Quantum in space to secure communication

Switch to Space 2

Space security and Defense

12 October 2020

Gilles LEQUEUX

European Commission

DG DEFIS / B2

*" […] I had many lives but always the same driver: **passion**.*

*And especially the passion of sciences, of astrophysics, of **quantum**, of relativity. Because there is nothing more noble and exciting than to try to understand and push the boundaries of our knowledge."*

*"I would especially like to integrate, within Copernicus, all the capacity that **quantum technologies** could bring to develop new services."*

***Commissioner** T. Breton*

22 January 2020

*"Europe should for instance invest massively in **quantum technologies**. This is a matter of technological sovereignty. Quantum could have important applications in the space domain:*

like in encryption or in the mapping from space of the underground landscape."

« Without digitalization there is no future. We have to master key technologies: *quantum technologies*, artificial intelligence, chip technologies. To achieve that we need to *work together*.»

EC President Ursula von der Leyen
27 November 2019

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Objectives and Priorities

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EU Objectives for Space Quantum

- Support the **EU Space policy** and **EU space programs** (Copernicus, Galileo, Govsatcom)
- Support **EU non-dependence** for the development of EuroQCI (Critical technologies / Horizon Europe)
- **Increase TRL** of quantum/space components (Horizon Europe) using EU technology
- Support **IOD/IOV missions** dedicated to testing quantum technology in space (Horizon Europe)

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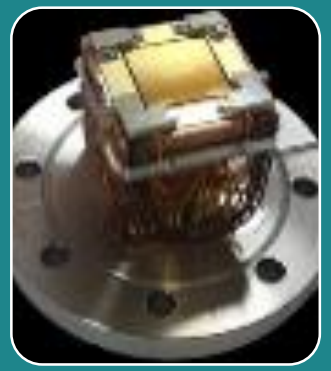
Space Quantum topics (Draft)



Quantum sensing

- Gravimetry

Quantum Communication

- Quantum Key Distribution

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Quantum Communication

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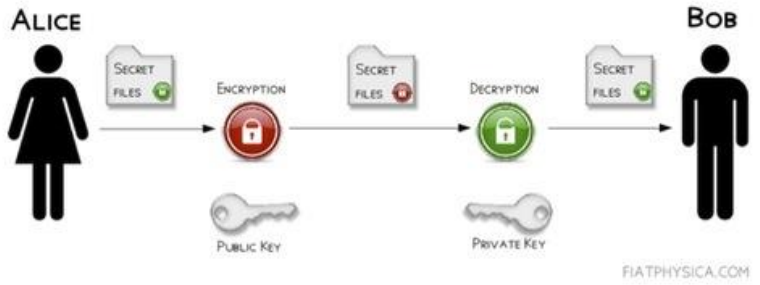
What is Quantum Key Distribution (QKD)?

- ***Quantum cryptography*** is using quantum physics properties to perform cryptographic tasks.
- **QKD** provides two parties with an intrinsically secure (guaranteed by law of physics) key in a way that an attacker (even with a quantum computer) cannot eavesdrop or control the system.



- QKD can offer quantum-safe security for long-term data protection including for critical infrastructures and applications.
- QKD will likely be a key part of hybrid quantum-conventional cryptographic solutions to reinforce security in the long term and with the broadest possible societal coverage.

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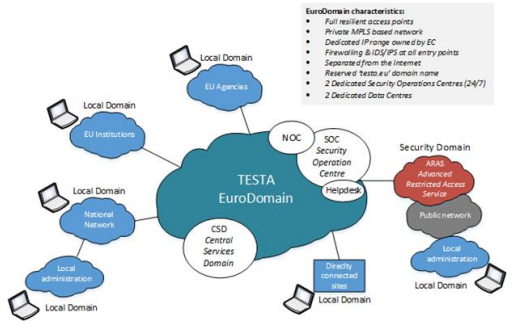
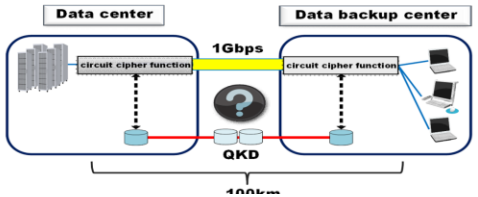
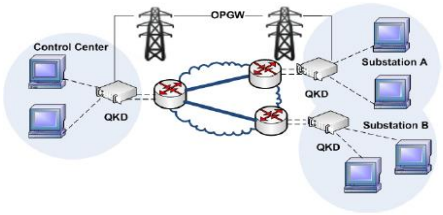
Examples of use cases with QKD

