tnc23
DIGITAL GENERATIONS
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# Quantum Internet Activities in European NRENs

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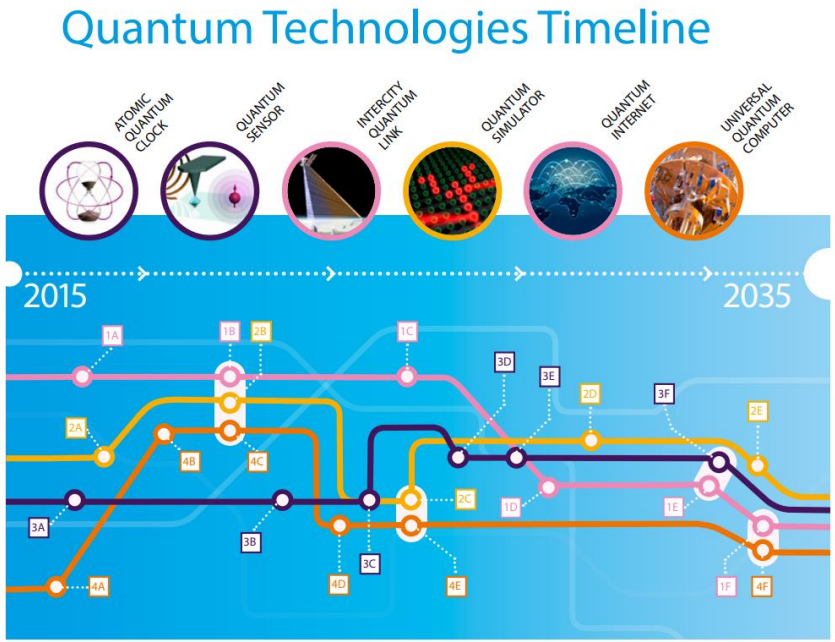
GÉANT
Co-funded by the European Union

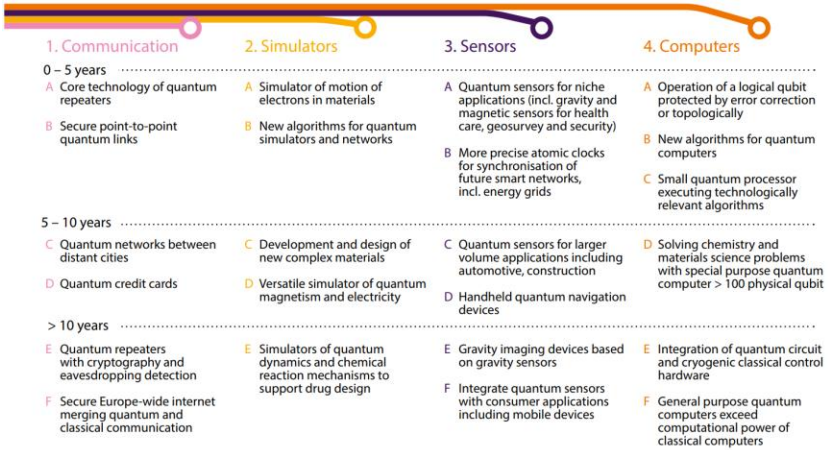
# Quantum Technologies - background

- **Allow for the manipulation and exploitation** of effects described by quantum mechanics.
- **We are currently in the process of 2nd quantum revolution** where quantum mechanics effects are used to enhance the capabilities of current measurement, simulation, computation and communication technologies.
- **Quantum Manifesto EU document released in 2016** → Recognizes importance of quantum area for Europe and drafts schedule for the research and real life applications. Foundation for future programs.
- **Since Quantum Manifesto** many programs and initiatives have been started by the **EU** to support the topic: **Quantum Flagship**, **Quantum Internet Alliance**, activities in **ESA**, and the latest is the establishment of the **European Quantum Communication Infratructure (EuroQCI) initiative**:
  - ✓ **Digital Europe Program (DEP)**
    - **Topic 1 – Industry** → **started**
    - **Topic 2 - Deployment of National QCIs** → **started**
    - **Topic 3 - Coordination and Support Action (CSA)** → **started (PETRUS)**
    - **Topic 4 - Deployment of large scale testing and certification infrastructure for QKD devices, technologies & systems enabling their accreditation and rollout in EuroQCI** → **waiting for the call**
  - ✓ **Connecting Europe Facility (CEF)** → **waiting for the call**
- QCI/QKD activities are important steps toward a general Quantum Communication and Quantum Internet.

# Quantum Technologies - background



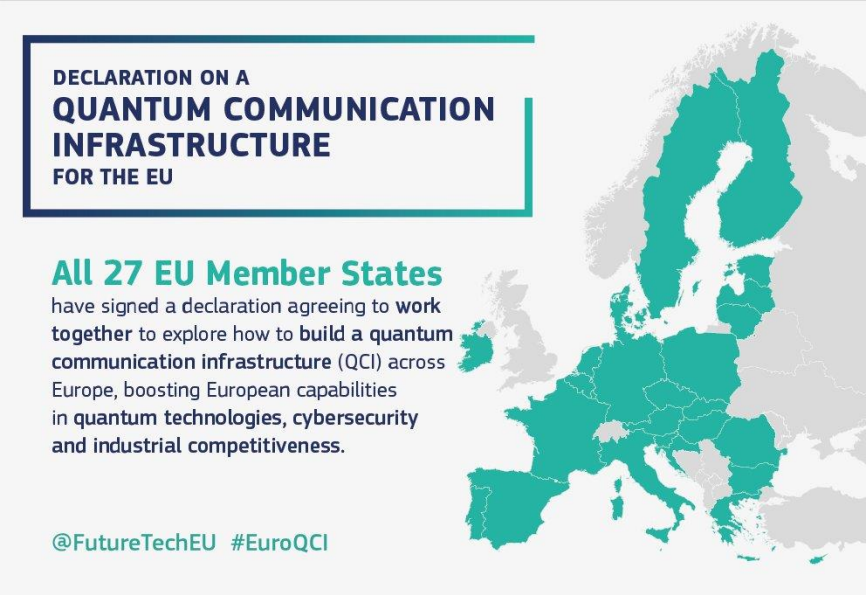

https://qt.eu/app/uploads/2018/04/93056_Quantum-Manifesto_WEB.pdf




- Different areas on quantum technologies
- All areas are interconnected
- Need to advance in one area to proceed to the next

