



**tnc23**

DIGITAL GENERATIONS

TIRANA, ALBANIA | 5-9 JUNE 2023

# Quantum Internet Activities in European NRENs

Dr. Ilias Papastamatiou (GRNET), Piotr Rydlichowski (PSNC)



Co-funded by  
the European Union

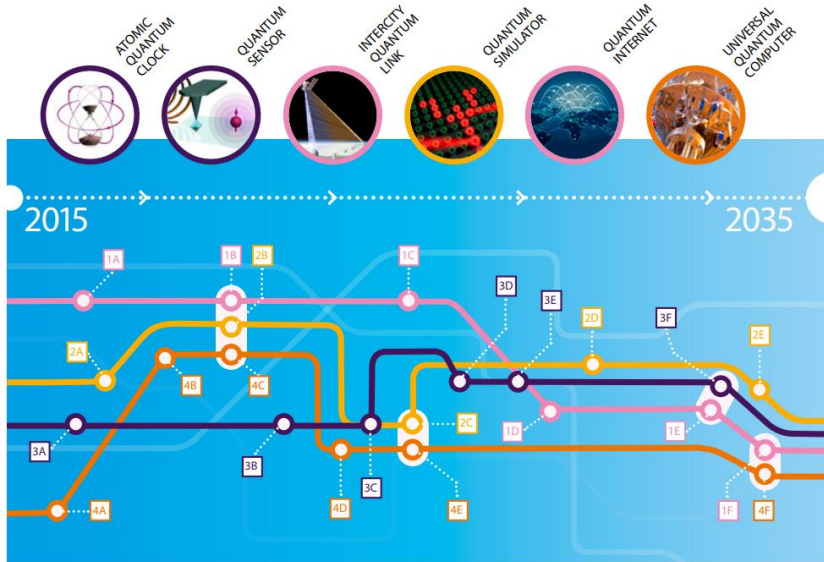
# Quantum Technologies - background

- **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 Infrastructure (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

## Quantum Technologies Timeline



[https://qt.eu/app/uploads/2018/04/93056\\_Quantum-Manifesto\\_WEB.pdf](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



## DECLARATION ON A QUANTUM COMMUNICATION INFRASTRUCTURE FOR THE EU

### All 27 EU Member States

have signed a declaration agreeing to **work together** to explore how to build a **quantum communication infrastructure (QCI)** across Europe, boosting European capabilities in **quantum technologies, cybersecurity and industrial competitiveness.**