- Government data storage and communications
- Data centres
- Critical Infrastructure
- Secured synchronisation for financial services







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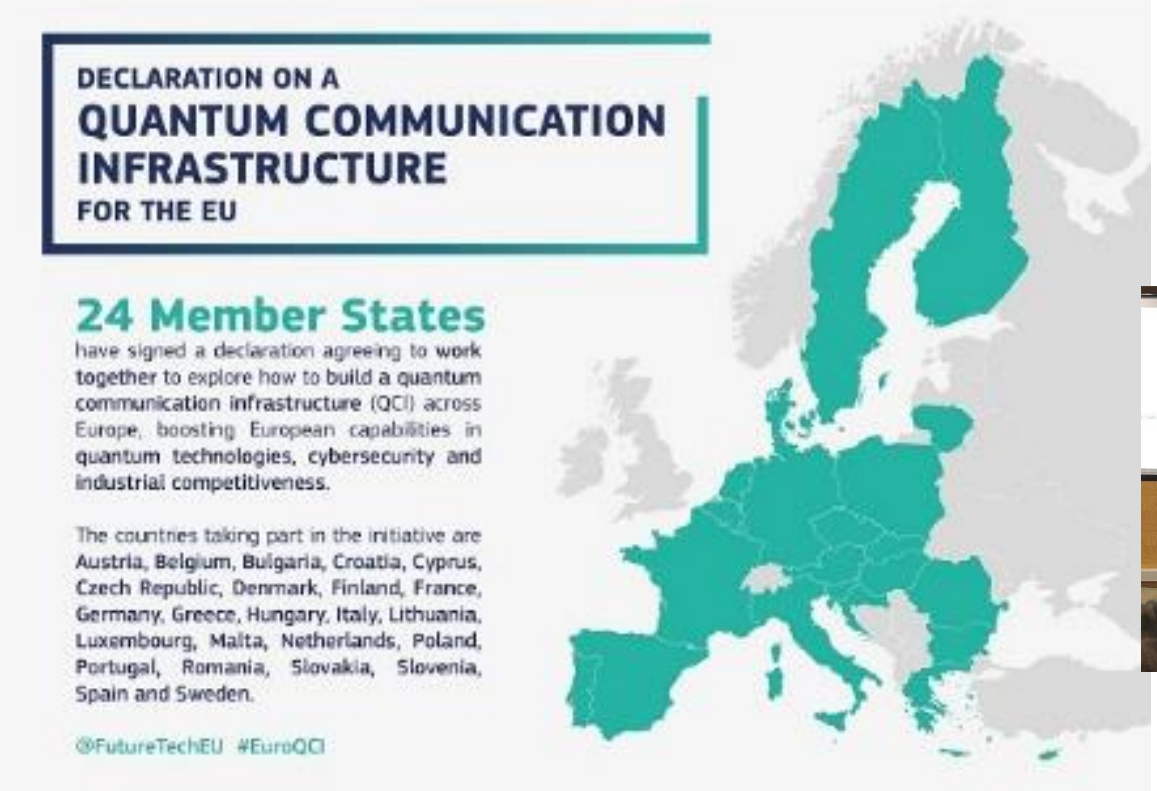
EuroQCI Status 24 Member States on-board



PT signs EuroQCI

Digital Assembly 2019

DK signs EuroQCI

RO signs EuroQCI

BG signs EuroQCI

AT signs EuroQCI

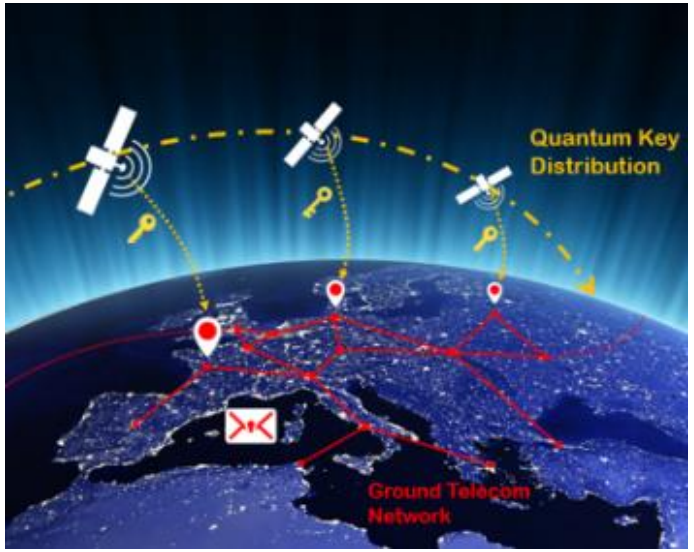
EuroQCI: A Terrestrial and a Space segment based on QKD

