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Project Acronym: NQCIS

Project title: National Quantum Communication Infrastructure in Sweden

Milestone Report

MS5 – Interim Report 2

Achievement date: 2025-06-30

Executive Summary

The National Quantum Communication Infrastructure in Sweden (NQCIS) project has established the first national quantum communication testbed, as part of the EuroQCI initiative, integrating quantum-based systems and deploying Quantum Key Distribution (QKD) into Sweden's existing communication infrastructure to enhance cybersecurity. A key milestone achieved is the opening of the national testbed to users outside of the consortia. The national testbed comprises a main hub in Stockholm, in the Albanova University center and a second node at the University of Linköping. The central testbed located at the AlbaNova University Centre in Stockholm, is the core node of a metropolitan QKD fiber network linking it to Kista as well as a long-distance backbone that extends to the Norrtälje municipality in the north and Linköping University to the south-west. The NQCIS testbed is operational since the spring of 2025 and accessible to trained users for developing quantum communication use cases. Moreover, it is currently hosting multiple experiments on testing device interoperability, switching and coexistence with classical communication, as well as delving deeper into the challenges of fibre-link deployments and long-distance quantum communications. In partnership with the national QCIs of Denmark, Finland, Estonia and Poland, NQCIS has laid the grounds for further cross-border connections in the Scandinavian and Baltic regions and to link the fiber and space segment of EuroQCI in the Albanova hub, thereby aligning with Sweden's specific needs for secure long-distance communication.

Means of Verification

The webpage and the report are publicly available at <https://nqcis.eu/> and its contents are available as the annex in this page. Screenshots of the website, LinkedIn and some of its contents are included in the annex of this report. The testbed is open to users now which can request access by filling in a form. The testbed and all its fibre connected nodes are functional and have been producing and sharing positive, usable secret keys over both the metropolitan and long-distance links, supporting services as e.g. teleconferencing over the fiber backbone.

Annex

Central node details

The central node of the NQCIS project—the Albanova open QKD testbed—was fully established in 2024 at the AlbaNova University Centre in Stockholm and was opened to the public on 04th-February-2025. The hub opening featured guests from the Swedish government, the Digital Europe program, the Swedish Research Council (Vetenskapsrådet), Sweden's Innovation Agency (Vinnova) and the Wallenberg centre for quantum technology (WACQT). Originally located in a temporary lab in 2023, it has since expanded into two adjacent rooms: a main room for active experiments and interaction with QKD systems, and a secondary room housing sensitive equipment such as superconducting nanowire single-photon detectors (SNSPDs). Fibre or cable routing between the rooms supports flexible reconfiguration based on evolving security or experimental needs. The node hosts high-capacity infrastructure and deployed dark fibre links connect it to nodes in Kista (RISE, Ericsson), Norrtälje, Nyköping, and Linköping. These links support both CV- and DV-QKD systems under real network conditions. Several features such as polarisation control, data on background rate from co-existing classical light are available. The facility can be accessed by filling in a form explaining the experimental needs. The second main node of the Swedish Quantum Communication infrastructure has been established by NQCIS at Linköping University and is supporting quantum communication experiments as well as QKD deployment all the way to the Stockholm hub (through a terrestrial stretch of ~270 km).

Features and capabilities

The central facility includes:

- The receivers for four QKD systems: Two CV-QKD and two DV-QKD.

- SNSPD system: A cryogenically cooled detection platform capable of housing up to 24 detectors (currently 8 are installed).
- Supporting equipment: Polarimeters, time taggers, wavelength filters, laser sources, and programmable polarization controllers.
- Network architecture: A secure IP-routed network managed via pfSense routers with IPsec tunnels, enabling node-to-node encrypted traffic independent of public internet conditions.

