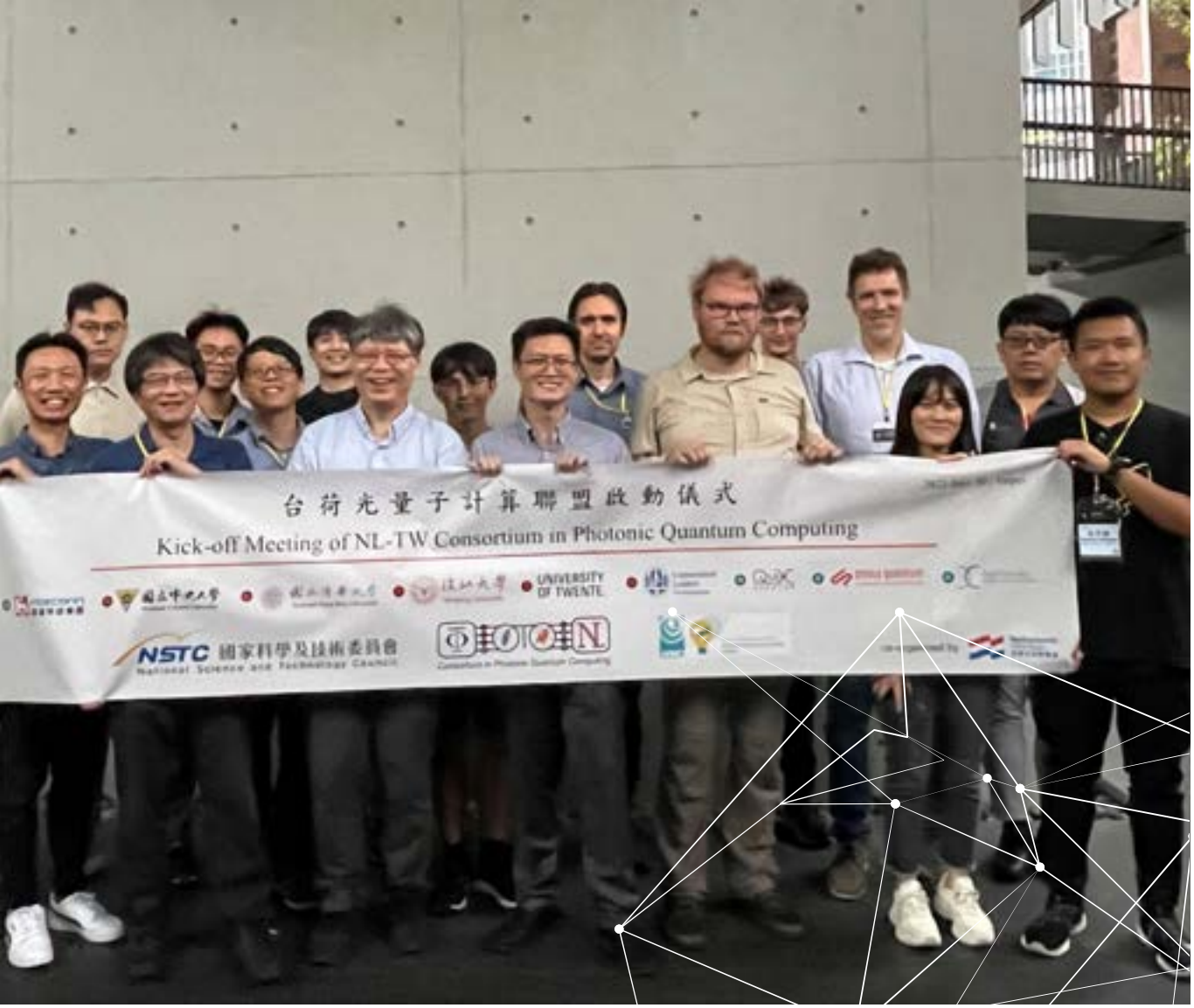
Taiwan's strength in the global quantum ecosystem lies in its strong foundation in the semiconductor industry. The country has extensive experience and expertise in chip manufacturing, management, materials, testing, and infrastructure. This advantage allows Taiwan to leverage its existing resources in the development of quantum computing.

While Taiwan excels in chip manufacturing, there has been a relative limitation in research and development. However, with the increasing demand for cutting-edge technologies, the emphasis on basic research is becoming crucial. The Taiwan National Quantum Computing Research Team aims to build a comprehensive research and development framework from upstream to downstream. Collaboration with institutions like ITRI and TSRC, along with industry linkages established by the Ministry of Economic Affairs, will promote integrated development in quantum components, computing, algorithms, and communication.