EuroQCI: A Terrestrial segment

- Cross-border connection of EU capitals using fibre networks for ultra-secure exchange of cryptographic keys, authentication, time & frequency distribution, …

... and a Space segment

- Overcoming the distance limitation of ground based segments (up to 50-100 km point-to-point connections)
- Covering all the EU territory and other continents
- In partnership with the *European Space Agency*



EuroQCI

- Protection of government data & communications, telecommunications networks, data centres, critical infrastructure (energy, finance, etc.)
- Securing EU space systems, etc.

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EuroQCI: Implementation Approach

2020-2023: 1st phase – The preparatory phase (Pathfinder mission)

Terrestrial Segment
- Mission Identification Study (Comparative Study)
- Analysis and Feasibility Study (System Study)
- OpenQKD Horizon 2020 project
- System and technology development

Space Segment
- Mission Identification Study (Comparative Study)
- Analysis and Feasibility Study (System Study)
- Preliminary System Definition
- System and technology development

2023-2025+: 2nd phase - The QCI demo and first deployment phase

Terrestrial Segment
- Operational Deployment
- Testing of cross-border QCI links
- QCI testing and compliance infrastructure

Space Segment
- Detailed System Definition, incl. R&D
- Preparation/demonstration of In-orbit mission components

2025+ ...: 3rd phase – The full QCI deployment and operational phase

Terrestrial Segment
- Full deployment
- Operationalisation

Space Segment
- In-orbit validation and mission deployment
- Operationalisation

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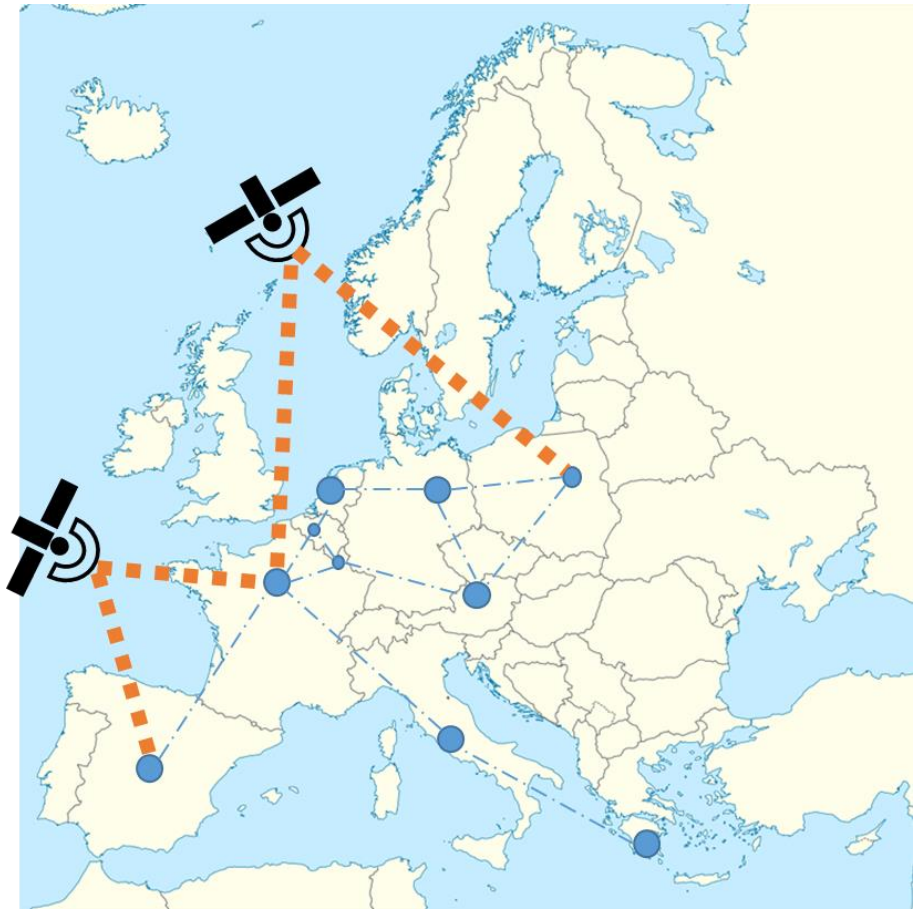
EuroQCI: National and cross borders links



