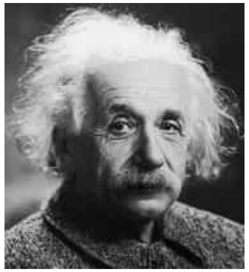
EC perspectives and introduction to EU investments in quantum technology

Gustav Kalbe
Acting Director
DG CNECT C - Digital Excellence and Science Infrastructure
European Commission

Quantum in Europe over the years

First quantum revolution
(1905 – 1960)



QIPC: EU's 1st quantum
program (1998 – 2010)




Second quantum revolution
(2010 - now)

QUANTUM FLAGSHIP

QUANTERA

Quantum Manifesto (2016)
Quantera (2016)
Quantum Flagship (2018)




SKILLS
GOVERNMENT INFRASTRUCTURES
BUSINESS

Digital Decade: Europe to be at the cutting edge of quantum by 2030

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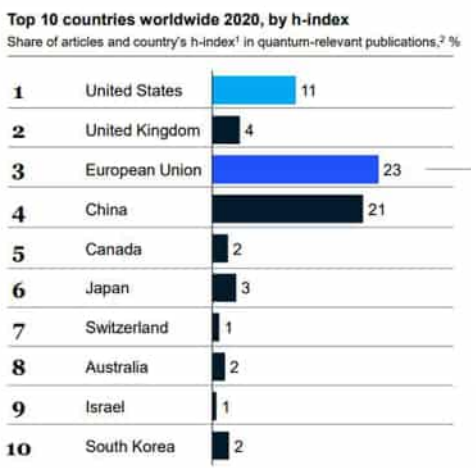
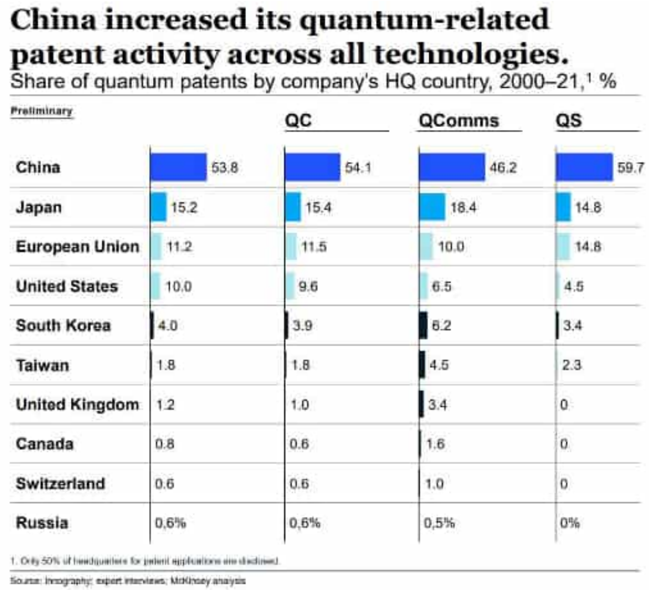
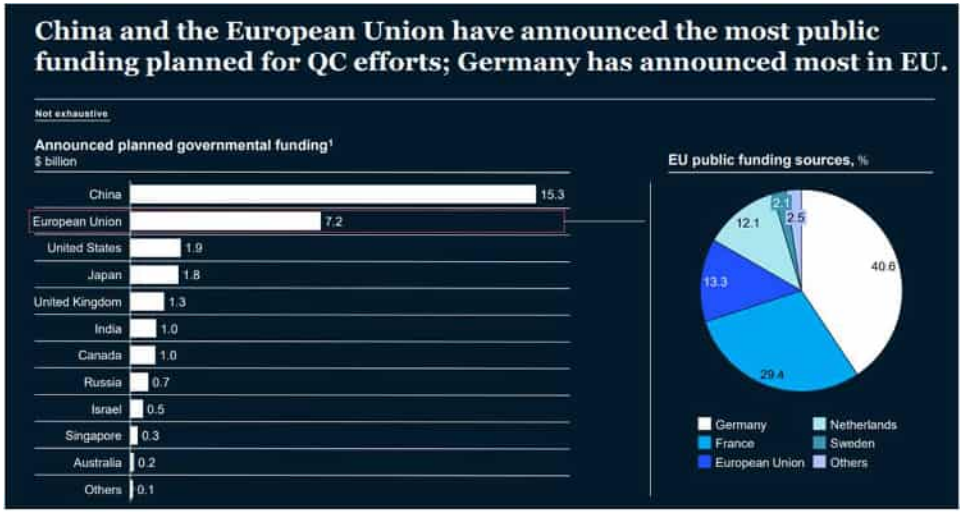
Quantum Excellence: Europe (EU+MS) and the rest of the world

Scientific Publications







- EU is home to 25% of the global number of QT companies
- 2010: 10 companies
  2020: > 70 companies
  2022: > 150 companies
- A growing nr of start-ups!