Several enhancements are planned to expand the capabilities of the central hub. One key upgrade involves establishing a dedicated fibre link to the Albanova telescope, enabling future integration with satellite-based quantum key distribution (QKD). This would position the facility to support space-to-ground quantum communication experiments. Additionally, the installation of specialized encryptors is underway to enable hardware-based quantum-safe communication over one of the existing fibre links, further strengthening the security and applicability of the infrastructure. The facility will also host small portable telescopes to assess the needs and challenges of free space quantum communication experiments using the existing QKD devices in the hub.

Preliminary results of QKD systems

The preliminary results of the QKD systems deployed within the NQCIS project offer critical insights into the performance, stability, and practicality of off-the-shelf quantum communication technologies under real-world conditions. In the facility we have performed measurements for key parameters such as fibre attenuation, background noise, polarization stability, and detector performance—across both metropolitan and long-distance links which informed our choice of devices. Our shortest links are 18 km long and our longest link is 163 km long (considering a single fiber strand from Albanova to Nyköping). The attenuation spans from 7-9 dB for the metropolitan links and 20-36 dB for the long-distance ones, which require the use of the SNSPDs. As all links are deployed, we have noticed polarization stability to be sufficiently good for the operation of polarization-based devices. The generated secret key rate is positive across all actively used links under operational conditions, further emphasizing the compatibility of the devices into existing infrastructures.

Results on the long-distance link to Linköping were first carried out in February 2025, where shared keys were generated between the node located at Linköping University and the intermediate trusted node at Nyköping, at a secure key generation rate of approximately 2 kbits/s, over a distance of approximately 110 km. Then, in collaboration with the group at Chalmers, a local link consisting of a 30 km multi-core fiber spool and input-output reconfigurable optical switches was assembled in the lab in Linköping, and connected to the long-distance QKD link to Nyköping, demonstrating actively reconfigurable QKD operation through a hybrid single-mode multi-core fiber link, with shared classical telecom traffic. Then, working together with the KTH group, the long-distance link between Nyköping and the NQCIS hub (163 km) was established, and connected to the hybrid link describing above, demonstrating continuous operation of key exchange through QKD between Linköping and Stockholm through 300 km hybrid optical fiber link, with a final secret key generation rate of approximately 100 bits/s.

Exploratory work

Sweden's unique geographical landscape, characterised by long distances and sparse population distribution, presents significant challenges for secure communication infrastructure. To address these, the NQCIS project is also actively exploring non-commercial alternative techniques and advanced quantum protocols. One such effort focuses on Twin-Field QKD, which enables secure key distribution over distances exceeding 1000 km without relying on quantum repeaters or trusted nodes. Promising early results from collaborative research at KTH and Linköping University have already been showcased at conferences in Europe and the US (CLEO 2025). In parallel, NQCIS has been preparing cross-border integration with neighbouring countries, particularly Denmark, Finland and Estonia, securing Swedish government support and enabling the follow-up plans for the upcoming Connecting Europe Facilities

call, leading to two parallel crossborder EuroQCI project applications, one addressing the space segment and the link to Finland and Estonia (from the NQCIS Stockholm node). and one to Denmark-Poland (from the Linköping NQCIS node), where the questions of network orchestration, different QKD domain connection, interoperability, device compatibility, secure key management and storage will be addressed for the ultimate integration of the national QCIs in the Nordic-Baltic region within the pan-European QKD network of EuroQCI.

Education and outreach

The NQCIS team has participated in open days, industrial days and workshops to educate stakeholders and the broader public. Our target audience has included telecom operators, researchers, and policy-makers. A pilot secure video conferencing system over the metropolitan QKD link was setup during the inauguration of the facilities to demonstrate real applicability of the QKD systems, which was appreciated by the broader community as attested by the various posts on social media. We have also delivered targeted talks on QKD systems, secure communication protocols to several interested industrial audiences on demand. We have also prepared outreach material such as a section for frequently asked questions, brochures about the facility and published the video from the inauguration of the central hub facility on our webpage.