Exploring Collaborative Opportunities Between Taiwan and the Netherlands

Taiwan and the Netherlands have significant potential for collaboration in the field of quantum computing technologies. Taiwan and the Netherlands have complementary strengths and expertise that can be leveraged for mutual benefit.

In the area of universal quantum computer hardware, Taiwan's expertise lies in superconducting circuit quantum computing and silicon-based quantum computing. The collaboration between Taiwan's National Quantum Computing Research Team and



“Taiwan and the Netherlands have significant potential for collaboration.”

Delft-based QuantWare, a startup specialising in large-scale superconducting quantum processors, holds promise. The goal is to advance superconducting qubit technology and scale up silicon qubits for silicon-based quantum computing.

Photonic quantum computing is another promising field for collaboration. Joint projects and initiatives can be explored to advance quantum photonic devices, quantum communication, and quantum networking. By joining forces and leveraging each other's expertise, Taiwan and the Netherlands can make substantial contributions to the advancement of quantum technology.

In conclusion, Taiwan is actively investing in the development of quantum technologies and forming strategic collaborations to drive innovation in the field.

With its strong foundation in the semiconductor industry and the potential for collaboration with countries like the Netherlands, Taiwan is poised to become a key player in the global quantum ecosystem.

Read more in the report Global Quantum Technologies Development and Strategies, with regards to the Netherlands & Taiwan Joint Research Opportunities on Innovations in Quantum Technologies by Industrial Technology Research Institute (ITRI)

Reach out to *TAI-IA@nlot.org.tw* if you would like to learn more about this report.

Netherlands Innovation Network Taiwan
Anouk van der Steen, Innovation Counsellor
anouk-vander.steen@nlot.org.tw

Inauguration of the Latin America Quantum Computing Center at Senai Cimatec in Belém in May 2021. Source: Courtesy of Valter Pontes/ Coperphoto/Sistema FIEB

Building a Dynamic Quantum Innovation Ecosystem

Brazil's recent investments in quantum technology are aimed at private sector innovation. This includes establishing the Latin America Quantum Computing Centre and a new EMBRAPII Competence Centre. The Brazilian quantum community is formulating a strategic roadmap that advocates the use of quantum technology for short-term economic and societal benefits, especially in fields like quantum sensing and communication for agriculture and healthcare. Private sector investments are pre-dominantly focused on oil, gas, and banking.

Brazil's quantum technology strategy is a component of the wider Policy for Scientific and Technological Development and Innovation for Enabling Technologies, issued in 2021 by the Ministry for Science, Technology and Innovation (MCTI). The policy encourages R&D, innovation, entrepreneurship, networking, infrastructure sharing, and international collaboration. While lacking specific actions or budgets for quantum technology, the ministry has launched various initiatives:

- The Network for Quantum Technology, partnered with SOFTEX, links government, research institutes,

and the private sector to support the quantum computation ecosystem. Coordinated by SENAI CIMATEC in Salvador, it hosts the Latin America Quantum Computing Centre, in partnership with Atos, featuring a supercomputer running a 35 Qubits quantum simulator.
- Investment of over €11 million in a new Competence Centre for quantum technologies, facilitated by EMBRAPII, an innovation funder linked to the ministry.
- Concession of 250 (post)graduate scholarships for quantum computing and photonics, administered by the ministry's research funding agency CNPq.
- Investment of about €4 million in a superconductor production facility for quantum computing and communication at the Brazilian Centre for Physics Research (CBPF) in Rio de Janeiro, funded by the ministry´s innovation funder FINEP.
- Funding research projects on quantum internet through Strategic Research for Internet calls for proposals, in collaboration with the Ministry of Communication, the Brazilian Internet Steering Committee (CGI) and the São Paulo Science Foundation (FAPESP).

"The Brazilian quantum community is formulating a strategic roadmap."

Consistent funding of basic science over the past 25 years has established a strong presence in quantum-related fields, including nuclear physics (open quantum systems) and optics, across multiple institutes and universities. The National Institute for Science and Technology in Quantum Informatics (INCT-IQ), led by the Federal University of Rio de Janeiro (UFRJ) and funded by CNPq and the Rio de Janeiro Science Foundation (FAPERJ), unites 29 institutions and about 120 leading researchers nationwide. The INCT-IQ is actively engaged in quantum encryption, communication, optics, and computation, having published over 1,100 papers to date.