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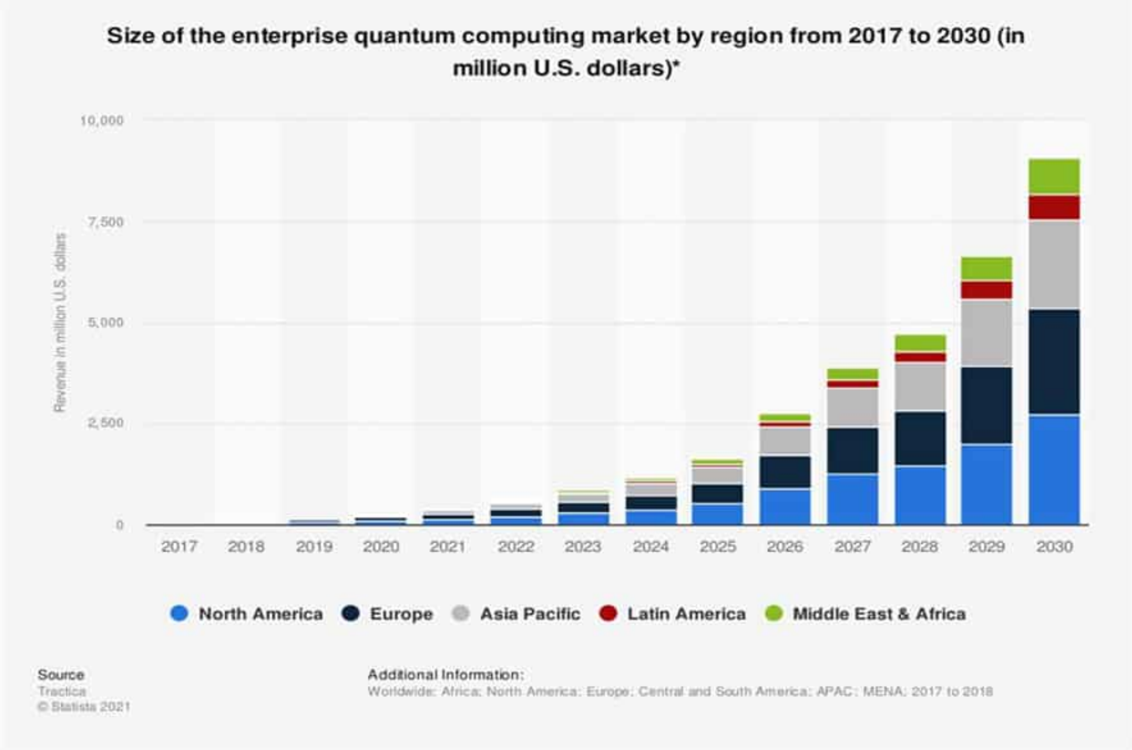
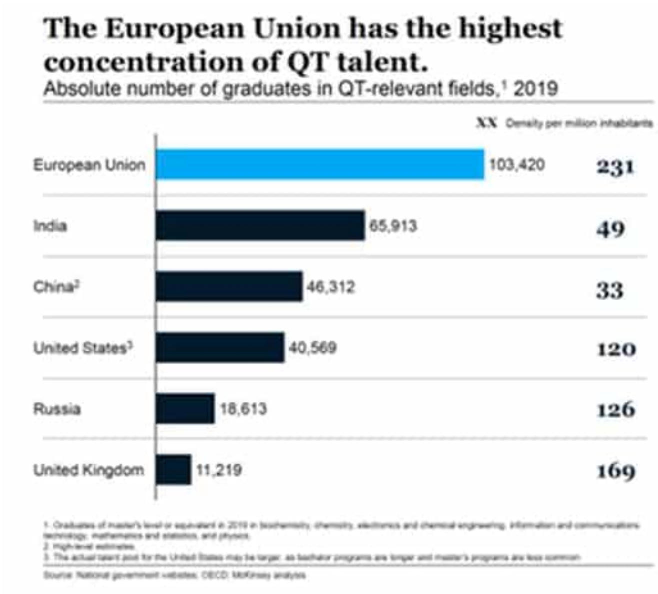
Prospects for Quantum Technologies: Markets and Jobs

QT Markets:
Exponential growth!



