



Quantum technology at the European Commission Joint Research Centre

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The role of the JRC in EU policymaking

In-house scientific and technical service of the European Commission

Independent of private, commercial or national interests

Policy neutral – no policy agenda of its own

Works for more than **30 policy departments** in the **European Commission**



JRC sites across Europe

Headquarters in **Brussels**
and research facilities located
in **5 Member States**:

Belgium (Geel)

Germany (Karlsruhe)

Italy (Ispra)

The Netherlands (Petten)

Spain (Seville)



European Quantum Communication Infrastructure (EuroQCI)

- An integrated satellite and terrestrial system spanning the whole EU for ultra-secure exchange of cryptographic keys (Quantum Key Distribution)
- The EuroQCI is part of the European Cybersecurity Strategy and is integrated into IRIS², the new EU Secure Connectivity Programme, - Regulation (EU) 2023/588

EuroQCI space segment

Distribution of quantum-secured encryption keys on a global scale



EuroQCI terrestrial segment

Federation of national terrestrial QCI networks with cross borders connections



EuroQCI - overview

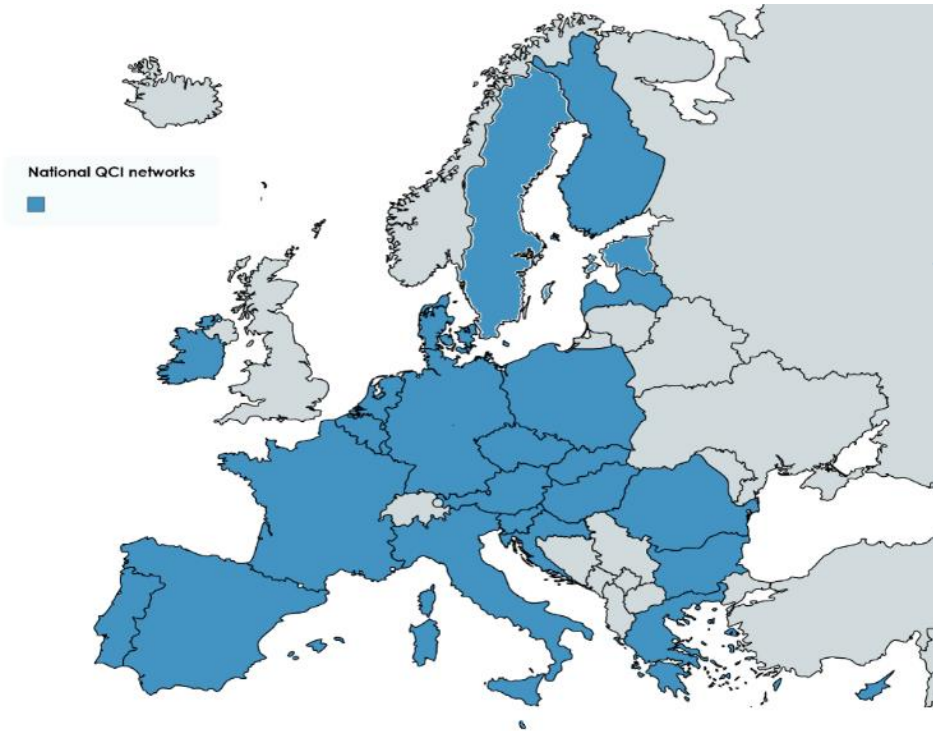
- The first operational system in the world providing Quantum Key Distribution (QKD)
- Exchange of information and data **protected by quantum technologies**



- ✓ EuroQCI Declaration signed by all **27 Member States**
- ✓ **Digital Europe Programme** DIGITAL-2021-QCI-01-DEPLOY-NATIONAL supports national deployments
- ✓ **Joined Action Plan** supporting the national **terrestrial** and **space** implementations
- 5 ✓ **European Declaration on Quantum Technologies signed (Dec 2023)**

EuroQCI Terrestrial: State of Play

- **26 Member States** starting to deploy **national QCI networks**
 - DIGITAL projects started 1 January 2023, 30 months
 - Initiate MS to QKD use, mature skills, test architecture, develop use cases, prepare for full deployment
- **6 DIGITAL industry projects** started for maturing EU QCI technologies:
 - QKD systems ready for integration into telecommunication networks
 - QKD modules (QRNG, optical component), key management software, encryptors. QKD protocols (e.g. CV-QKD and MDI-QKD)
- **Nostradamus** - testing and evaluation infrastructure
- Coordination and Support Action - **PETRUS**
- **Cross border & deployment of optical ground stations** (CEF) published Oct 22nd 2024 (to synchronise with Eagle 1)



EuroQCI Space Segment



Eagle 1 – LEO satellite for in orbit demonstration and early tests

- Eagle 1 under development, led by ESA
- Funded by Horizon Europe / ESA / Industry
- Operations:
 - QKD proof of concept & testing interfaces with OGS
- Launch Nov 2025-Feb 2026

SAGA 1st Generation - deployment of LEO satellites with EU technology

- First prototype satellite by EU/ESA
- Possibly additional satellites by Member States
- Operations:
 - Exchange quantum keys between different sites on EU territory
 - First validation of end to end system: interconnected LEO satellites + ground stations + terrestrial systems
 - Initial coverage of user and security requirements – Incremental approach

SAGA 2nd Generation - deployment of a fully operational system integrated with IRIS² for secure connectivity

Full coverage of user and security requirements

EuroQCI use-cases

-  - Telecommunication
-  - Transport
-  - Finance
-  - Energy
-  - Health
-  - Space assets
-  - Water
-  - Emergency/disaster response infrastructure
-  Cyber Security Operation Centres

EuroQCI – Space & Terrestrial deployment



EuroQCI (product) security testing & evaluation

Terrestrial

Deploy 1st generation (DEP)
Mature EU Technologies
National deployments

Expand 1st Generation National QCI
Prepare QKD Tech for 2nd Generation
(Market ready and EUCI certified tech)