# European Quantum Communication Infrastructure - EuroQCI

EuroQCI




Since **June 2019**, all 27 EU Member States have signed the **EuroQCI Declaration**, signaling their commitment to establish the EuroQCI

The participating countries are working with the **European Commission** and the **European Space Agency** to design and deploy the EuroQCI

The aim of the EuroQCI is to safeguard **sensitive data** and **critical infrastructures**, providing an additional security layer based on **quantum physics**

Building the EuroQCI will boost Europe's capabilities in **quantum technologies**, **cybersecurity** and **industrial competitiveness**.

# EuroQCI Space and Terrestrial Segments

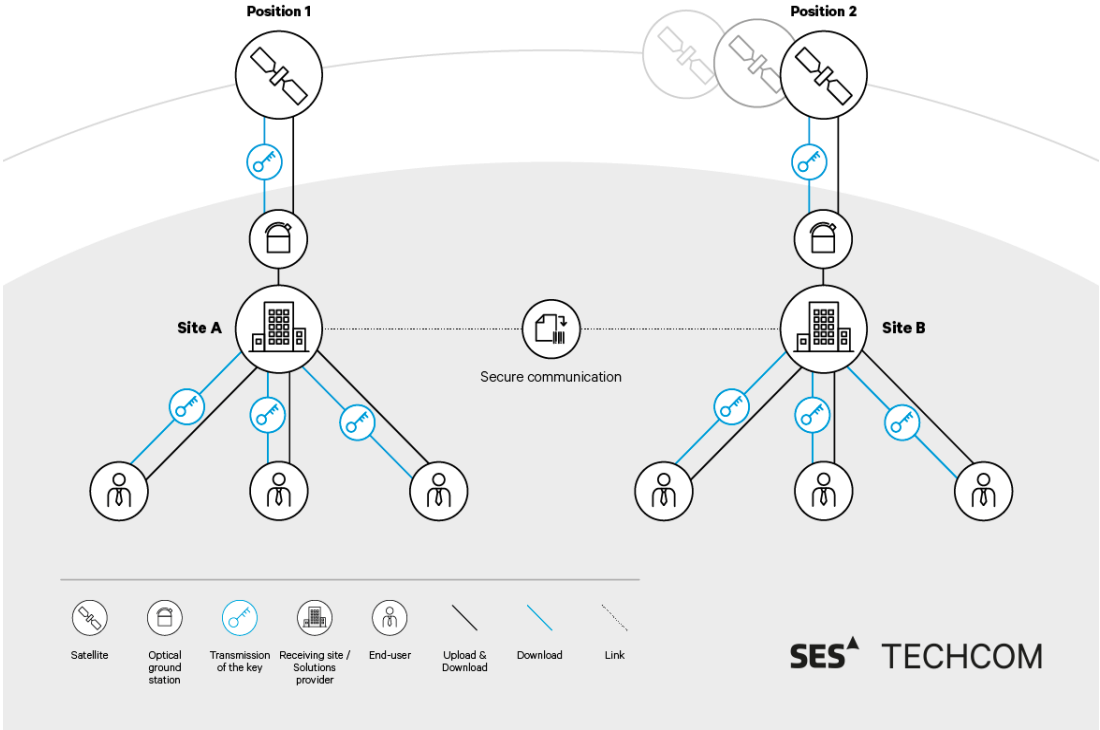
## Space segment

implemented by **ESA**
**EAGLE-1 Satellite** is being built by SES/ESA

## Terrestrial segment

implemented by the **Member States** and the support of **PETRUS project.**

Both under the supervision of the **European Commission**




Operational **EuroQCI** → **Interoperable** and **reliable** Space and Terrestrial Segments

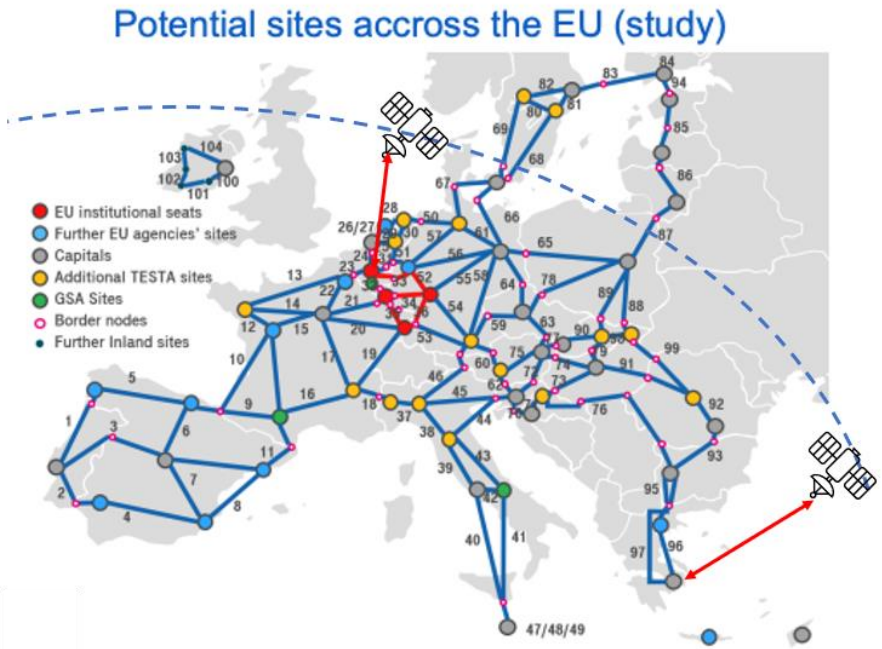
# EuroQCI Space and Terrestrial Segments