@FutureTechEU #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

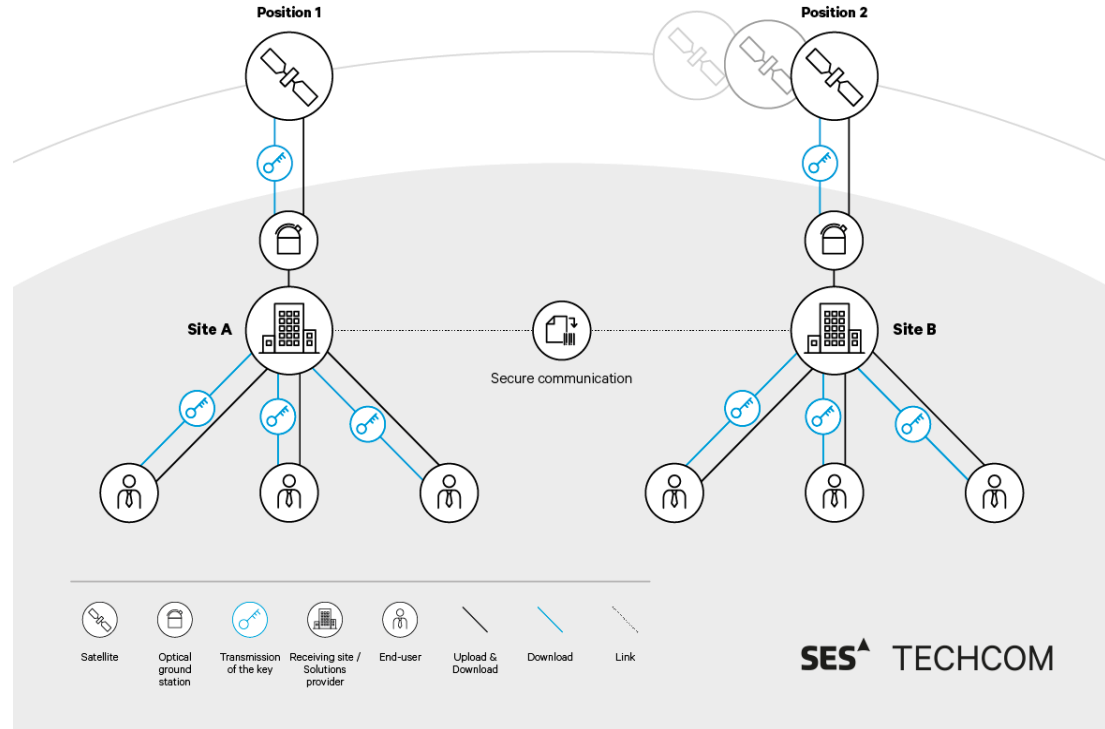
implemented by **ESA**

**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**



SES<sup>A</sup> TECHCOM

Operational EuroQCI → Interoperable and reliable Space and Terrestrial Segments

# EuroQCI Space and Terrestrial Segments

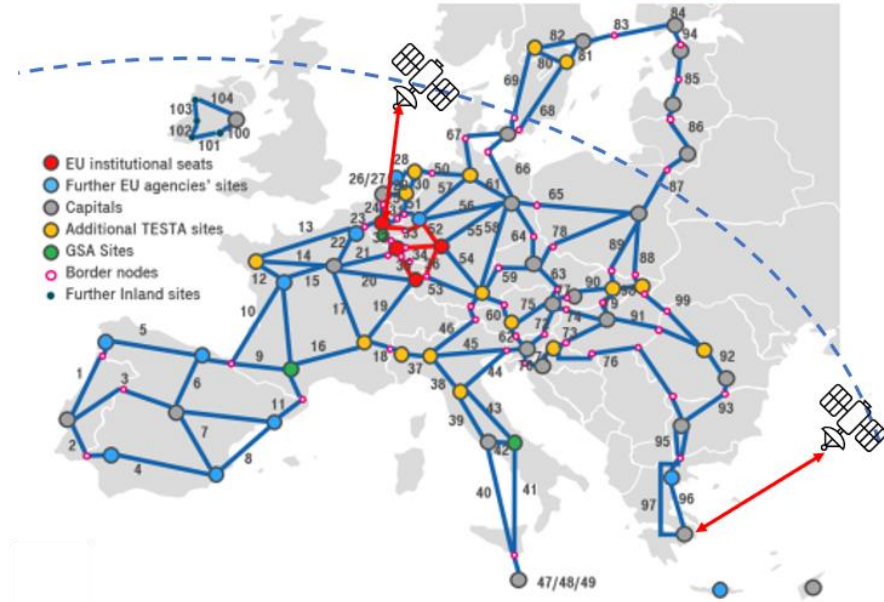
## Terrestrial segment

- 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

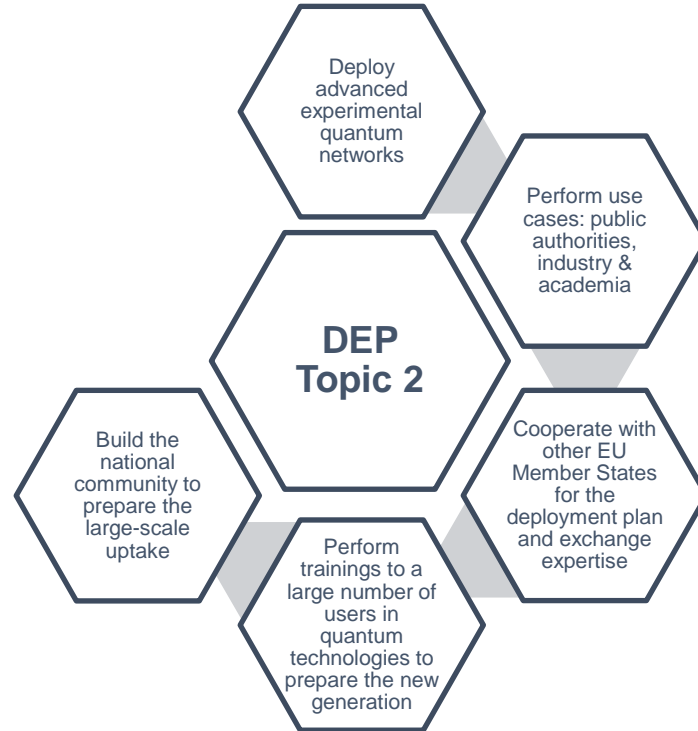
- Bypass cross-boarder operation
- Only solution for island countries
- Ideal for south countries due to clear skies
- Alternative route in critical events
- NRENs and GEANT possible new domain of activity to engage