Deploy 2nd Generation
Operational
Accredited EUCI

Deploy 1st Generation (CEF)
Cross-border connections
Optical Ground Stations



Eagle 1

Development



Eagle 1 operation

Space

EuroQCI 1st generation

EuroQCI Space 1st generation – SAGA



1st generation EuroQCI operation

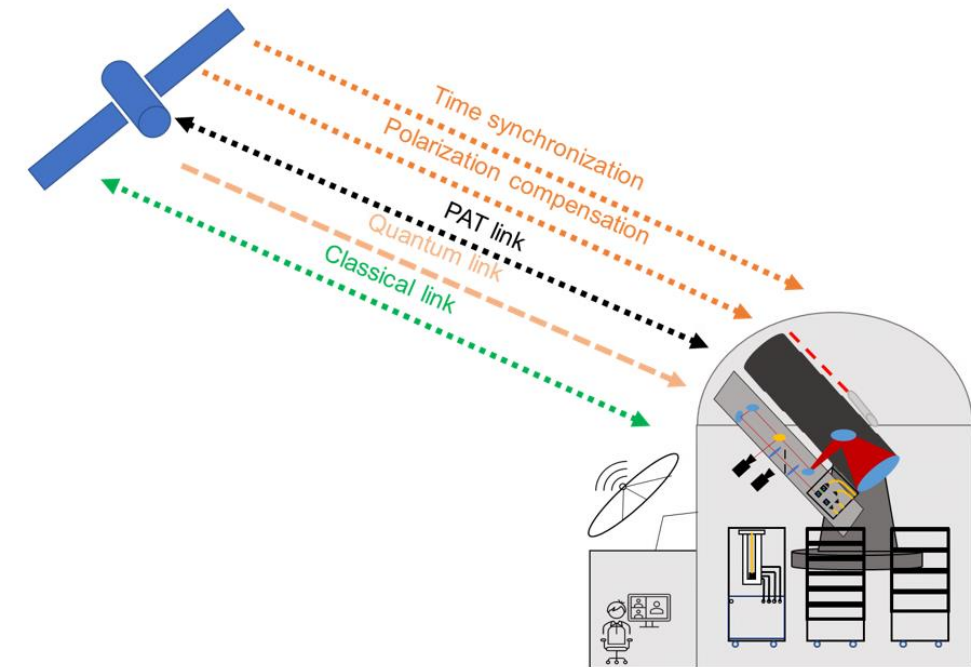
EuroQCI system security baseline

EuroQCI Space 2nd generation
Certified QKD tech – Accredited EUCI & integrated in IRIS²

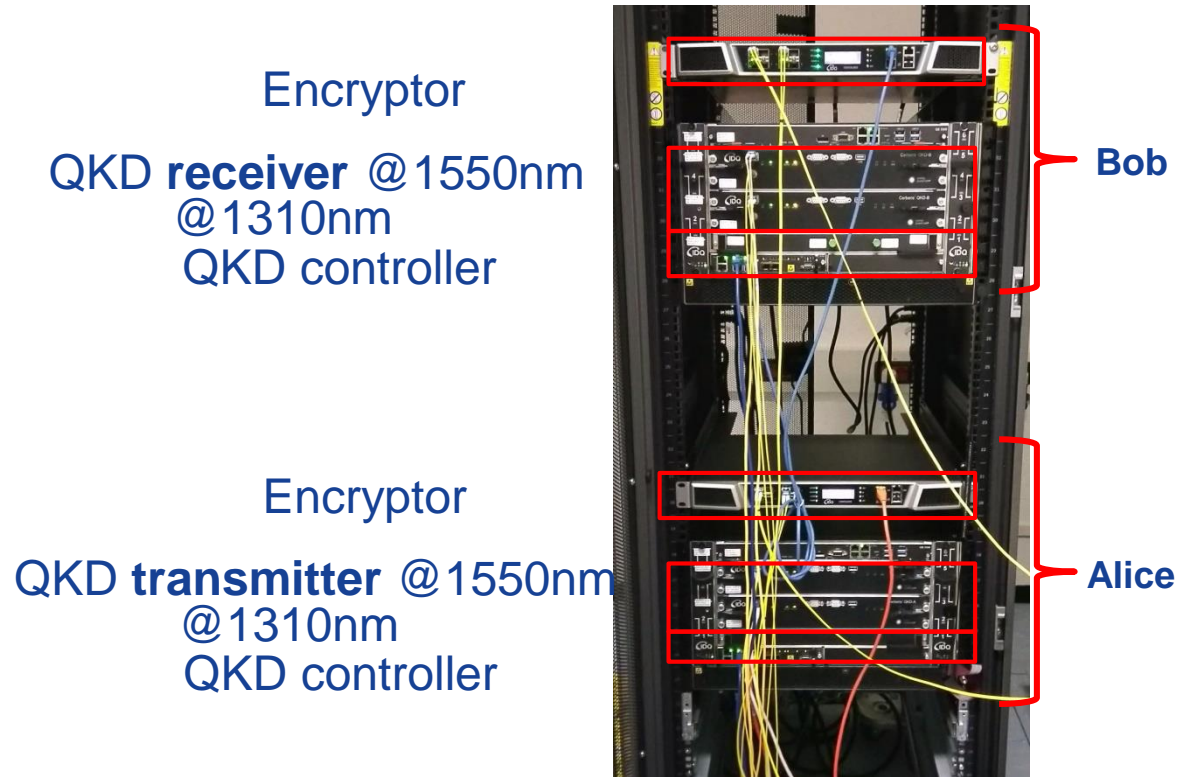


Readiness for **EuroQCI QKD operational service** developments:

- QKD technology maturation and European supply chain readiness
- Definition of the initial EuroQCI QKD protocol
- Prepare for QKD components' security certification/approval
 - Component identification
 - Protection profiles
- Define QKD security proof – collaboration with JRC
- Perform in-orbit validation
 - QKD performance profiling
 - System verification (QKD pen-testing) and qualification
 - Preliminary service validation



What does a quantum key distribution installation look like?