Local Q-network (dark fiber)

Ground-based Q-link
(trusted nodes / q-repeaters)

Satellite-based Q-link
(LEO, MEO, GEO)

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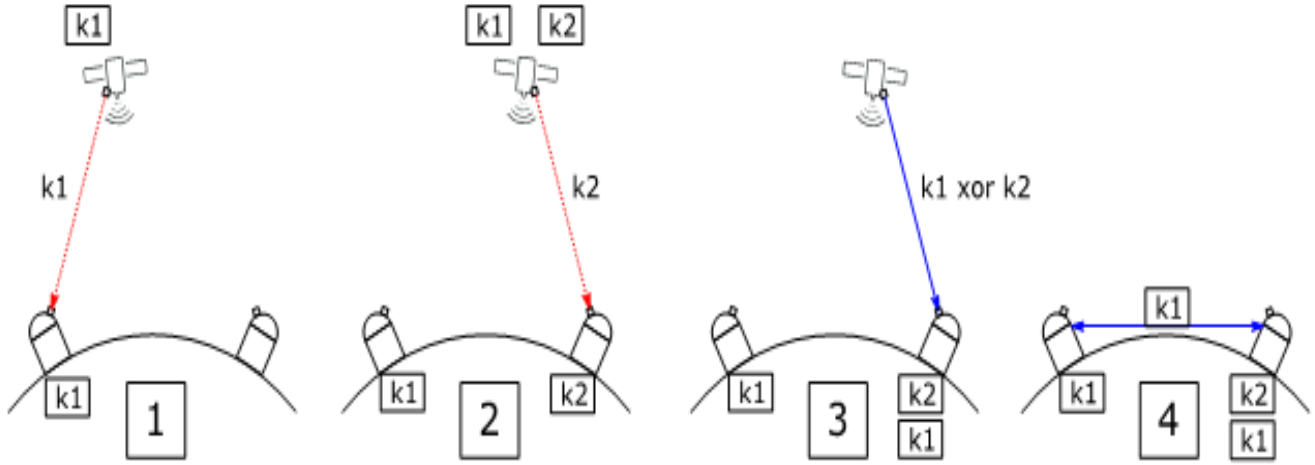
One way satellite QKD (BB84 or similar)

One way satellite QKD



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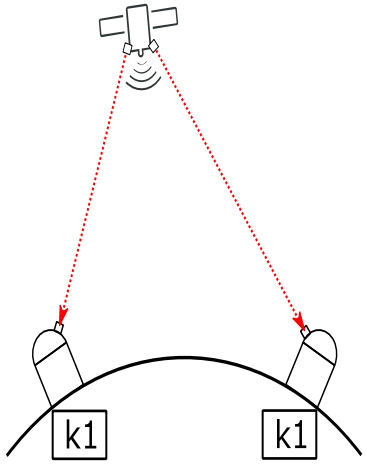
1. Satellite creates **keys** between itself and ground users
2. Shared key between ground users is created by xor different keys on board
   - **Advantages**: single link; suitable for LEO; feasible with small telescopes
   - **Disadvantages**: satellite node and operator requires trust and protection