In 2020, São Paulo researchers initiated QuInTec for a strategic quantum technology programme funded by the São Paulo Science Foundation. In early 2023, the Brazilian quantum community gathered for Quantum Technologies, introducing the Quantum Delta NL model. Objectives include promoting private sector and academia collaboration, attracting talent, and enhancing international competitiveness. Key areas for short-term benefits are quantum sensing and communication, particularly in agriculture, health, energy, and banking.

Some examples of ongoing publicly funded R&D projects related to sensing and communication:

- Rio Quantum Network: Developing a quantum communication network among three universities and a research institute in Rio de Janeiro, coordinated by Fluminense Federal University (UFF) in Niterói.
- Second-generation quantum technology: Developing single-photon emitters in 2D materials and quantum sensors for applications such as subsoil mapping, coordinated by the Federal University of São Carlos (UFSCAR).
- Enhancing X-ray imaging: Developing applications for enhanced imaging using quantum-correlated X-ray photons for the Brazilian Sirius facility's beamlines, coordinated by the University of São Paulo (USP).
- Routing protocols: Developing routing algorithms and protocols for quantum communication networks, coordinated by the Federal University of Pará (UFPA) in Belém.

Brazil's strong research has spawned several startups in second-generation quantum technology like Dobslit, based in São Carlos, offering Quantum Computing as a Service, and NtropiQ, also in São Carlos, developing optimisation algorithms for platforms like D-Wave and AQT. Other startups include Quantuloop, part of NVIDIA´s Inception Programme, and Quanby, a spin-off from the Federal University of Santa Catarina.

Major Brazilian banks like Itaú and Bradesco have joined the IBM Quantum Network to explore the potential and risks of quantum technologies. Bradesco is also adopting quantum-safe cryptography through IBM Quantum Safe Explorer. Additionally, the Brazilian Central Bank has studied 'post-quantum' cryptography to secure the country's PIX instant payment system, amidst advances in Open Finance.

The oil and gas sector, including Petrobras in Brazil, is also investing in quantum technology. Petrobras funds research on quantum algorithms for seismic geophysics and quantum memory development at the Brazilian Centre for Physics Research to support networks like the Rio Quantum Network.

Netherlands Innovation Network Brazil
Ernst-Jan Bakker, Education and Science Counsellor
Robert Thijssen, Innovation Counsellor
sao-ia@minbuza.nl

Ingrid Romijn
Co-founder and CEO
of Q*Bird

Dutch Quantum Technology Takes Flight

*Q*Bird Falcon*
*Source: Q*Bird*

It will probably still be years before quantum computers are commercially available. Nonetheless, Q*Bird is already entering the market with a fully operational system for network security based on quantum communication. The concept was developed by TU Delft (via QuTech), and in 2022 the startup spun off to further commercialise the technology. Co-founder and CEO Ingrid Romijn sheds light on this unique Dutch product.

Q*Bird's system establishes a secure connection between two users through a quantum link, allowing organisations to exchange information securely. If the connection is overheard by a third party or if the connection is attacked, the quantum entanglement link between the two computers is broken. "Our system can detect such eavesdropping. The data transmission or communication can then be halted. The possibly intercepted quantum keys used to secure the data transfer can be destroyed. This ensures that unsecured data is never sent. The data connection between two companies or organisations is therefore untappable. Our systems do not store data themselves, so they cannot be intercepted or hacked. Furthermore, it's quantum future-proof: in the future, our system can also connect quantum devices such as quantum computers."

The product can be easily scaled up to larger networks. In the port of Rotterdam, the system is currently being tested on a larger scale between five locations. "The port is a vital infrastructure for the Netherlands where many different parties exchange data that needs to be properly secured. It's the perfect environment to further test and build out the technology."

The technology holds great promise, and the potential market is enormous. Ingrid Romijn explains, "our mission is to provide quantum networking equipment for the current and future internet. Today, we build devices for quantum-secured data communications. Tomorrow, we will enable general-purpose quantum connectivity."

Learning Through Experimentation with Quantum Technology

The aviation industry is constantly on the look-out for new technological developments. And that includes quantum technology. What possibilities do quantum computers offer? And what threats might be looming? Jeroen Mulder works in the IT & Technology Innovation department of Air France-KLM, and he keeps a close eye on it all.