ID Quantique Cerberis 2

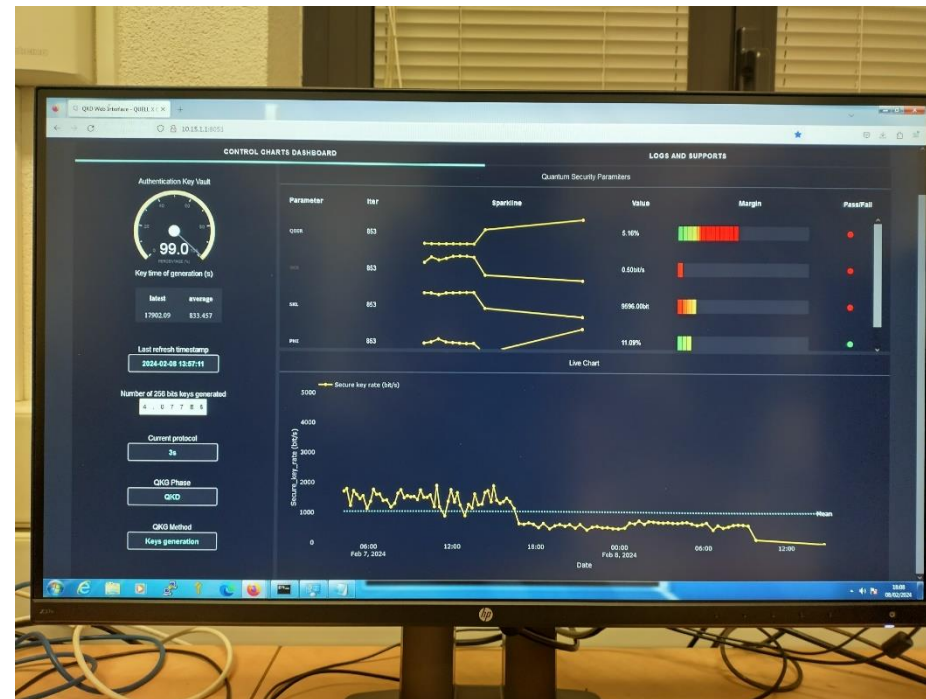
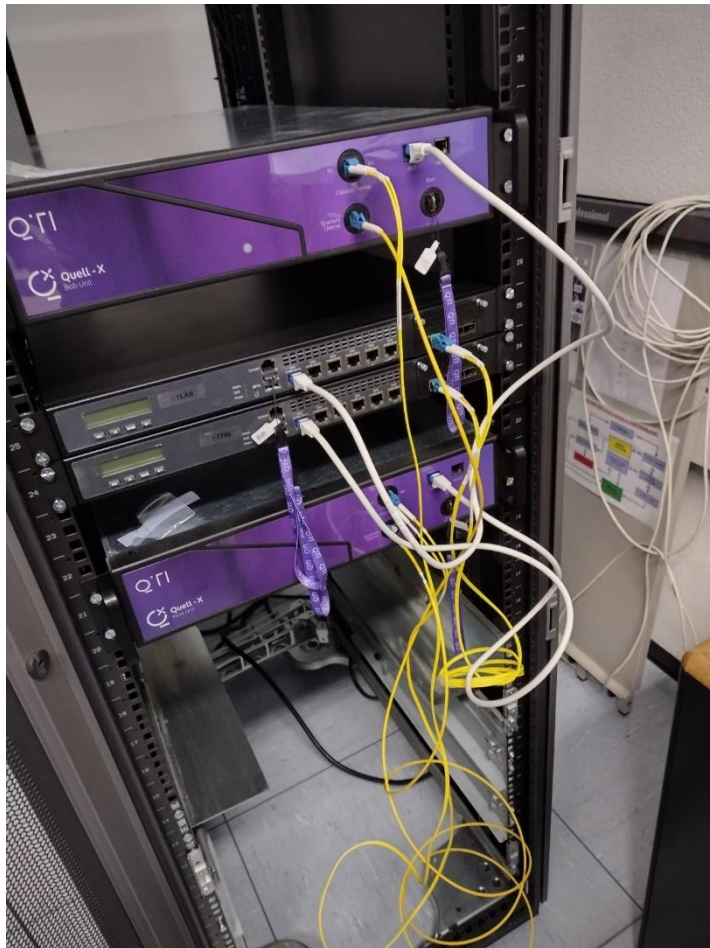


DLR transportable optical ground station

Evaluation of QKD systems at JRC

Quantum Key Distribution (QKD) system by QTI (QUELL) for a secure exchange of encryption keys

- Tested on Ispra fibre network on site (few km)
- Tested with 5G traffic



Nostradamus - Objective

Blueprint for a Testing & Validation Infrastructure

“It is the goal of this Consortium to describe the blueprint for a Testing & Validation Infrastructure in order to enable the evaluation and certification of QKD devices and related technologies, as well as to implement and operate a prototypical testbed facility to offer initial evaluation services which are mandatory for the accreditation from a European security authority.”



Deutsche Telekom Global Business Solutions Belgium NV/SA
(DTGBS, including Deutsche Telekom Security GmbH and Deutsche Telekom Technik GmbH)



AIT Austrian Institute of Technology GmbH (AIT)



Thales SIX GTS France
(TSGF, including Thales Alenia Space France and Thales Belgium)



Nostradamus test combinations

Split the challenges in small portions which are easier to handle. Applicable for various aspects. e.g. distribute the academic contributions across Europe.

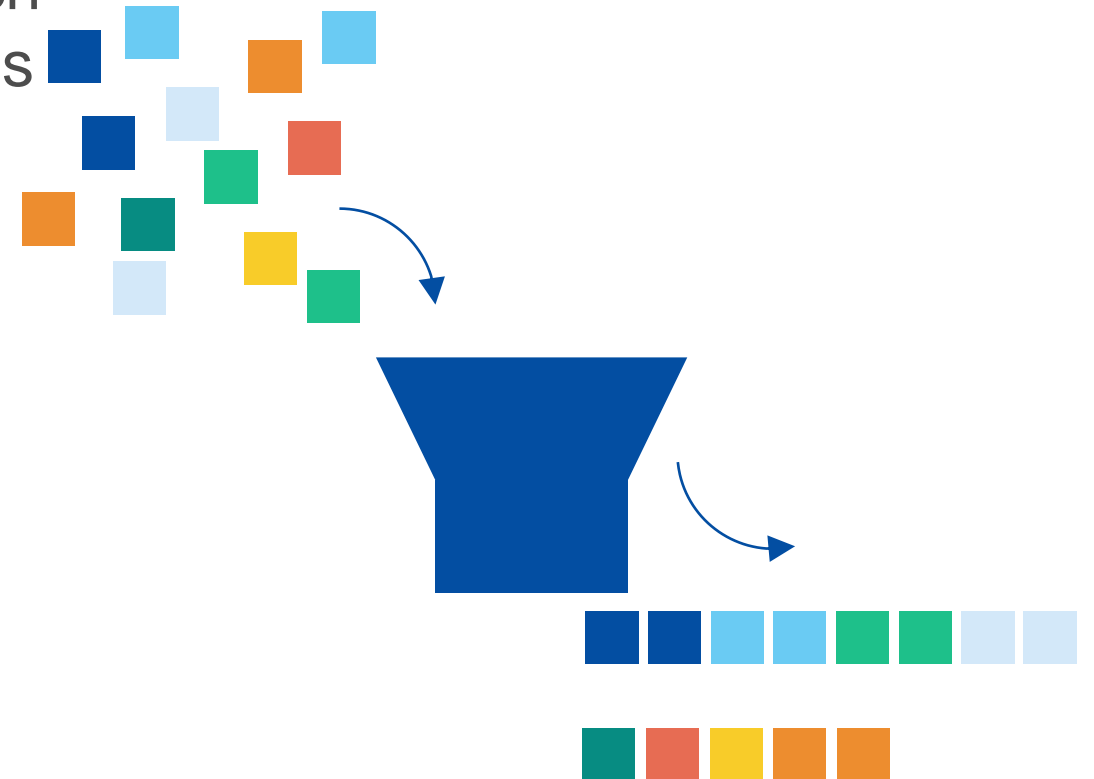
Central notion “Test Combination”:

Prioritization based on triplets of:

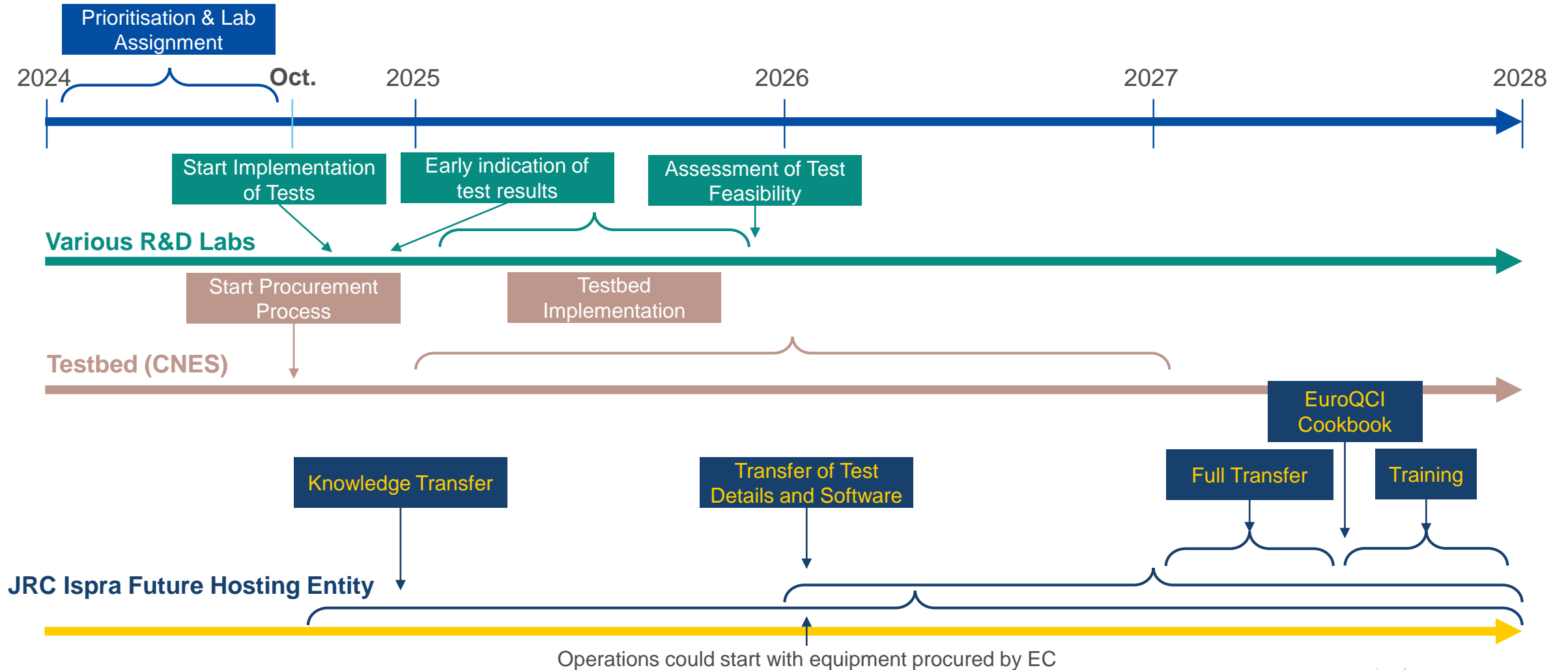
QKD Product

QKD Protocol

Side Channel Attacks



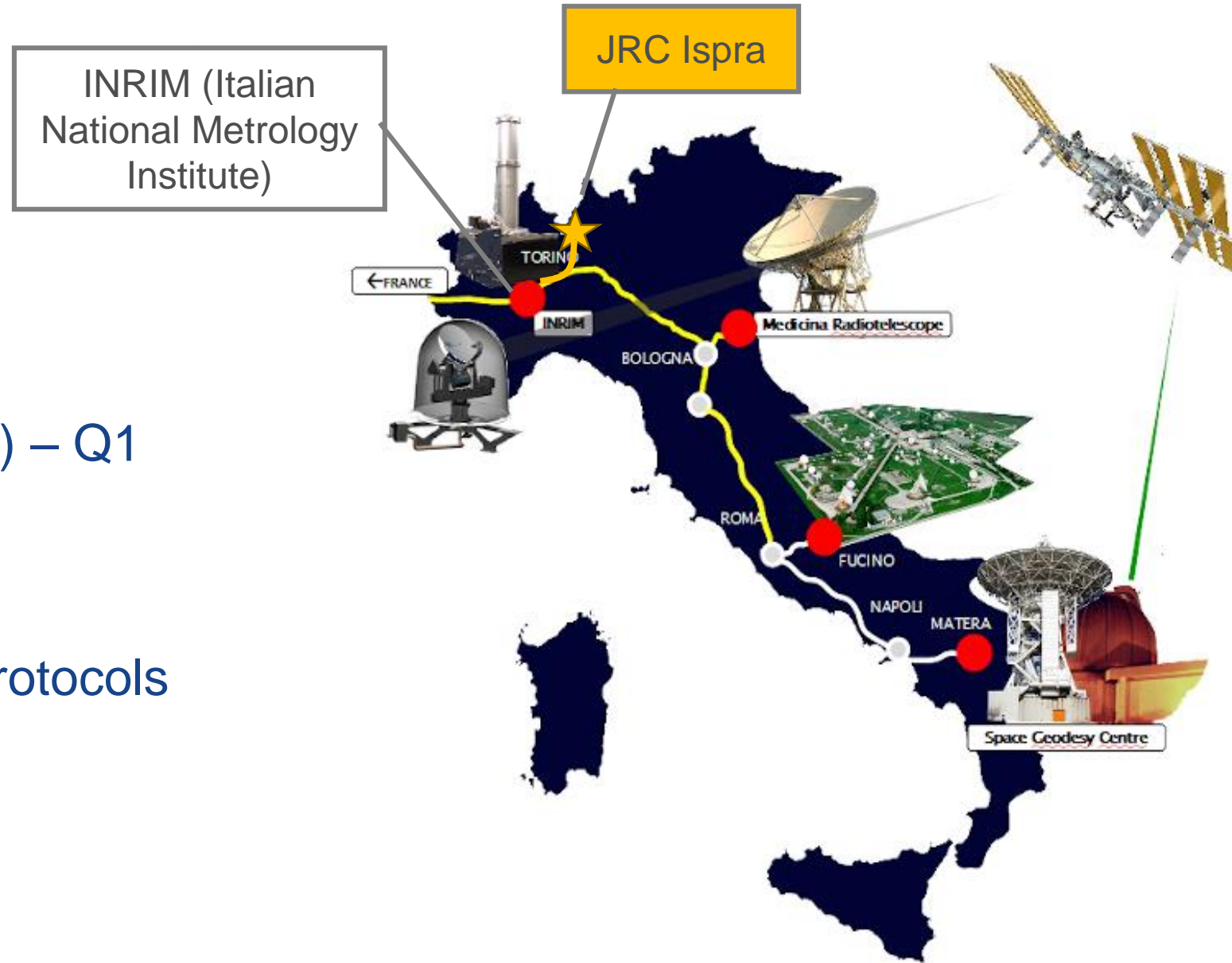
Proposed timeline for transferring testbed to JRC Ispra