## Potential sites across the EU (study)



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

# DEP topic 2 - Deploying advanced national QICs



<b>Call Budget: 110 M€</b>		
EU funding rate at 50% - Simple grant		
10 M€ per grant EU Funding per grant: 5 M€	Deadline for submission: 22 February 2022	Starting Day of NatQICs: 1 January 2023

	HellasQCI – Greece   GRNET
	PIONIERQ – Poland   PSNC
	CroQCI – Croatia   CARNET
	BE-QCI   BELNET
	IrelandQCI – Ireland   HEANET
	QCIHungary – Hungary   KIFÜ
	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](#)



## 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



# 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

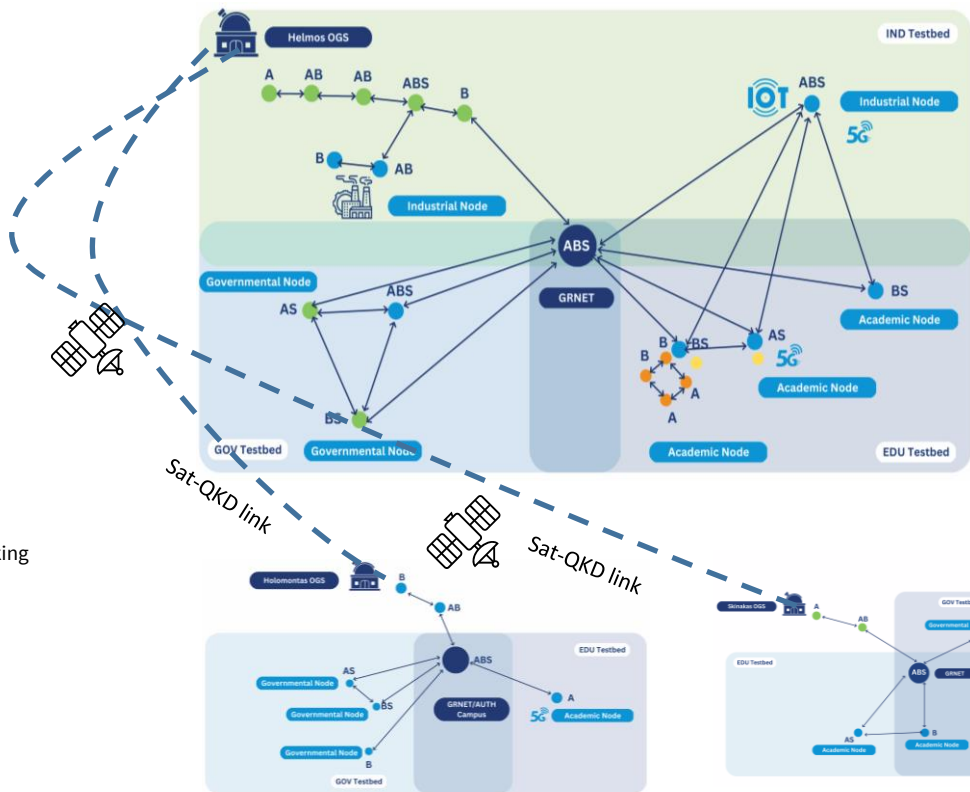
- Governmental (GOV)
- Industrial (IND)
- Research and Innovation (EDU)