## Terrestrial segment

- Federation of national terrestrial QCI networks with cross-border connectivity
- Many NRENs participate in QCI endeavors
- Possible role for GEANT to support the cross-border connections
- Several technical and admin challenges
- Control/Management of the network
- National/EU regulation

## Space segment

- Bypass cross-boarder operation
- Only solution for island countries
- Ideal for south countries due to clear skies
- Alternative route in critical events
- NRENs and GEANT possible new domain of activity to engage




*Jean-François Buggenhout"* EU Quantum Technologies Flagship and the quantum internet" ENISA TELECOM SECURITY FORUM, 29 June 2022

# DEP topic 2 - Deploying advanced national QCIs

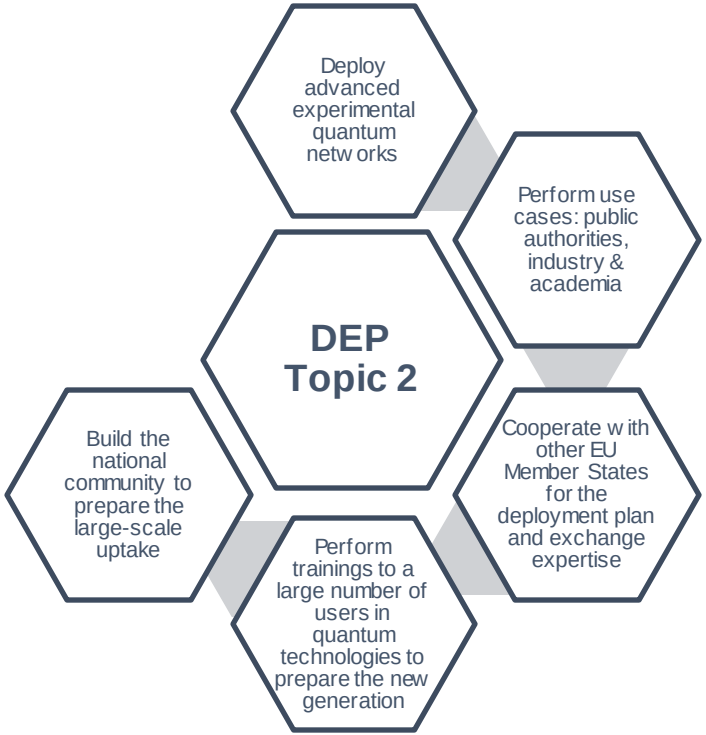
Digital Europe Programme (DIGITAL)

Call for proposals

EU secure Quantum Communication Infrastructure

(DIGITAL-2022-QCI-02)

Version 1.0
23. 08.2022




**Call Budget: 110 M€**

EU funding rate at 50% - Simple grant

| | | |
|---|---|---|
| 10 M€ per grant<br>EU Funding per grant: 5 M€ | Deadline for submission:<br>22 February 2022 | Starting Day of NatQCIs:<br>1 January 2023 |

tnc23 DIGITAL GENERATIONS

- HellasQCI – Greece | GRNET
- PIONIERQ – Poland | PSNC
- CroQCI – Croatia | CARNET
- IrelandQCI – Ireland | HEANET
- RoNaQCI – Romania | RoEduNet
- CZQCI – Czechia | CESNET
- QCINed – The Netherlands | SURF
- CYQCI – Cyprus | CYNET

# Example of NRENs participation in the NatQCIs

- Large number of NRENs **lead** or **participate** to the NatQCIs and there are NRENs that participate **indirectly** to the NatQCIs
- **GEANT** through the **Quantum Strategy Group** and the **GN5-1 Quantum subtask** facilitates the **information sharing** between the NRENs
- **Exchange of expertise** is crucial to create a secure and operational EuroQCI → same challenges – most of the NRENs started from scratch


Info share link

# HellasQCI

**Build the National Quantum Networks as part of the EuroQCI**

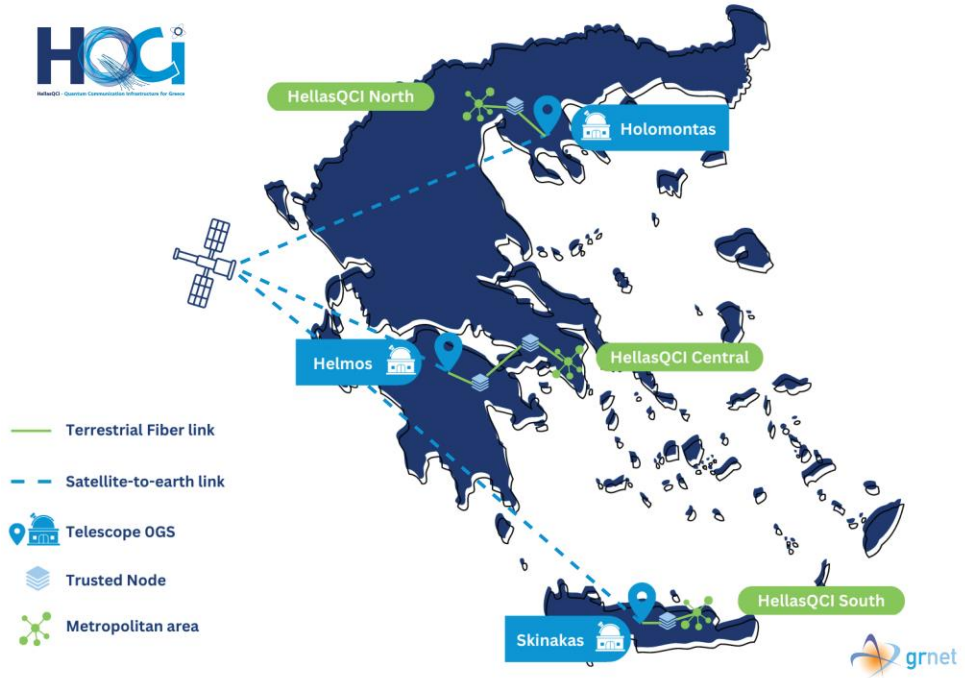
- 3 national test-sites
- 3 OGS will be connected to the closest test-site
- 450km length of fiber links will be deployed