Connecting JRC to the Italian Quantum Backbone

Collaboration with INRIM for:

- Precise timing signal (Galileo) – Q1 2025
- QKD – Q2 2025
- testing innovative quantum protocols



JRC timing activities

- JRC has contributed to the development of **CEN/CENELEC standard for Galileo Timing Service Receivers**
 - First worldwide standard for GNSS timing receivers
 - Published in December 2024
- JRC has developed a state-of-the-art **test-bed for GNSS-based time transfer** and synchronization solutions
- On-going cooperation with BIPM for **absolute and relative calibration** of GNSS receivers/antennas

EUROPEAN STANDARD

EN 16605

NORME EUROPÉENNE

EUROPÄISCHE NORM

December 2024

ICS 33.070.40

English version

Space - Galileo Timing Receiver - Functional and Performance Requirements and associated Tests

Espace - Récepteur de signaux Galileo pour référence temps - Exigences fonctionnelles et de performances, et essais associés

Galileo timing receiver standard



INRIM White Rabbit interconnection

- Expected to become **operational Q1 2025**
- JRC will be in a **unique position** to do both GNSS and fiber-based time transfer
- Support to definition of future **Galileo Timing service**
- **Key element** for compliance to Galileo Receiver Timing Standard and associated tests



GALILEO TIMING SERVICE MESSAGE OPERATIONAL STATUS DEFINITION (TSM OSD)

Issue 1.1 | December 2024

The European Radio Navigation Plan

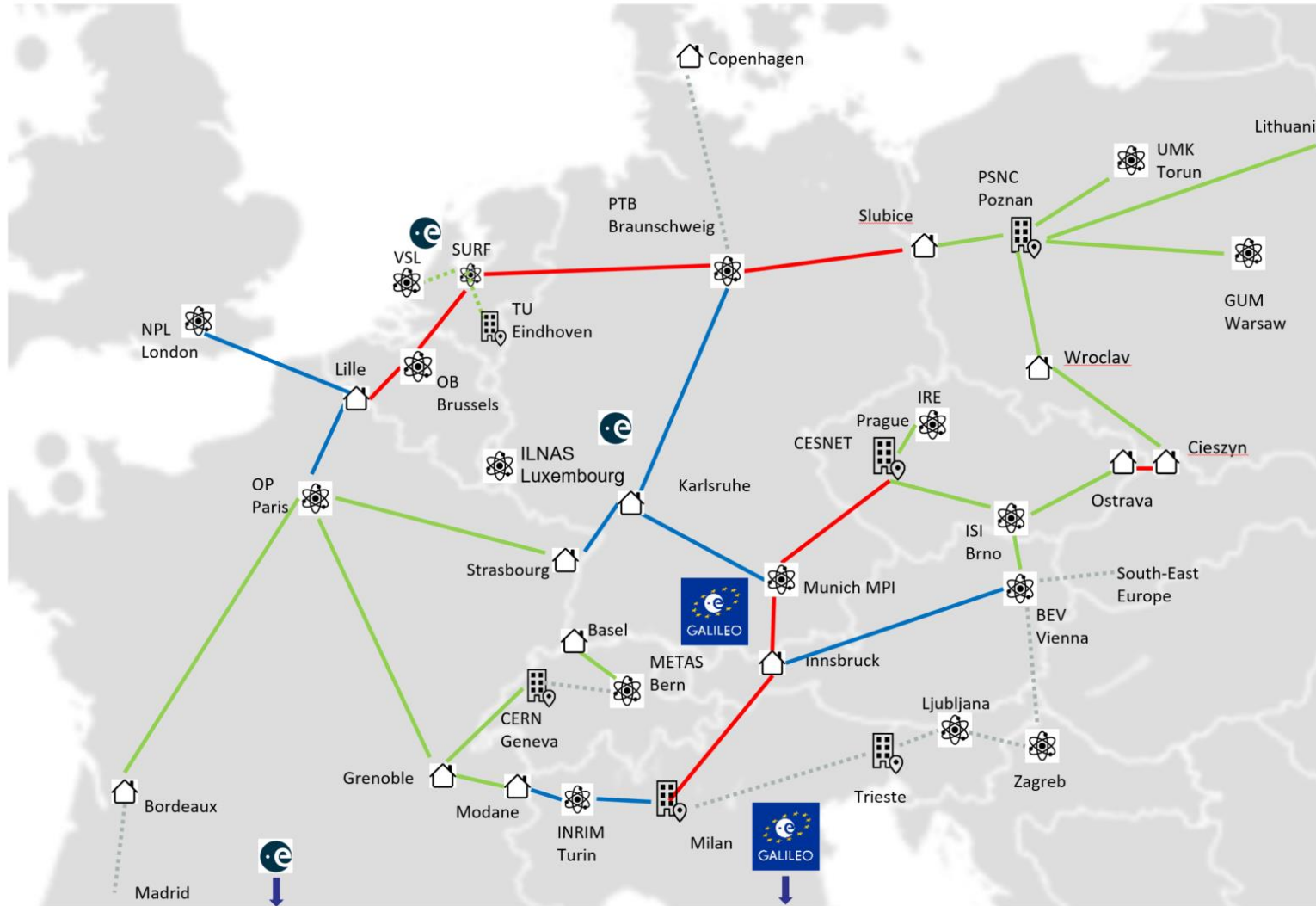
Was mandated in 2016 Space Strategy for Europe. The 2023 edition is the EC staff working document, written by DG DEFIS and DG JRC. The document aims to:

1. Provide information on **conventional and emerging PNT** systems and services;
2. Facilitate the uptake of the European GNSS (Galileo and EGNOS) services by
 - providing **detailed information on European GNSS** current and future services and their **added value**;
 - Recommending **EU level actions for the uptake of EGNSS** in across market domain/sector, including legislation and standards.
3. Recommend actions to **increase the resilience of PNT** services in the EU and explains the **EU PNT policies** while summarizing international ones.
4. Outline **the medium-term vision of EU PNT evolution** based on the COM exercise (2022-2023) and inputs from stakeholders, clarifying that **this is not yet an agreed policy**.