Double link satellite QKD



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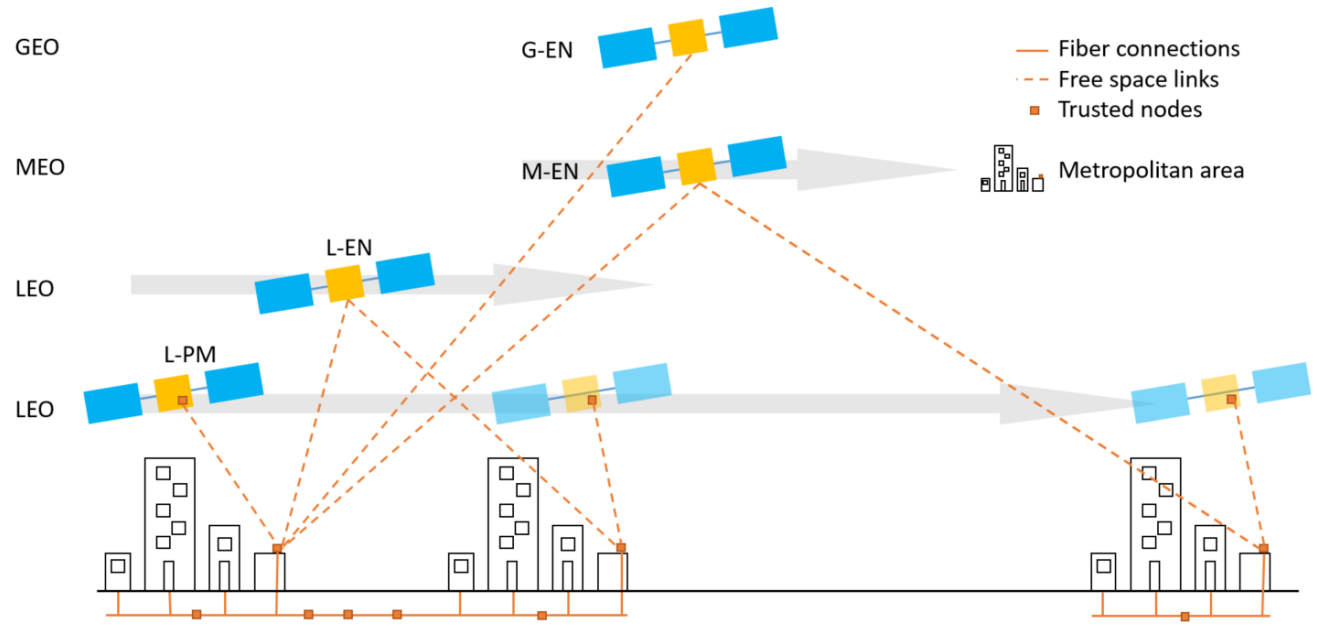
1. Satellite distributes **entangled photons** pairs to two ground users which generate the key
   - **Advantages**: satellite and operator do not need to be trusted;
   - **Disadvantages**: dual downlink; larger telescopes; entangled photon source

QCI Space Segment

Different orbits and QKD concepts:



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G-EN GEO based Entangled QKD Satellite(s)
M-EN MEO based Entangled QKD Satellite(s)
L-EN LEO based Entangled QKD Satellite(s)
L-PM LEO based Prepare & Measure QKD Satellite(s)

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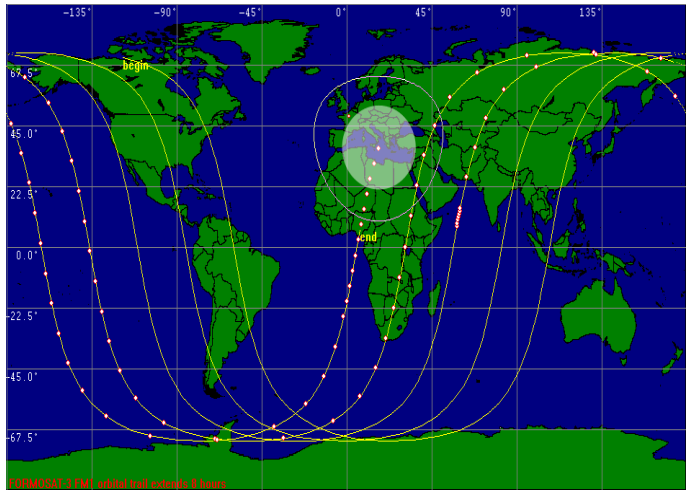
LEO Characteristics (300-1500km)

- Single satellite can cover the complete globe
- Only little time per orbit spent over Europe
- Service area not sufficiently large to cover all EU in a single flyover (limiting double downlinks to <1000 km)
- Terminals (ground and space) need fast tracking mechanisms