## Three test-sites

- Athens (Capital of Greece) – Economic/Administrative Centre
- Thessaloniki - North Greece/ terrestrial boarder
- Heraklion/Crete - Island Greece, Southernmost point of Europe, geostrategic location

## Quantum Satellite Connectivity

- Builds on Helmos, Holomontas and Skinakas OGS
- All 3 telescopes part of ESA ARTES Scylight, Hydron and SAGA programmes
- HellasQCI will provide the terrestrial links to the OGS
- Implement the National Quantum Backbone Network
- Connect to QKD satellites for connecting our test-sites and also connect with the rest of the EU
- Avoid costly terrestrial QKD links



# HellasQCI - Powerful Metropolitan Testbeds

## Develop and Deploy advanced quantum systems and networking technologies

- **3 QKD technologies will be deployed**
  - ✓DV-QKD technology (Most mature solution)
  - ✓CV-QKD technology (low-cost deployment)
  - ✓Single photon detectors and sources (entanglement)

### Three Quantum Network domains

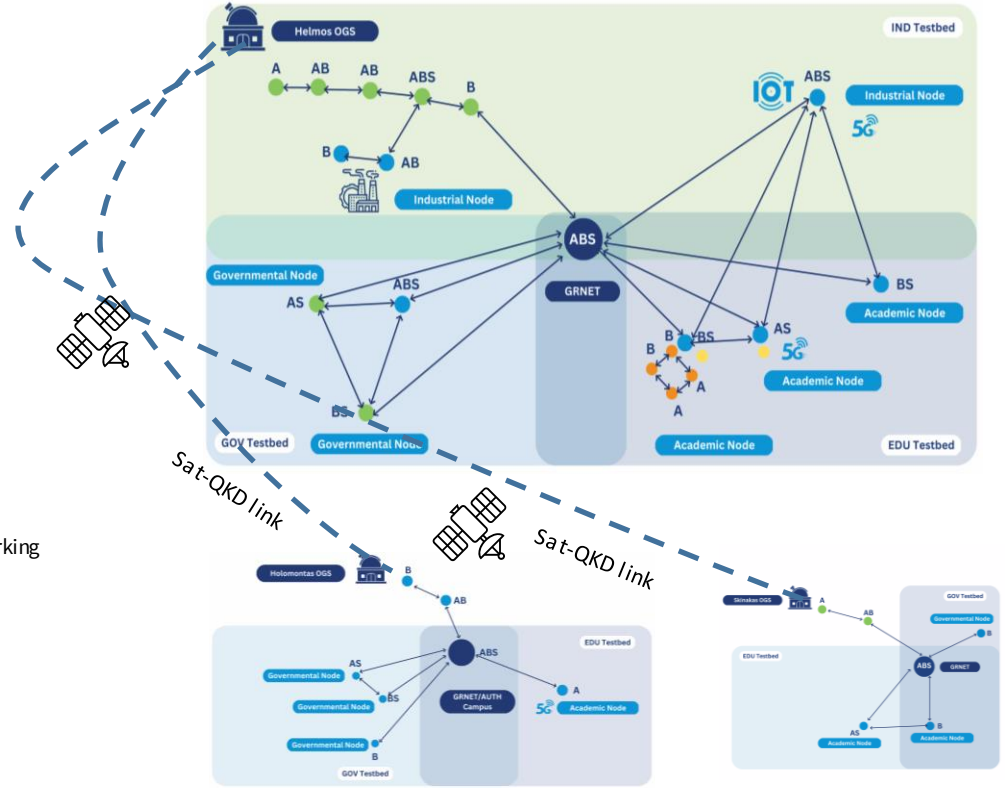
- Governmental (GOV)
- Industrial (IND)
- Research and Innovation (EDU)

### Advanced QKD technologies

- Dynamic QKD for optimal resource allocation, resilience and flexible networking
- Co-existence of Quantum and Classical Channels
- Enhanced PUF encryption schemes

### Extensive Metropolitan Networks

- >12 Nodes in Athens | >6 nodes in Thessaloniki | >4 Nodes in Heraklion



# HellasQCI 16 Multidisciplinary Use cases

**Advanced use cases in different application scenarios**

- 16 use cases
- 7 National Security and Governmental nodes connected
- 6 Critical infrastructures, health sector and ICT industry nodes connected
- 6 Research and Innovation nodes connected
- Entanglement distribution network 4 receivers – 2 nodes

## National Security

Use Case 1 — QKD for National Security
Use Case 2 — Enhanced QKD resilience for National Security Links
Use Case 3 — Satellite QKD connectivity for remote National Security Nodes
Use case 16 — HellasQCI space and terrestrial segments