Preparatory Phase of **Pan-European** optical fibre service

Proposed C-TFN - Option A plus ESA sites



Included:

- 10-year IRU for fibre on **red routes**
- Bidirectional amplifiers as needed to light the fibre on the red routes

Excluded:

- Green lines – fibre built by NRENs
- Blue lines – fibre built by NMIs
- Dashed grey – proposed future links
- Flywheels, counters frequency combs needed are to be funded by the national time/frequency providers
- Time/Frequency overlay services

ESA:

- ESA/ESTEC (Noordwijk, NL)
- ESA/ESOC (Darmstadt, DE)
- ESA Ground Station (Villafranca, ES)
- EUSPA/Galileo GCC (Fucino, IT)
- EUSPA/Galileo (Oberpfaffenhofen, DE)

- NMI Frequency reference
- Research institute
- Hut for housing RLS

Quantum for Timing and Timing for Quantum

Two different but interrelated technologies

Timing for Quantum:

Timing for Quantum Key Distribution

Quantum for timing:

Quantum-secure Time Distribution

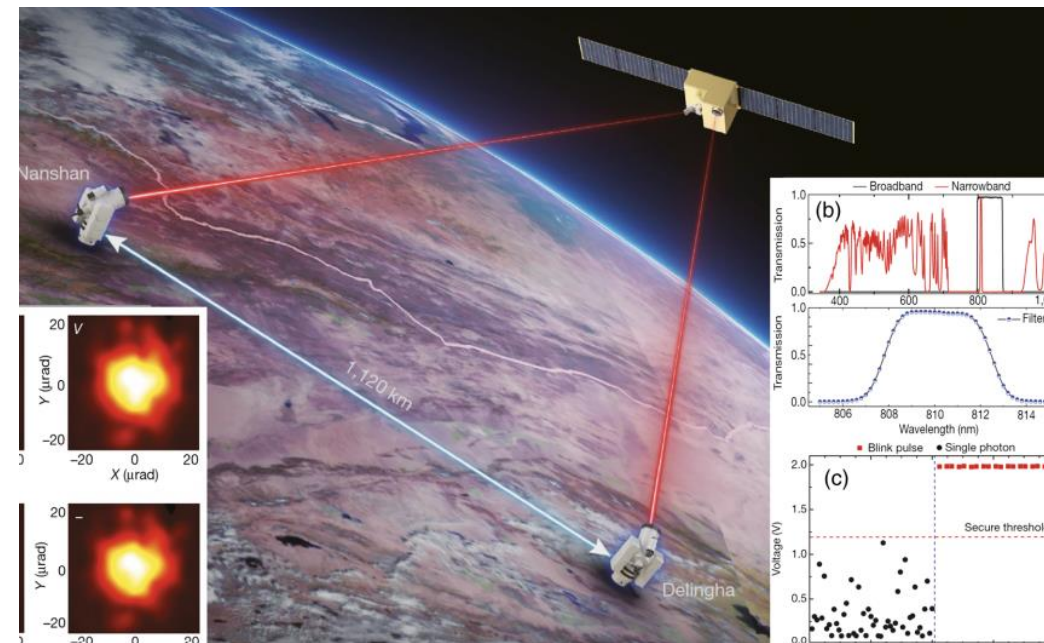
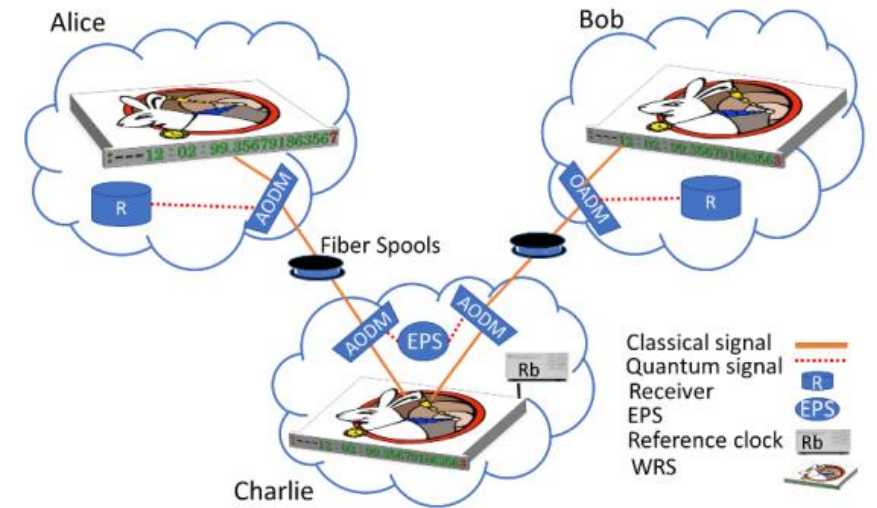
Quantum Clocks for Accurate Timing

Timing for Quantum Key Distribution

White Rabbit precise time protocol exploited in Twin-Field QKD and in entanglement distribution networks

Synchronization is more complex in satellite-based quantum communications

MICIUS satellite used both a GPS PPS and an assistant pulse laser for synchronization in QKD and entanglement distribution experiments