KLM AIRBUS A321 Neo
Source: KLM

Quantum computers can handle great complexity in logistical challenges. In the future, they could assist KLM in tasks such as flight planning and personnel scheduling. These computers take into account far more factors than current systems do, both within and outside the organisation. Think of aircraft breakdowns, staff dropping out due to illness or major airport disruptions. "Thanks to the Quantum Application Lab (QAL), part of the Quantum Delta NL programme, we were able to conduct low-threshold experiments with quantum technology."

The QAL experiment has made KLM more aware of the possibilities. "We are looking at our existing operational challenges through a different lens. This has given us new insights and inspiration that we are already benefiting from. The real big breakthroughs in quantum computing will only happen later, when quantum technologies — computers and software — are widely commercially available. By experimenting now, the potential transition to quantum technology in the future will be less daunting and disruptive. We continue to follow developments with keen interest.

In the coming years, we will work hard to make our computer systems quantum-proof and safeguarding our data. Security must be able to withstand attacks from quantum computers, which are capable of breaching many existing security codes. We must prepare ourselves with so-called post-quantum cryptography."

Dr. Jeroen Mulder
IT Innovation Project Manager
Air France KLM – IT&Technology Innovation department

Korea's Quantum Future: Ambitious Plans and Growing Global Partnerships

Korea has invested heavily in developing quantum technologies and plans to become a global leader over the next decade. With billions budgeted for research and development as well as initiatives to foster international collaboration, Korea aims to play a major role in realizing the promise of quantum computing and related fields.

Early Investments and Building Capabilities Korea started investing in quantum research back in 2012 with the establishment of the Korea Institute of Science and Technology's specialized quantum program. Major government funding ramped up in 2019 with KRW 44.5 billion over 5 years to boost core technologies like hard-ware and explore new areas like algorithms and soft-ware. Korea recognized quantum's potential for both economic growth and national security.

While still behind major players like the US, Germany and China, Korea acknowledged the need to catch up quickly. Private sector investments grew from a mere KRW 13.6 billion in 2019 to an expected KRW 62.3 billion by 2023. These early moves helped Korea develop domestic expertise and infrastructure as it prepares for the next stage of ambitious development targets.

Ambitious 10-Year Plan

In 2023, the Ministry of Science and ICT unveiled an expansive 10-year quantum technology policy and €2.5 billion budget. Over 70% will come directly from the government and the rest from private partnerships. Three focus areas were identified: quantum computing, the quantum internet, and quantum sensing.

To advance these areas, Korea will pursue strategic objectives around human resources, technology capabilities, and market share. The goal is to increase the number of quantum researchers from 350 to 2,500, boost Korea's overall technology level from 62.5% to 85% of leaders, and grow its world market share from 1.8% to 10%. This will position Korea as a global top-4 player by 2035.

Concrete Development Targets

Korea aims to hit concrete milestones along the way to demonstrate progress. This includes developing a 50-qubit quantum computer by 2027 and 1,000-qubit system by 2031. Advancing quantum repeater and transmission technologies is also a priority.

> "Student and researcher exchanges are highlighted as core parts of Korea's global partnership approach. "

Significant infrastructure investments are planned, such as opening a researcher-focused quantum cloud lab by 2027, a public quantum R&D foundry by 2031, and encouraging private foundries by 2035. Startup growth targets include increasing quantum ventures from 10 today to 100 in over a decade. National security uses are also being explored through new dedicated centers by 2025.

Global Engagement and Partnerships

While pursuing its ambitious domestic agenda, Korea recognizes that international collaboration will be crucial. Recent cooperation agreements have been signed with the US and UK.

The Netherlands and South Korea signing an MoU for strengthening bilateral collaboration in digital technologies, smart industry and also quantum. Source: Office of the President Official Photographer - Kim Yong Wii

The Korea-Europe Quantum Science Technology Cooperation Center was also launched to better engage with the EU on initiatives like Horizon Europe. Exploratory discussions have also been held with the Netherlands about areas like quantum AI and post-quantum cryptography.

Student and researcher exchanges are highlighted as core parts of Korea's global partnership approach. Over 500 exchanges are planned over the next decade. Major conferences like Quantum Korea in 2024 aim to further strengthen these international ties.

Realizing Quantum's Promise

With thorough 10-year planning, massive investments of billions, and a growing global engagement strategy, Korea is clearly serious about realizing the wide-ranging potential of quantum technologies. Their combination of ambitious domestic targets and cooperative international approach seeks to establish Korea as a dominant global quantum power within the next decade. Success would be a major step toward harnessing quantum effects for computing, communications, and more.