## 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

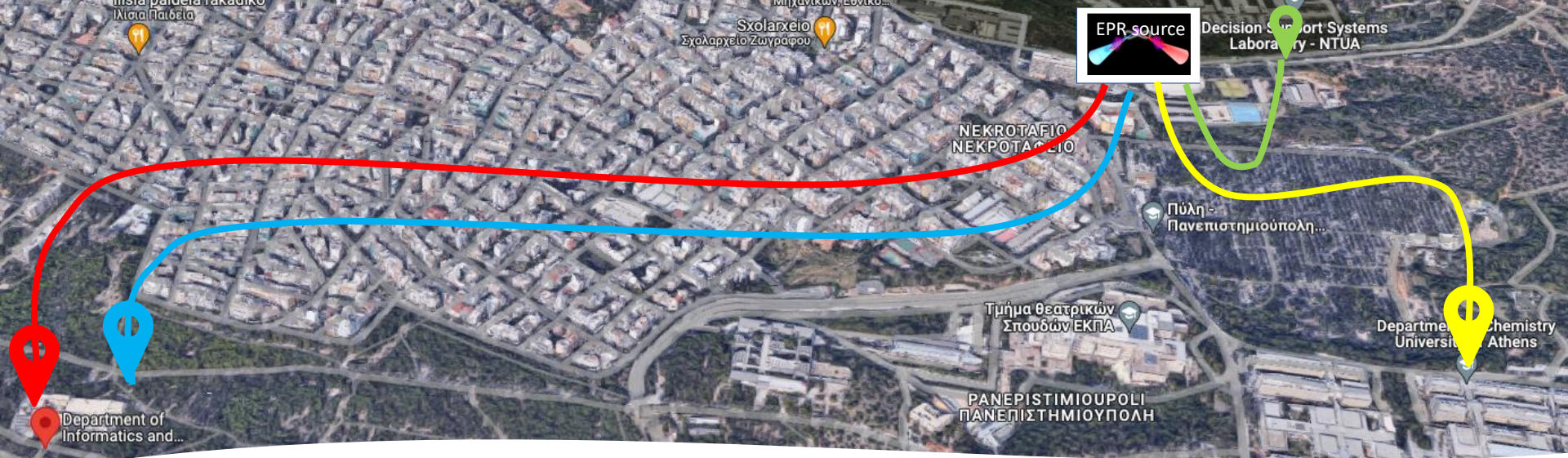
## Research

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

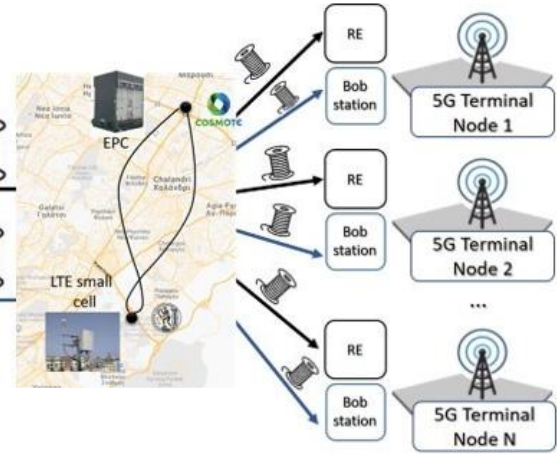
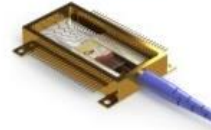


HELLAS QCI  
National and Kapodistrian  
University of Athens  
EST. 1827

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



REC  
Alice station



## Quantum key encryption and distribution



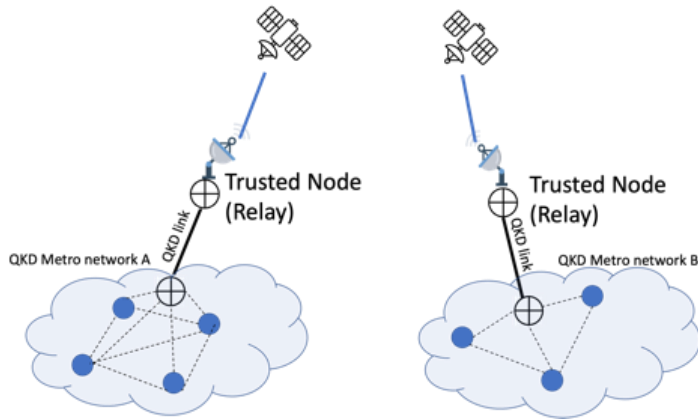
## Quantum-safe messaging and communication application