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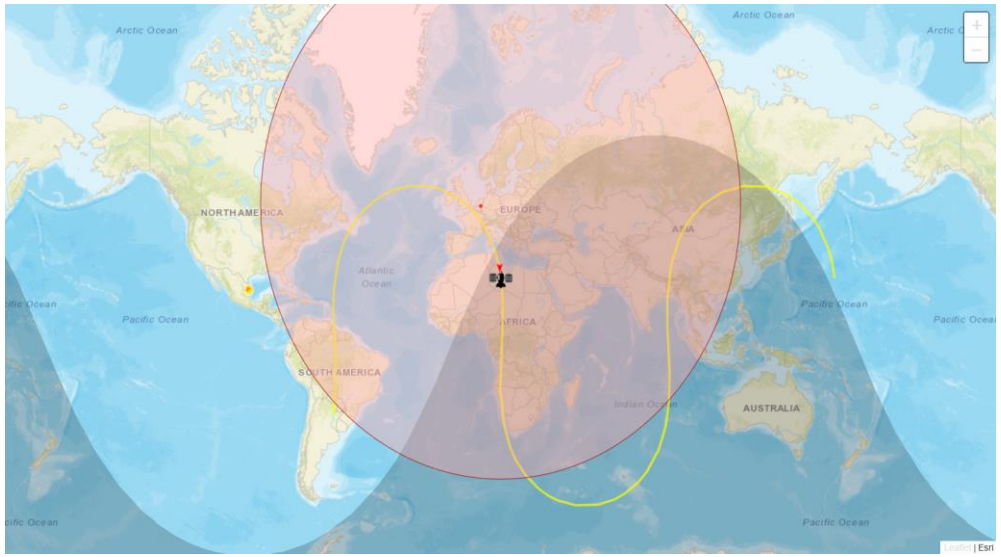
MEO Characteristics (12000-24000km)

- Single satellite can cover the complete globe
- Only part time per orbit spent over Europe
- Service area sufficiently large to cover all EU in a single flyover
- Terminals (ground and space) need tracking mechanisms



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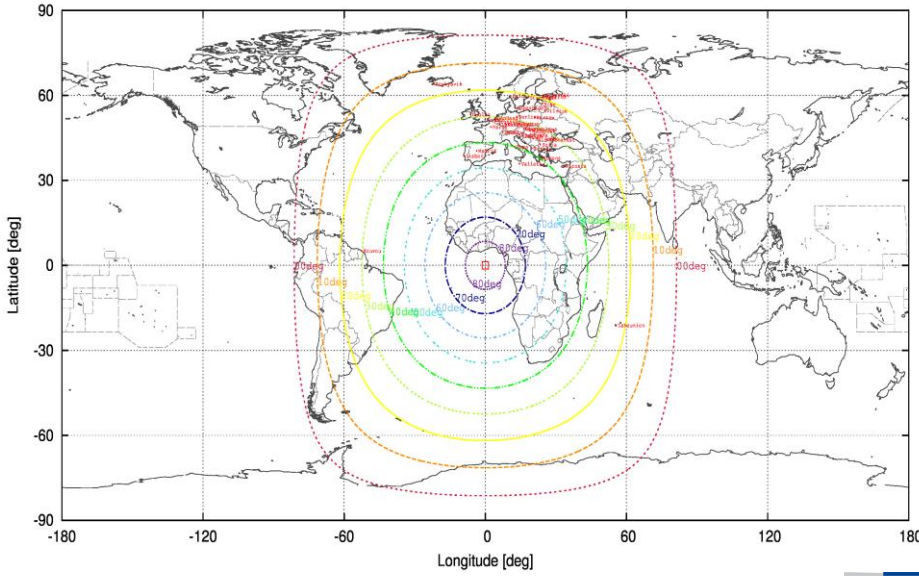
GEO Characteristics (36000km)

- Single satellite can cover 1/3 of the globe
- 3 satellites for global coverage
- Full EU coverage with 1 satellite
- Terminals (ground and space) do not need tracking



QCI State of Play

- Several QCI projects and deployments worldwide
- China has built experimental network on ground and in space
- No professional QCI network currently in production anywhere
- EU is developing its strategy and QCI at a very timely moment
- EU and MS have all skills and technologies necessary for QCI

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Global Secure Connectivity

- Assessment to provide a global connectivity service as a third pillar of the EU space policy in addition to earth observation and navigation
- This new pillar on global secure communication should be:
  - Satellite based
  - Secure & resilient
  - Complementing ground network / 5 G
  - Targeting governmental/institutional as a priority
- Use of quantum technologies
  - Integration of EuroQCI (or in combination with)

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Quantum in Galileo

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Galileo Experimental Payloads

- **Quantum-Communication (studies on going)**
  - In MEO orbit testing of QKD payload embarked on Galileo satellite (G2G)

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Thank you

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