For an in-depth look at all the details of Korea's comprehensive quantum programs, policies and leading organizations, please see the following link *quantuminkorea.org/national-quantum-strategy/*.

Netherlands Innovation Network Korea
Peter Wijlhuizen, Innovation Counsellor
pw@nost-korea.com

Quantum in the UK

Minister George Freeman signed a Memorandum of Understanding between the UK Government and the Netherlands for cooperation in quantum technologies. Source: James Gifford-Mead Photography

The UK has set out a ten year vision in their National Quantum Strategy, which was published in March 2023 and builds on the previous ten year program. This National Quantum Technologies Programme (NQTP) was first formed in 2014 and the first national quantum strategy in the world. The ultimate goal for the UK is to be a world leading quantum-enabled economy, building on scientific excellence and creating a thriving quantum sector to ensure that quantum technologies are an integral part of the UK's digital infrastructure and advanced manufacturing base, driving growth and helping to build a strong and resilient economy and society. The Office for Quantum in the Department for Science, innovation and Technology (DSIT) has been established to ensure focus and drive to implement the National Quantum Strategy and will report regularly to the National Science and Technology Council, chaired by the Prime Minister.

The UK National Quantum Strategy Objectives, as set out in the National Quantum Strategy are: (1) ensuring the UK is home to world-leading quantum science and engineering, growing UK knowledge and skills; (2) supporting business, making the UK the go-to place for quantum businesses and an integral part of the global supply chain, as well as a preferred location for investors and global talent; (3) driving the use of quantum technologies in the UK to deliver benefits for the economy, society and national security; (4) creating a national and international regulatory framework that supports innovation and the ethical use of quantum technologies, protects UK capabilities and national security.

National Quantum Strategy Missions

As part of the National Quantum Strategy the UK has, in November 2023, published 5 Missions:

- Mission 1: By 2035, there will be accessible, UK-based quantum computers capable of running one trillion operations and supporting applications that provide benefits well in excess of classical supercomputers across key sectors of the economy.
- Mission 2: By 2035, the UK will have deployed the world's most advanced quantum network at scale, pioneering the future quantum internet.
- Mission 3: By 2030, every NHS Trust will benefit from quantum sensing-enabled solutions, helping those with chronic illness live healthier, longer lives through early diagnosis and treatment.
- Mission 4: By 2030, quantum navigation systems, including clocks, will be deployed on aircraft,

providing next-generation accuracy for resilience that is providing next-generation accuracy for resilience that is independent of satellite signals.
- Mission 5: By 2030, mobile, networked quantum sensors will have unlocked new situational awareness capabilities, exploited across critical infrastructure in the transport, telecoms, energy, and defense sectors.

UK Ambitions per Priority Area

- Quantum Computing: for quantum computing, the UK's ambition is to support the development of and access to state-of-the-art and eventually fully scalable machines in order to explore beneficial applications for the economy and society and undertake research. At the same time it should give the quantum sector the best opportunity to capture a significant share of the global market, creating jobs and delivering value to the UK economy.
- Quantum sensing, Timing and Imaging: For quantum sensing, timing and imaging, the UK's ambition is to develop the technology so that the UK is in a strong position to play an important role globally in the next generation of sensors and position, navigation and timing (PNT) capabilities, working with international partners.
- Quantum Communications: For quantum communications, The UK's ambition is to realise both the potential of these technologies for secure communications where clear benefits can be demonstrated, as well as the opportunities they present for networking to help scale quantum computers, sharing information and addressing data storage challenges. Collaborating with international partners is a key element of this approach.

UK Ecosystem

In July 2024 the UK Government announced five new quantum hubs that will continue to build on the work of the four hubs that have been in place since the start of the UK National Quantum Technologies Programme, being the Quantum Computing & Simulation Hub (Oxford), the Quantum Communications Hub (York), the Quantum Technology Hub – Sensors and Timing (Birmingham) and QuantIC – Enhanced Imaging (Glasgow).

- The UK Quantum Biomedical Sensing Research Hub (Q-BIOMED), University College London and University of Cambridge

  Explores quantum sensors for ultra-sensitive disease diagnosis, including rapid blood tests, and biomedical scanners to facilitate earlier diagnosis and treatment of diseases such as cancer and Alzheimer's disease.

- UK Quantum Technology Hub in Sensing, Imaging and Timing (QuSIT), University of Birmingham

  Focuses on the development of quantum sensing for practical applications - brain scanners for dementia, cancer diagnostics, and advanced security and infrastructure monitoring.