# HellasQCI Industrial and Research Use Cases

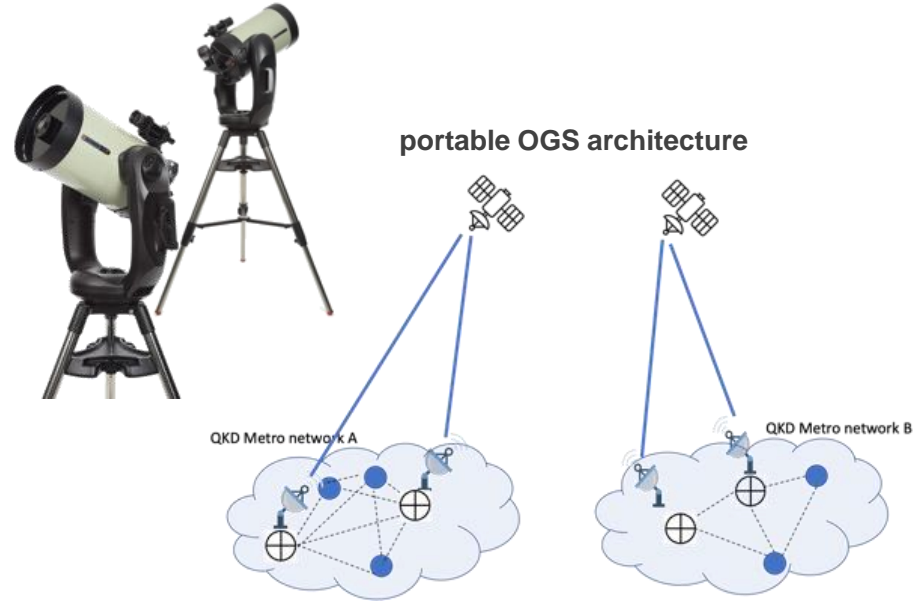
- HellasQCI will experiment with FSO and portable OGS to address the need for higher key rates
- Remove requirement to transform an observatory-OGS into a trusted node → the trusted node becomes an OGS