## Public Health

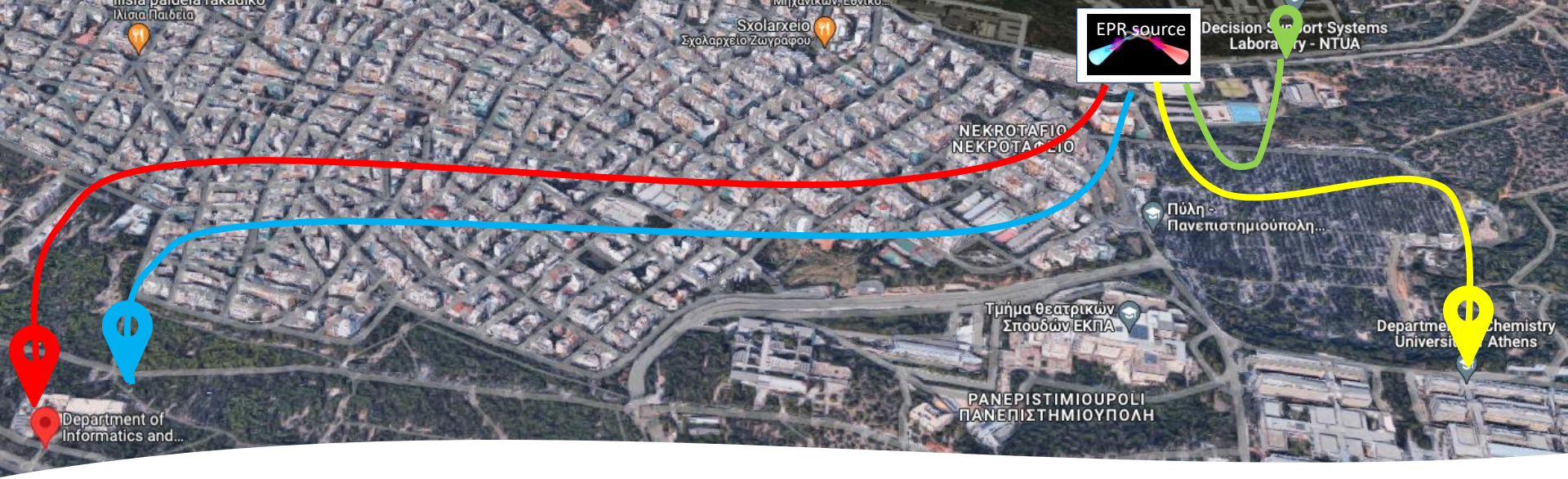
Use Case 4 — Secure communications for Public Safety applications
Use Case 5 — Quantum Secure technologies for cloud Health Applications
Use Case 6 — Secure transmission of medical imaging data for Public Hospitals
Use Case 7 — QKD for secure connectivity to HPC infrastructure

## Industrial | Critical Infrastructure | ICT

Use Case 8 —QKD in Harsh industrial environments - Oil Refinery Infrastructure
Use Case 9 — ICT sector | Secure storage in cloud data centres
Use case 10 — ICT sector | QKD over 5G
Use case 11 — ICT sector |Next Generation Quantum Secured FTTH services
Use case 15 — Preparation of a quantum encrypted software application

## Research

Use case 12 — Preparing for the quantum internet
Use Case 13 — Advanced quantum network controls
Use case 14 — PUF-based hybrid authentication for switched QKD



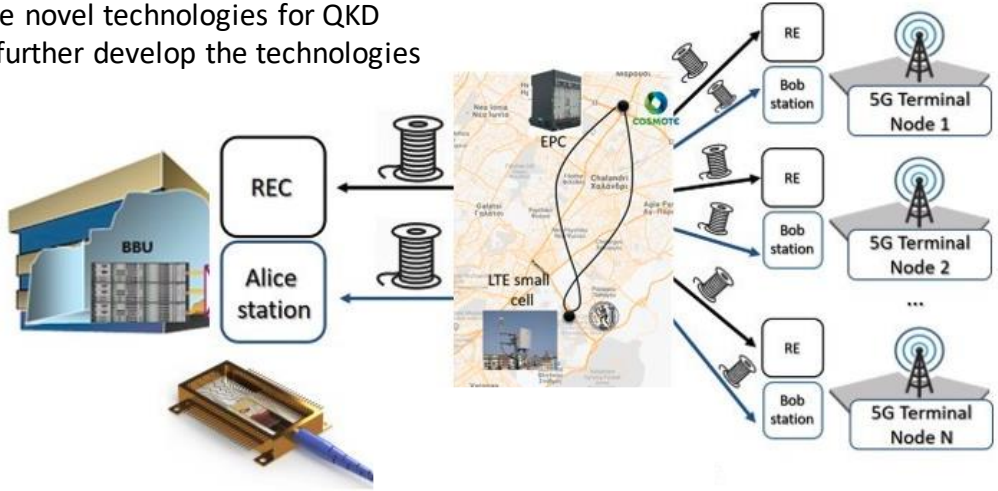

*HellasQCI will pave the way towards the Quantum Internet in Greece*

- ✓ Two experimental active entanglement distribution stations will be permanently installed in two universities in Athens
- ✓ HellasQCI will implement a state-of-the-art active entanglement distribution network using **cryogenic single photon detectors in NKUA** and **entanglement sources in ICCS/NTUA**

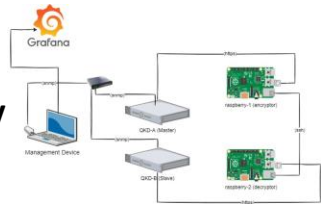
# HellasQCI Industrial and Research Use Cases

- Industrial and Academic partners will demonstrate novel technologies for QKD
- HellasQCI offers a field testbed as the sandpit to further develop the technologies

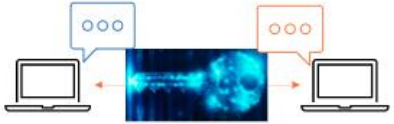
**QKD over 5G**
**QKD for FTTH**
**QKD for DC**