- Integrated Quantum Networks Quantum Technology Hub (IQN), Heriot-Watt University

  Aims to deliver the technologies for a future UK-wide 'quantum internet', enabling future-proof cybersecurity and powerful distributed quantum computing.

- Hub for Quantum Computing via Integrated and Interconnected Implementations (QCI3), University of Oxford

  Develops technologies for building quantum computers, advancing UK capabilities across hardware and software and targeting applications in a wide range of industry sectors.

- The UK Hub for Quantum Enabled Position, Navigation and Timing (QEPNT), University of Glasgow

  Creates quantum-based positioning and navigation systems for critical infrastructure, autonomous vehicles, and improved indoor and underwater navigation.

The hubs act as the engine for UK quantum ambitions, weaving the science of quantum technologies with ideas for their commercialization and delivering a route to market. Each hub brings together experts from universities, national laboratories, business development and industry partners to steer a proposed development. The result of this organized collaboration to clear commercial goals is the key underpinning to the UK quantum community and the emerging industrial sector.

In addition to the hubs there are several other centres that form an important part of the UK's research capabilities, like the Harwell Campus Quantum Cluster that includes the National Quantum Computing Centre (NQCC), the Quantum Metrology Institute of the National Physical Laboratory (NPL), the Hartree Centre, the Defence, Science and Technology Laboratory, The National Dark Fibre Facility and the Catapult Network.

Clusters in the UK that support research into quantum technologies are the Scotland Photonics Cluster, the Wales semiconductor cluster and the Northern Ireland nanotechnology cluster. The UK quantum industry is represented by UKQuantum, a membership organization formed in 2021.

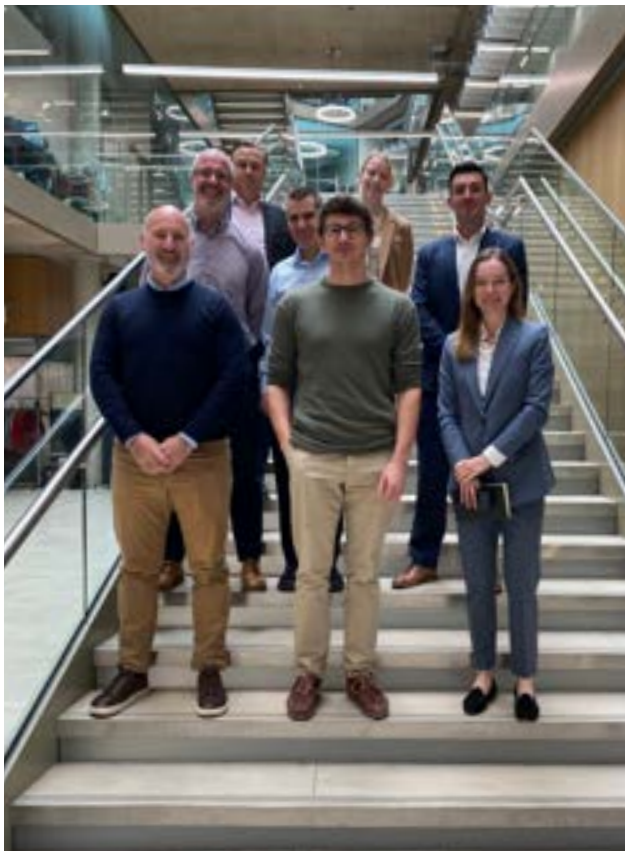
In 2020 the Quantum Technology Innovation Network at Innovate UK Business Connect gathered the quantum capabilities in the UK in the form of an interactive, searchable and open access tool, mapping the existing businesses, publicly funded projects and research groups, the UK national centres and the available postgraduate training programs. It has since been updated adding fabrication facilities and a list of quantum computers launched by companies that have operations in the UK.

Collaboration

On 2 November 2023, the UK and the Netherlands signed a Memorandum of Understanding (MoU) for cooperation in Quantum Science and Technologies. With the signing of this MoU there is renewed momentum to pursue collaboration between the quantum ecosystems in the UK and the Netherlands. In the last year a working plan with concrete follow-up actions has been compiled, which will put into practice the commitments agreed to in the MoU. These include visits to both the Dutch and British ecosystems, knowledge and talent exchange programs, research collaboration and (new) funding opportunities.