## Large OGS architecture

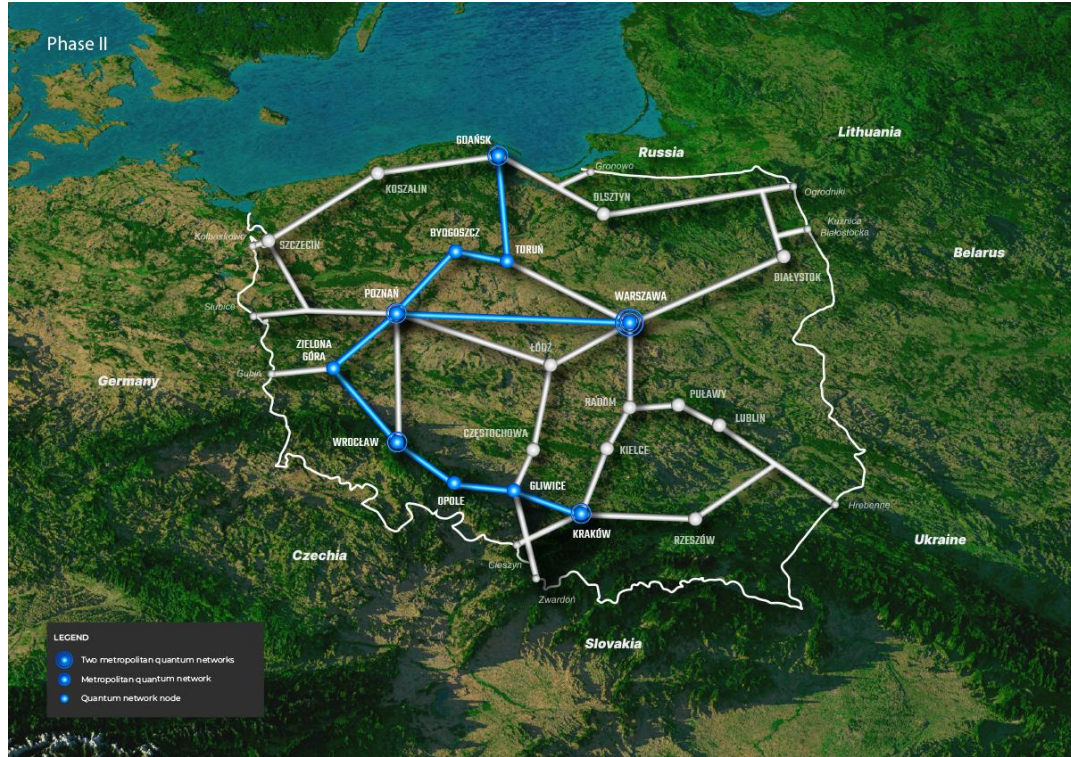


- ✓ Portable telescope provided by NOA: CPC DELUXE 1100HD
- ✓ FSO link 28 cm Telescope (Rx)



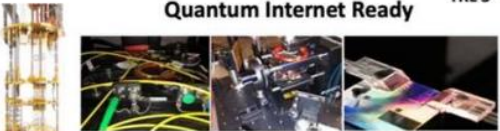
## portable OGS architecture



- 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 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	<p>TRL 9</p>  <p>Prepare &amp; Measure QKD</p>	<p>TRL 7 EuroQCI Ready</p>  <p>MDIQKD &amp; Entanglement</p>	<p>Quantum Internet Ready TRL 3</p>  <p>Cryogenic Stations   Interfaces   Repeaters &amp; Memories   PIC Packaging</p>
QI Stage			
Month	M0   M3	M6   M9   M12	M15   M18   M21   M24   M27   M30

## National Backbone Network

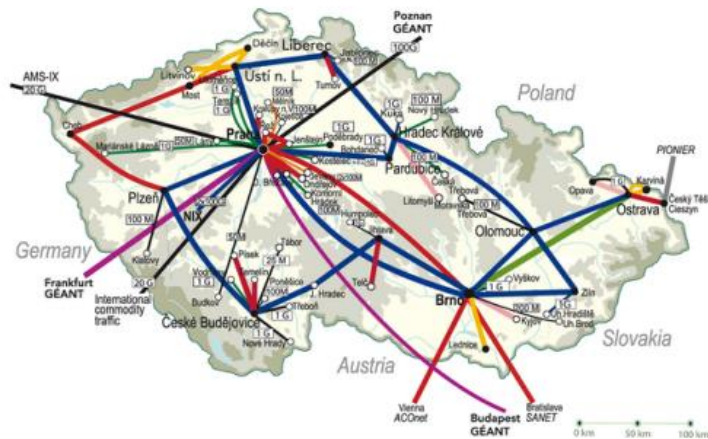
- M12: PM QKD
  - 3 End Nodes
  - 1 Trusted Node
- M18: PM + SNSPDs QKD
  - 3 End Nodes
  - 2 Bypass Nodes
- M20: MDI QKD
  - 4 End Nodes
  - 2 Core Nodes