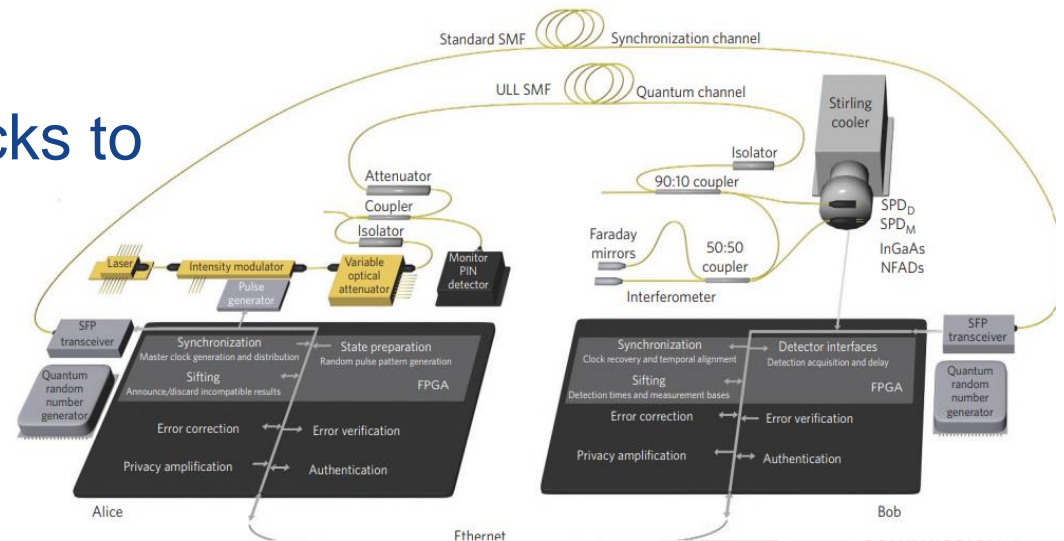
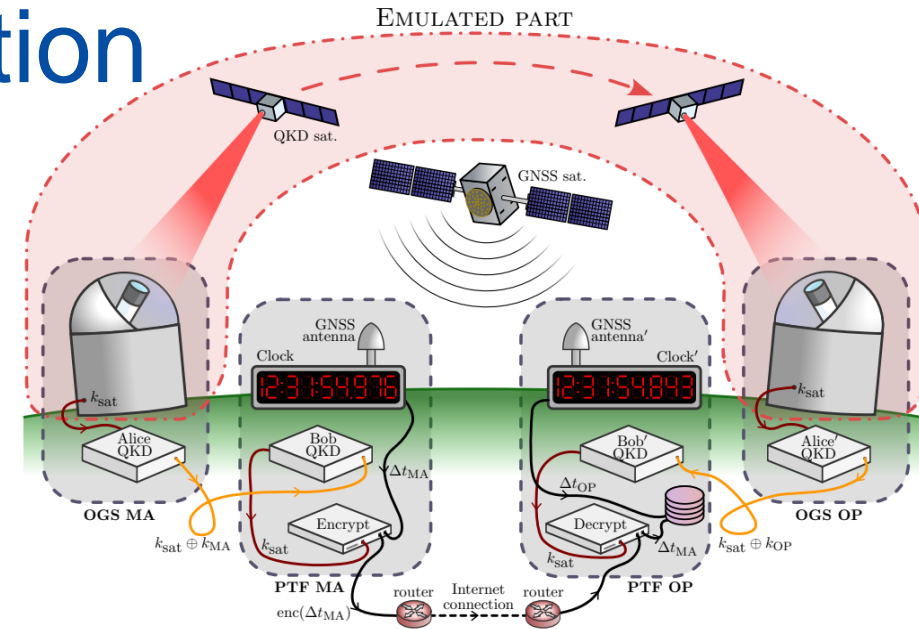


Quantum-secure Time Distribution

QKD to encrypt time transfer by securing the connections between independent GNSS systems

QKD synchronization (time, frequency, phase) allows for the correct shared key

sharing transmitter's clock via separate (or same) quantum channel - locking both clocks to external (GNSS) time ref - analysing Bob's measurement data (Qubit4Sync protocol)



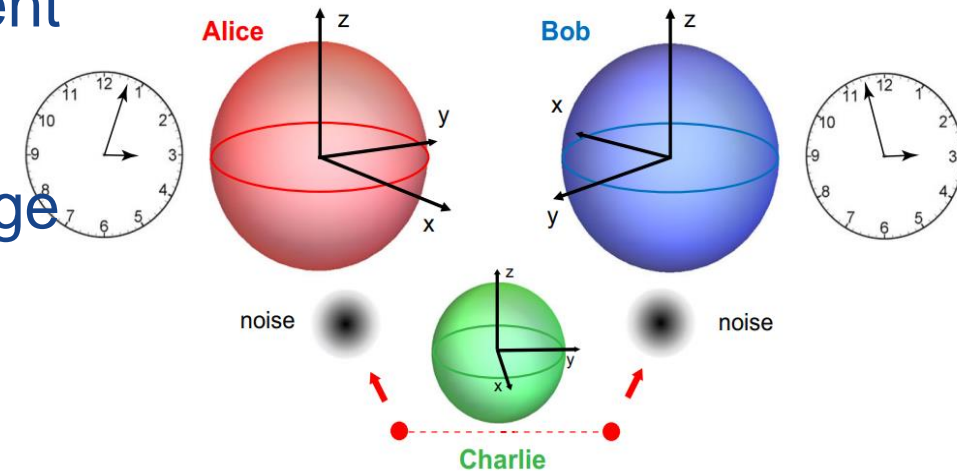
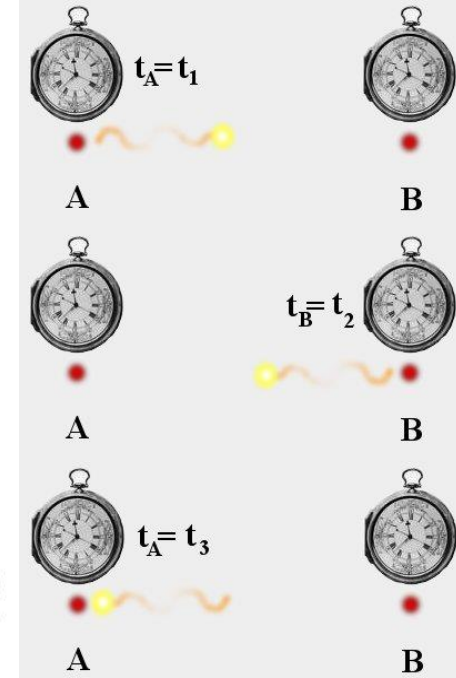
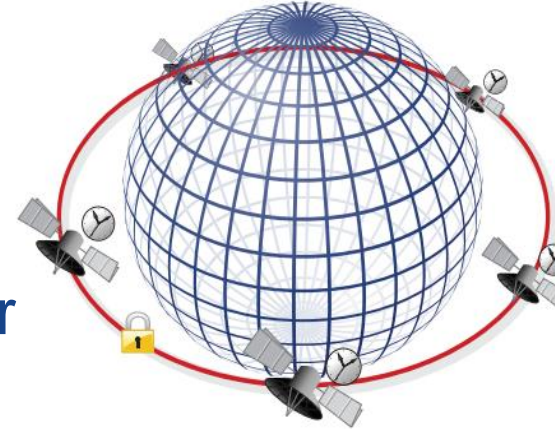
Quantum Clocks for Accurate Timing

Classical Einstein's and Eddington's synchronization

Quantum clock synchronization based on prior entanglement sharing (Josza et al., 2000)

Quantum clock synchronization without prior common phase reference based on entanglement purification (Ilo-Okeke et al. npj, 2018)

Worldwide quantum clock network based on large GHZ entangled states (Komar et al. nature physics, 2014)