See for more information:
www.rvo.nl/onderwerpen/buitenlandnetwerk/ia-netwerk/verenigd-koninkrijk#publicaties

Netherlands Innovation Network United Kingdom
Martijn Bergmans, Senior Innovation Advisor
martijn.bergmans@minbuza.nl



Quantum technology missions, lectures and other related events in the United Kingdom.
Source: NIN United Kingdom

Programs, funds and more

Quantum Delta

The Quantum Delta NL Program will receive €615 million from the National Growth Fund to position the Netherlands as a leading international center and hub for quantum technology: the Quantum Delta NL. The ambition is to develop a leading European knowledge cluster in seven years, with a contribution to gross domestic product (GDP) of €5 to €7 billion and 30,000 high-quality Dutch jobs in the long term. The Quantum Delta NL program is an action plan focusing on all links in the ecosystem:

- From talent to research and entrepreneurship to cleanroom facilities
  click here
- Learn more about the National Growth Fund
  click here
- Learn more about Quantum Delta NL
  click here

EU Policy

Learn more about EU policies and ambitions in the Quantum technology field
click here

Funding/programs

EU programs with funding can be found in the major programs, usually with specific calls:

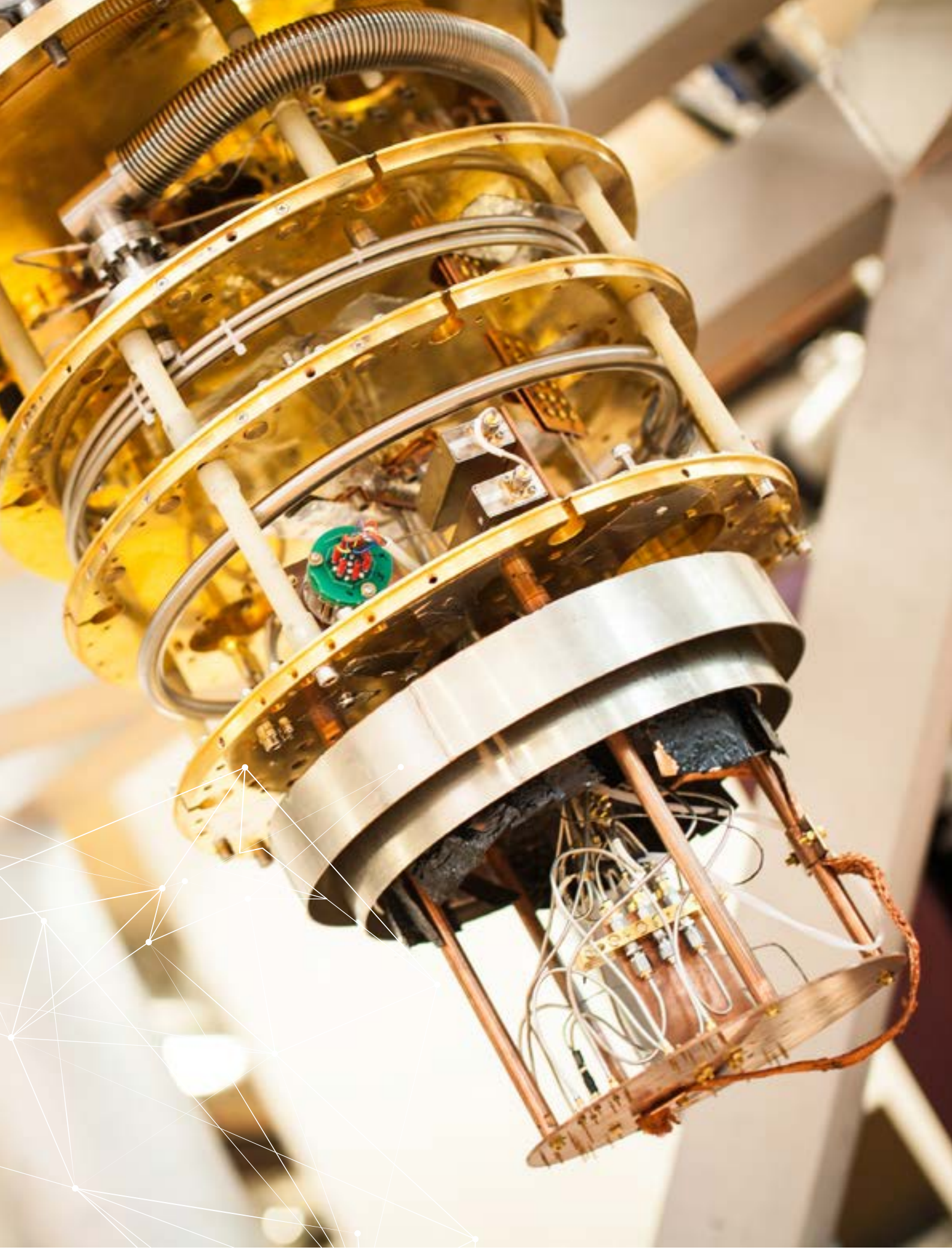
- Horizon Europe - R&D related to quantum technology
- Digital Europe - Accelerating implementation and knowledge dissemination
- Connecting Europe Facility Digital - Quantum communication infrastructure
- European Defence Fund - Defense-oriented quantum research and development