## 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)



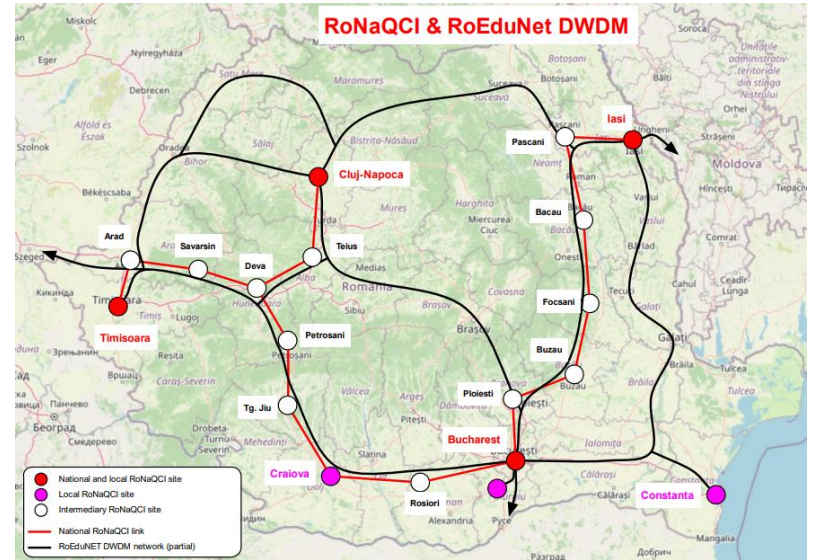
lines with capacity 25Mb and more  
March 2023

- Czech Light transmission system n x 100G
- Czech Light transmission system n x 10G
- Czech Light transmission system n x 10G started by 1G
- Czech Light transmission system n x 1G
- Cisco transmission system n x 100G
- Infinera transmission system n x 100G
- Infinera transmission system n x 10G
- Single colour transmission system
- Leased capacity
- Microwave
- Optical and Microwave

- PoP
- User Point

# 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



# 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



Support Dutch researchers by ensuring that our members can be quantum safe

Develop understanding of use cases for scientific applications

Gain experience integrating quantum technologies

Support research on quantum internet architectures



## CYPRUS QUANTUM COMMUNICATIONS INFRASTRUCTURE



### 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

## 9 PARTNERS



### Coordinator

Croatian Academic and Research Network –  
CARNET

### Beneficiaries

- Ruđer Bošković Institute (IRB)
- Marine Electronic Center Ltd (PCE)
- University of Zagreb University Computing Centre (SRCE)
- Institute of Physics (IFZ)
- University of Zagreb, Faculty of Electrical Engineering and Computing
- University of Zagreb Faculty of Transport and Traffic Sciences (FPZ)
- Transmitters and Communications Ltd (OIV)
- Office of the National Security Council (UVNS)

## WORK PACKAGES

WP1 - Building blocks for quantum communication

WP2 - Network architecture

WP3 - Terrestrial fiber infrastructure

WP4 - Space connectivity

WP5 - Key management and application use-cases

WP6 - Education

WP7 - Communication and dissemination



# 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

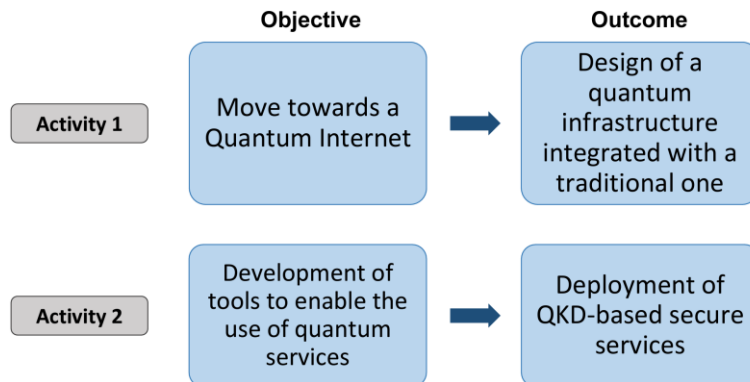


**Need for platforms that enable quantum experimentation**

GEANT event: Celebrating The World Quantum Day – 14 April 2023

i2t research group

## 2. SareQuant objectives and planned activities



GEANT event: Celebrating The World Quantum Day – 14 April 2023

# 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 coexistence 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 possibilities. 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.**



# tnc23

DIGITAL GENERATIONS

TIRANA, ALBANIA | 5-9 JUNE 2023

## Thank you

### Any questions?

Dr. Ilias Papastamatiou (GRNET)

[ipapastamatiou@admin.grnet.gr](mailto:ipapastamatiou@admin.grnet.gr)

Piotr Rydlichowski (PSNC)

[prydlich@man.poznan.pl](mailto:prydlich@man.poznan.pl)



Co-funded by  
the European Union