Standards for Quantum-Safe communication

- ETSI ISG QKD and TC CYBER Quantum Safe



- CEN CENELEC JTC22



Standardization Roadmap on Quantum Technologies

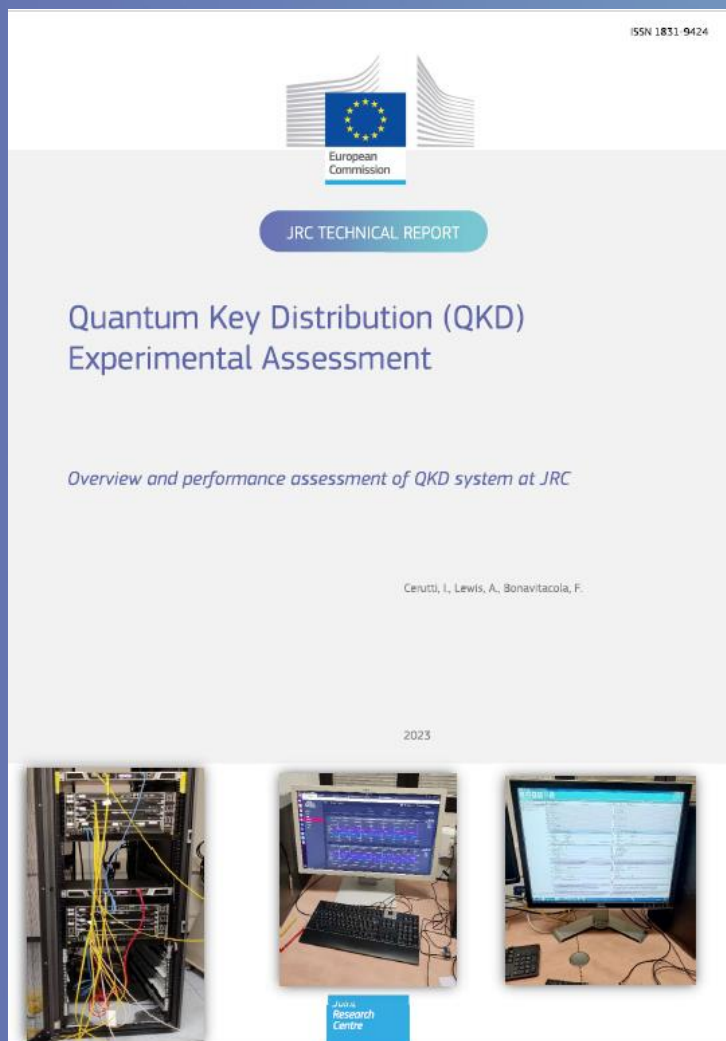
New edition in preparation

- ITU-T

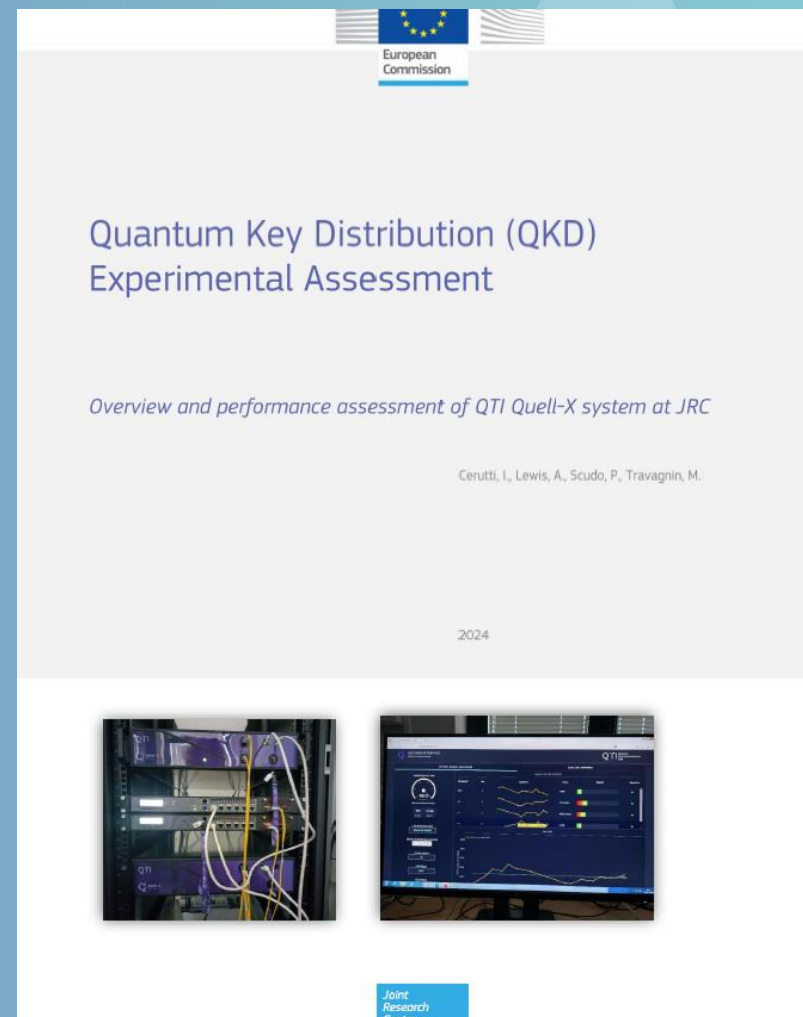


- IEC/ISO JTC3



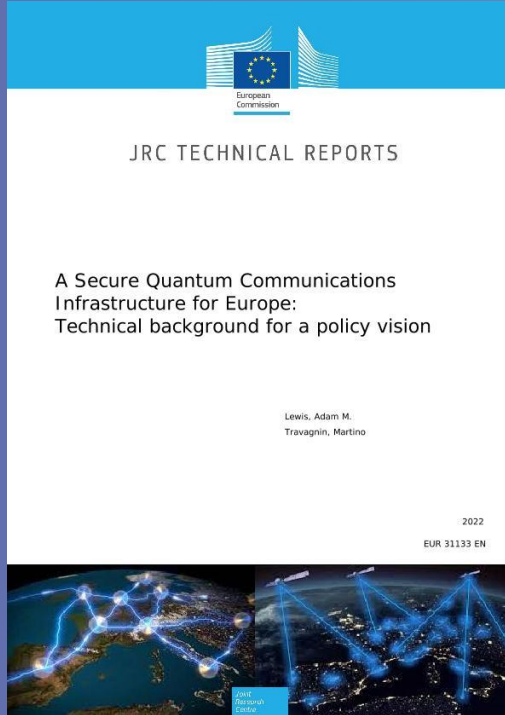


IDQ Cerberis 2 system
Ref. JRC132426 2023



QTI Quell system
Ref. JRC138248 2024

EuroQCI - a secure quantum communication infrastructure spanning whole EU, including overseas territories.



- [Quantum technologies - European Commission \(europa.eu\)](https://digital-strategy.ec.europa.eu/en/policies/european-quantum-communication-infrastructure-euroqci)

- <https://digital-strategy.ec.europa.eu/en/policies/european-quantum-communication-infrastructure-euroqci>



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