**Quantum key encryption and distribution**



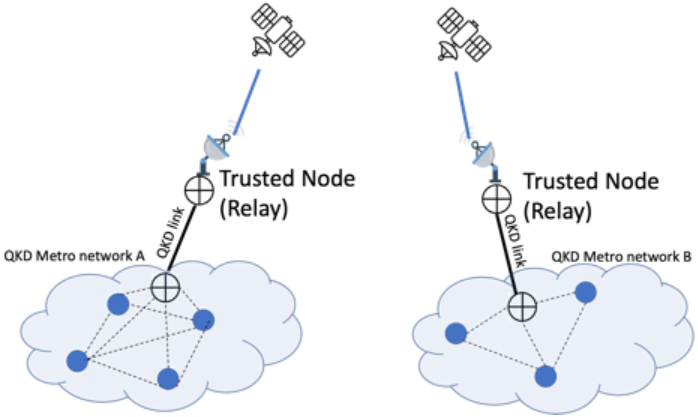

**Quantum-safe messaging and communication application**



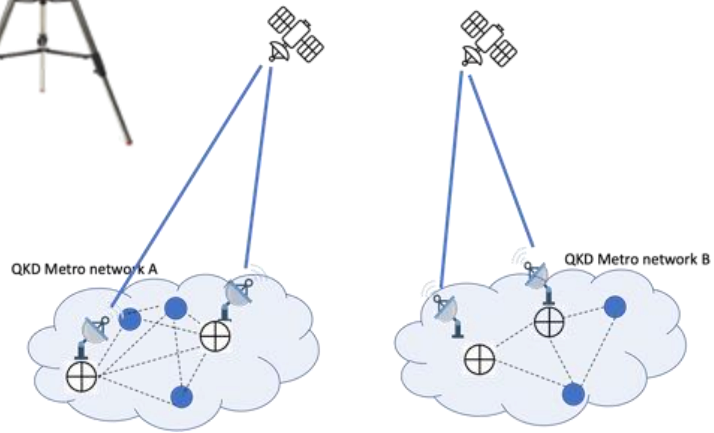
# HellasQCI Industrial and Research Use Cases

- HellasQCI will experiment with FSO and portable OGS to address the need for higher key rates
- Remove requirement to transform an observatory-OGS into a trusted node → the trusted node becomes an OGS

**Large OGS architecture**




**portable OGS architecture**

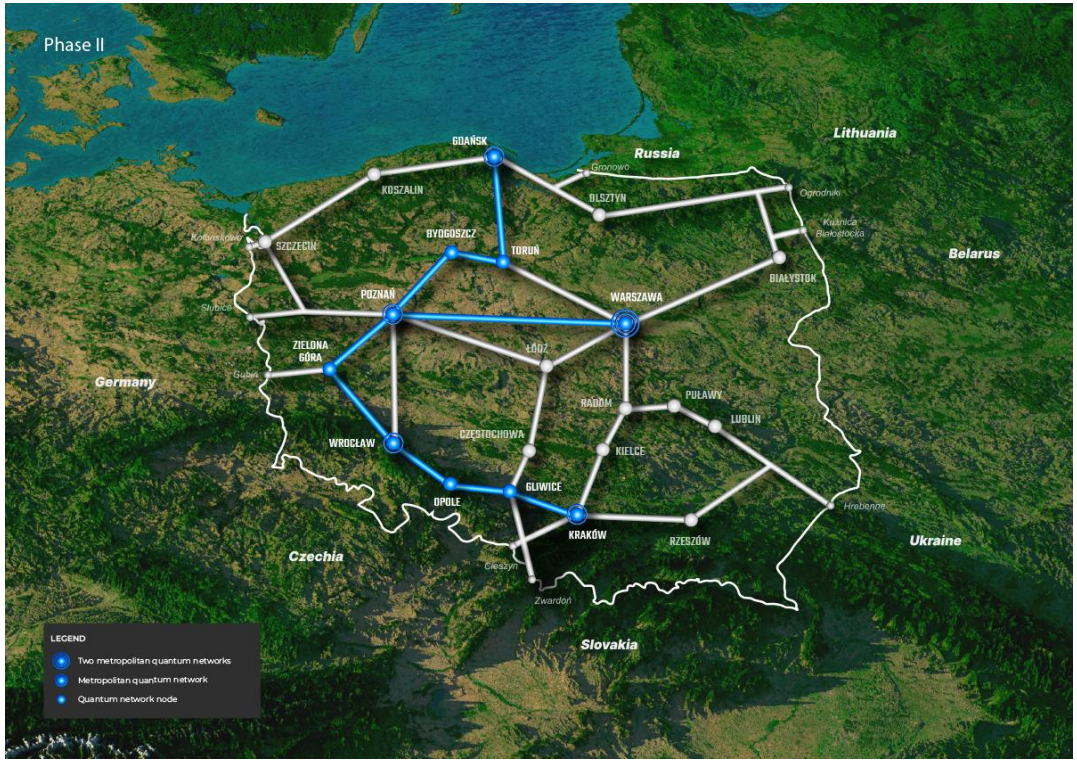



- ✓ *Portable telescope provided by NOA: CPC DELUXE 1100HD*
- ✓ *FSO link 28 cm Telescope (Rx)*

POLISH QUANTUM COMMUNICATION INFRASTRUCTURE

# Overview

- 6 partners (PSNC coordinator)
- Start date: 01.02.2023
- Duration: 30 months
- Budget: 10 Meuro
- Deliverables: EU restricted
- Infrastructure
  - ✓ 1300km of intercity QKD links over dedicated fibers
  - ✓ Trusted nodes nodes in main cities of Poland and ready for metro QKD system installations with different topologies
  - ✓ Each partner has 2 metro QKD systems with encryptors set
  - ✓ NSA connected by dedicated QKD system
  - ✓ Separate “QKD services” layer and integrated with PIONIER infrastructure and services