Attachments

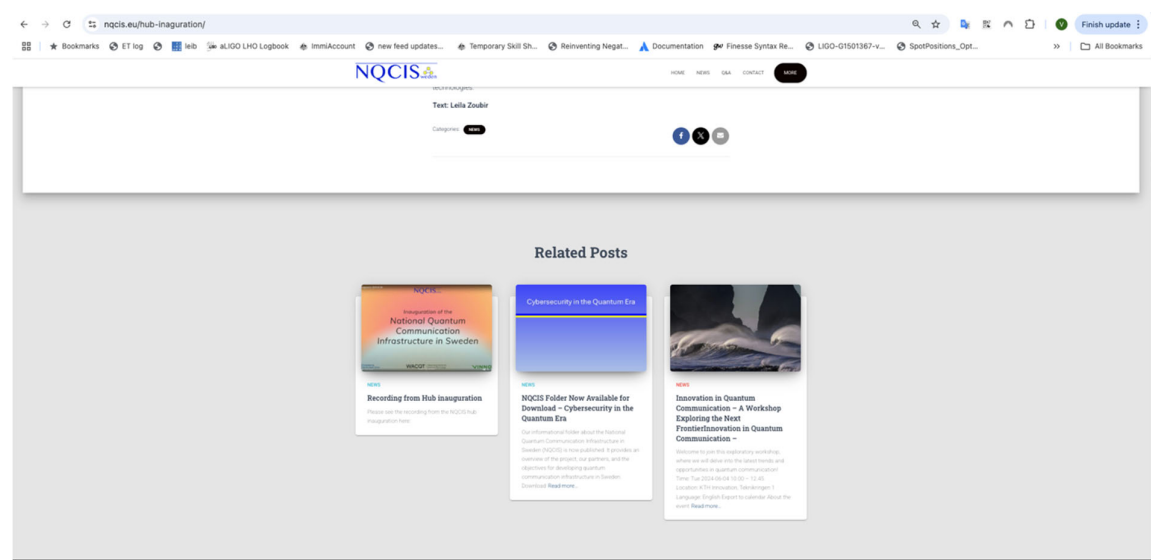


Figure 1 Screenshot of the webpage with the public outreach material.



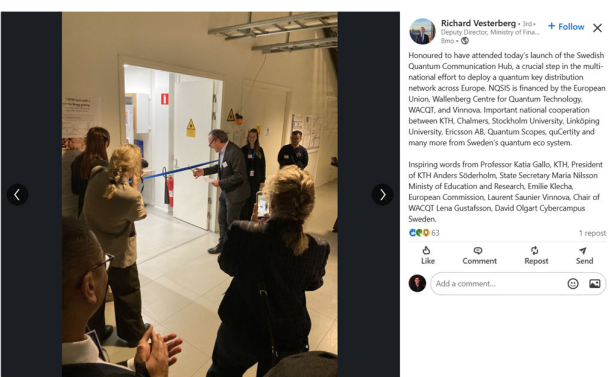
Figure 2 Main room of central facility.



Figure 3 Detector room.



Figure 4 Social media posts.



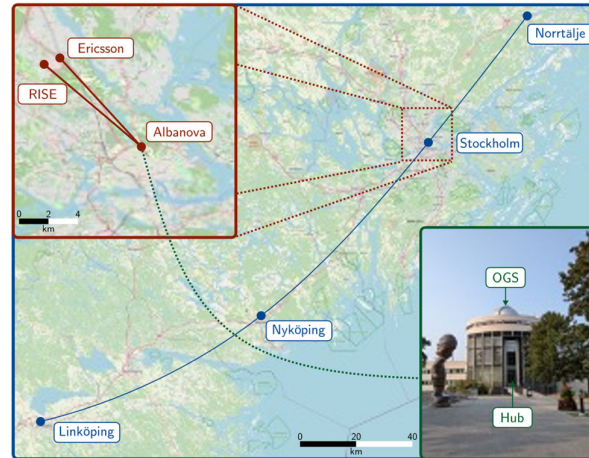


Figure 5 Network map.