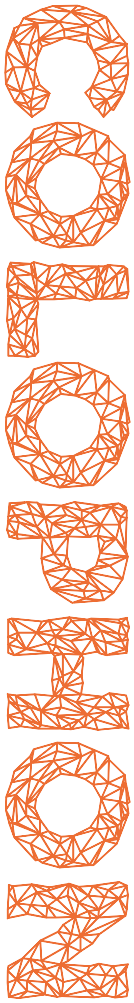
For an overview of Quantum related calls within the current European Multiannual Financial Framework (2021-2027) click here.

Network in EU - Quantum Flagship

Learn more about the Quantum Flagship, the main quantum network funded by the European Commission
click here

This technically runs until 2026.





This is a publication of:
The Netherlands Enterprise Agency
(Rijksdienst voor Ondernemend Nederland)

Visiting address
Prinses Beatrixlaan 2
2595 AL Den Haag
T (088) 602 15 04
E ianetwerk@rvo.nl
www.ianetwerk.nl

Postal address
PO Box 93144
2509 AC The Hague
The Netherlands

Quoting & referring
Please note that you are free to quote or refer to this document provided you mention the source in your publication and inform the Homebase for the Netherlands Innovation Network at RVO by sending an email to: ianetwerk@rvo.nl

Photography and visuals
We have exercised the utmost care in trying to track down all rights owners of photos etc. used as visual illustration in this magazine. However, should you feel an infringement of your copyright has taken place, please contact the publisher.

Design
DDK, Utrecht

Interviews and overview article
DDK, Utrecht

Editors
Krisztina Árvai-Nagy, Ernst Jan Bakker, Martijn Bergmans, Mihoko Ishii, Roy Keesenberg, Li-Anne Krol, Joanette Polo, Dr. Madhav Pulipati, Astrid Seegers, Sean Silbert, Dhoya Snijders, José Snoep, Anouk van der Steen, Rob Stroeks, Robert Thijssen, Wendy Wanner, Peter Wijlhuizen.

Government of the Netherlands

Netherlands Innovation Network

The Netherlands Innovation Network stimulates international cooperation between companies, research institutes and public authorities in the fields of innovation, technology and science. We do this on behalf of the Ministry of Economic Affairs. Our network's activities support implementation of the Dutch government's international knowledge and innovation agenda. We address national and global challenges with our global network of offices in: Brazil, Canada, China, France, Germany (incl. Switzerland), India, Japan, Singapore, South Korea, Sweden, Taiwan, Türkiye, the United Kingdom and the United States.

We develop international cooperation by:

- providing knowledge and information on the latest innovation, technology and science developments around the world;
- connecting to potential partners abroad;
- organizing innovation missions, seminars, workshops and matchmaking events abroad;
- identifying funding mechanisms for bi- and multilateral cooperation.

We look forward to the opportunity to help you become involved in sustainable innovation partnerships, so we can together advance our common innovation, technology and science ambitions.

CONNECTING INNOVATION WORLDWIDE
Netherlands Innovation Network

A network of
the Ministry of Economic Affairs

Juri Roerink
Coordinator Netherlands Innovation Network

ianetwerk@rvo.nl
@ianetwerk
www.linkedin.com/company/innovatie-attache-netwerk

This is a publication of
Netherlands Enterprise Agency
Prinses Beatrixlaan 2
PO Box 93144 | 2509 AC The Hague
T +31 (0) 88 042 42 42
Contact
www.rvo.nl

This publication was commissioned by the ministry of Foreign Affairs.

Publication number:RVO-067-2025/RP-INT

NL Enterprise Agency is a department of the Dutch ministry of Economic Affairs that implements government policy for Agricultural, sustainability, innovation, and international business and cooperation. NL Enterprise Agency is the contact point for businesses, educational institutions and government bodies for information and advice, financing, networking and regulatory matters.

Netherlands Enterprise Agency is part of the ministry of Economic Affairs .