# IrelandQCI Roadmap towards EuroQCI

| | | | |
|---|---|---|---|
| **Use-case** | QKD Encryption | City & National Quantum Network | Quantum Technology Laboratories & Testing Facilities |
| **End-User** | Government, cybersecurity, data centres | Government, standards, internet exchange, satellite industry | Academia, financial banking, photonics industries, high performance computing, quantum computing, simulators and emulators |
| **Application** | QKD as a service & data storage | Classical/quantum coexistence | Staging quantum internet, quantum interfaces & emitters, quantum PIC assembly & packaging |
| **Software** | QKD protocols & key management | System architecture, SDN, Protocols, security, standards | Quantum algorithms, quantum money schemes, quantum states, distributed quantum computing |
| **Hardware** | TRL 9  | TRL 7 **EuroQCI Ready**  | TRL 3 **Quantum Internet Ready**  |
| **QI Stage** | Prepare & Measure QKD | MDIQKD & Entanglement | Cryogenic Stations · Interfaces · Repeaters & Memories · PIC Packaging |

Month M0 M3 M6 M9 M12 M15 M18 M21 M24 M27 M30

**National Backbone Network**

- M12: PM QKD
  - 3 End Nodes
  - 1 Trusted Node
- M18: PM + SNSPDs QKD
  - 3 End Nodes
  - 2 Bypass Nodes
- M20: MDI QKD
  - 4 End Nodes
  - 2 Core Nodes

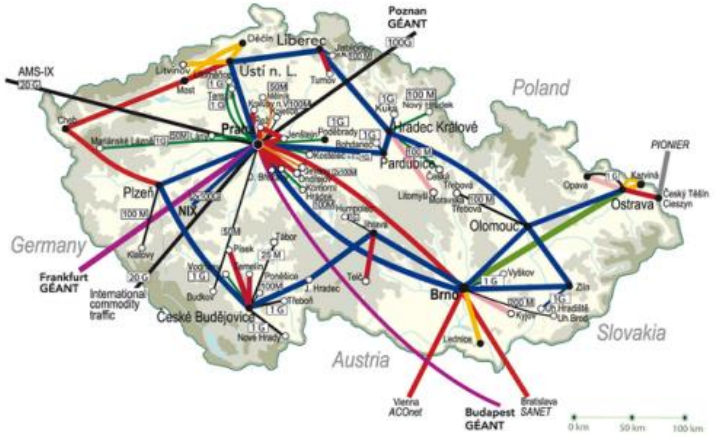

HEAnet
Ireland's National Education & Research Network

# Quantum communication

cesnet

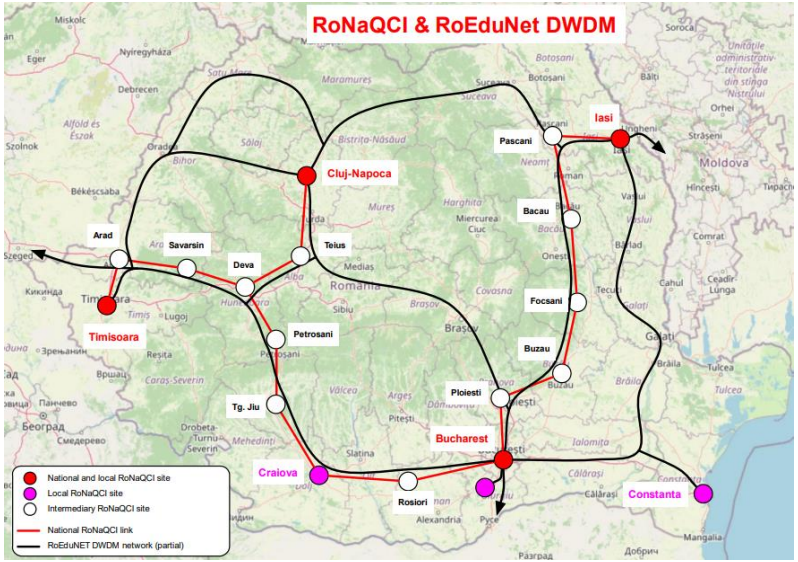
Entanglement-based QKD on CESNET telecom fibers:

- in metropolitan areas (so far deployed QKD in lab, QBER 4.8 %, preliminary key rate 86 bits/s)
- between two cities in CZ (upgrade to twin-field QKD or to multi-entangled source), ongoing in three projects (private, national, QCI)




# RoNaQCI – in numbers

- Deployment of a 1500km+ QCI network including 6 metropolitan networks in the cities of Bucharest, Iasi, Cluj-Napoca, Timisoara, Craiova and Constanta
- 36 QKD links spanning Romania and connecting 10 universities, 5 research institutes, 5 public bodies, 3 data centers and a medical clinic, and with future links planned for quantum Internet interconnecting with neighbors



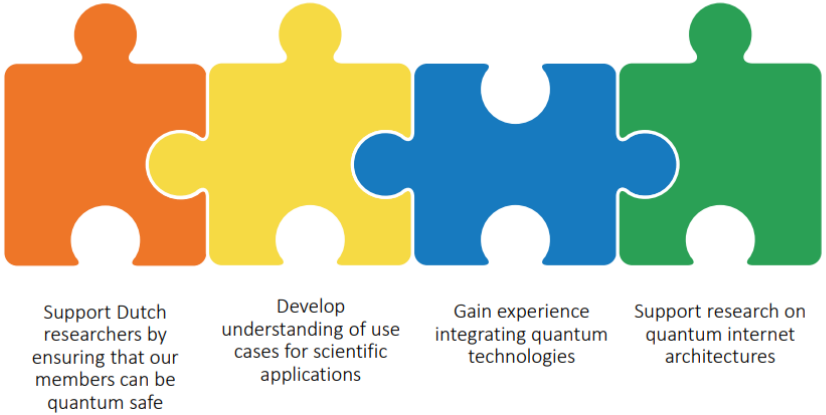

RoEduNet

ronaqci

# QCINed (part of EuroQCI)

- Work package leader
- Preparing deployment of development network in Utrecht
- Defining QKD service
- Developing tools and workflows for the integration of QKD hardware
- Engaging with vendors about feature development

## SURF's role in quantum communication / internet



CYQCI
safe communications

# CYPRUS QUANTUM COMMUNICATIONS INFRASTRUCTURE

CYNET
CYPRUS RESEARCH AND ACADEMIC NETWORK

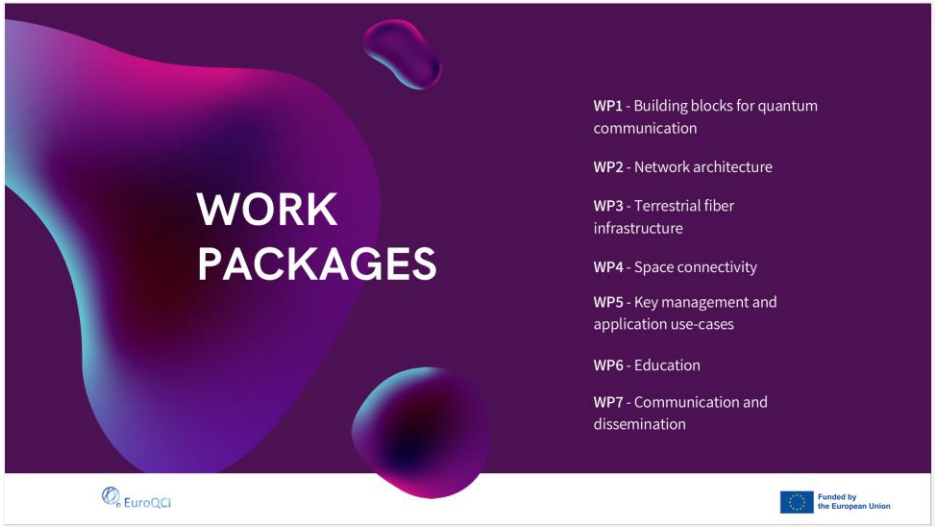
**About the project:**

The Cyprus Quantum Communication Infrastructure (CYQCI) project will be the first to address the ***deployment of quantum communications in Cyprus***, introducing the technology to the island and setting the foundation for active participation of the country in the **EuroQCI** initiative.


**CYQCI will:**

- deploy an advanced experimental quantum network
- demonstrate use-cases whose security is vital for the operation of the country
- set the foundation for EU connectivity via the development of an optical ground station
- kick-start local research and innovation through the development of pilot hardware and software supporting the functionality of the network
- support the EU technological autonomy by procuring its critical equipment from EU suppliers
- contribute to the international standardisation efforts for quantum communications
- Quantum Communications Competence Centre (QCCC) to promote societal interest and quantum technologies

# CroQCI Overview

# SareQuant Overview

i2t research group

## 1. Background

- EHU Quantum Center (https://www.ehu.eus/quantum-center)
  - Gathers EHU's quantum related activity (quantum sensors, quantum computing, communications, fibre manufacturing…)
  - Part of the Basque Country IKUR initiative.
- I2T research group (https://i2t.ehu.eus/es) brings:
  - Telecommunications engineering, expertise in networking
    - Software Defined Networking control planes
    - Cybersecurity
    - 5G deployments, operating infrastructures.
- Quantum Information and Communication Technologies
  - Great impact on society expected in medium-term future
  - Enabling technologies for the applications and communication networks of the future
  - Full support of National (Complementary Plan in Quantum Communications) and Regional (IKUR initiative) governments cofunded with NextGEN EU funds


**Need for platforms that enable quantum experimentation**



i2t research group

## 2. SareQuant objectives and planned activities

| | Objective | Outcome |
|---|---|---|
| Activity 1 | Move towards a Quantum Internet | Design of a quantum infrastructure integrated with a traditional one |
| Activity 2 | Development of tools to enable the use of quantum services | Deployment of QKD-based secure services |

# Quantum Key Distribution Technologies and NRENs

- From the NREN point of view the interesting aspects of quantum technologies and projects are:
  - Quantum Communication
  - Quantum Metrology in view of the T&F signals transmission and activities, it requires R&D
  - **Quantum Communication and Networks and its coexistance with existing networks in principle**
  - **Quantum Computing and its integration with quantum communication and classical HPC and hybrid quantum-classical services**

- These areas are advanced in terms of development and real life application possibilites. Quantum computing and associated simulation still target quantum advantage applications.

- Quantum communication is a base for the quantum Networks and **Quantum Internet Concept. Quantum Internet Research Group (QIRG) and Quantum Internet Alliance (QIA) have been launched** and discuss about technology solutions and possible standardisation.

- **Quantum Key Distribution (QKD)** can be regarded as example of quantum communication and step toward more advanced quantum transmission schemes. **QKD can be used for more than only encryption keys.**

# Quantum Key Distribution Technologies and NRENs, activities within GÉANT

- **Within the GN4-3 and GN5 project, WP6 T1** activities have been formed and ongoing to support and follow QKD and quantum technologies advancements and its possible application in GÉANT, NRENs networks.

- **It directly involves GÉANT and NREN community in the QKD technology development validation and contacts with QKD vendors**. GÉANT/NRENs have potential capabilities and infrastructure to establish QKD distributed testbeds in MAN networks (fibers and equipment) and moreover this community already provides wide set of services that rely on cryptography. Focus on training and education.

- **GÉANT/NRENs infrastructure and experience have potential elements** to also establish and validate QKD technology in the current generation data transmission networks and services.

- **GÉANT Quantum Strategy Group has been formed.**


# Thank you

## Any questions?

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