Concentration of QT Talent



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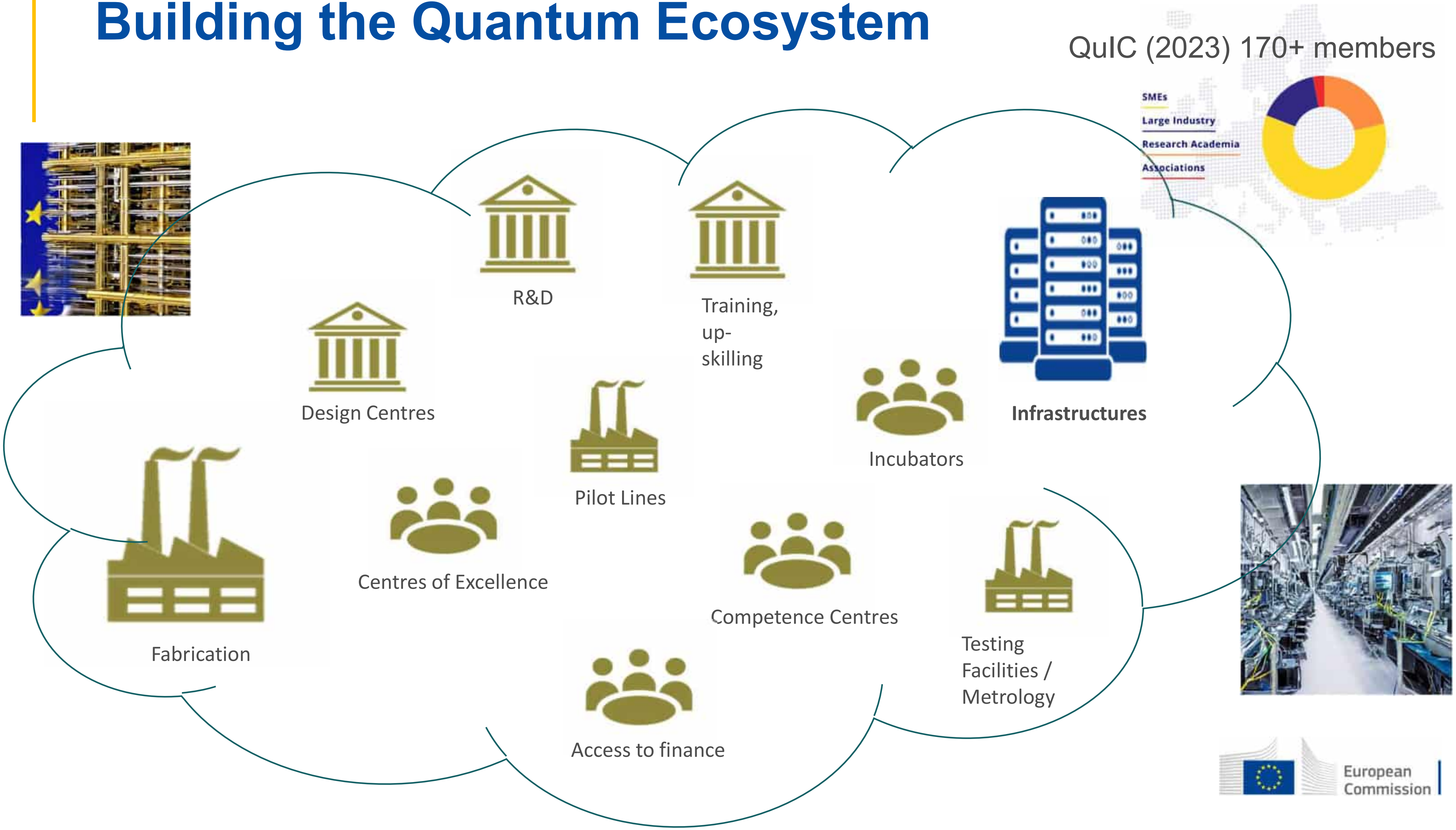
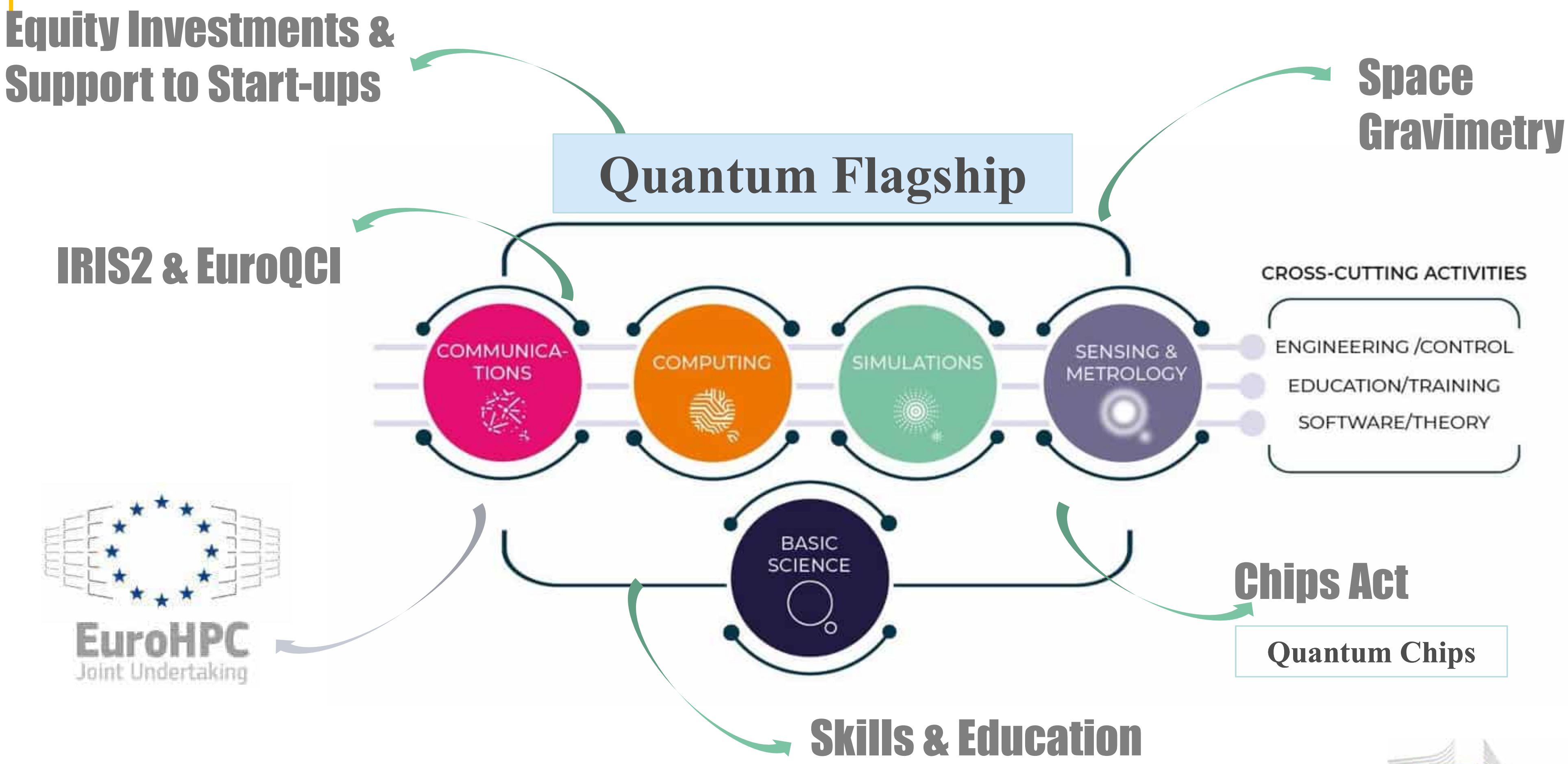
Building the Quantum Ecosystem



Quantum in Europe: state of play (2/2)



Quantum Flagship
A Success story

21 innovation- and science-driven projects and 3 coordination actions

175 million EUR funding since 2016

1,654 scientists and experts from 236 collaborating organisations in 31 European countries

1,313 scientific papers published (further 223 under review), **105 patents filed and 25 start-ups founded**

Quantum Flagship success stories

QUANTUM Communication

For a secure digital society and a quantum enabled internet

- ✓ **World-leading advances** in cont. variable QKD
- ✓ High efficiency and **multiplexed quantum memories**
- ✓ Development of advanced systems' components

QUANTUM Simulation

Simulating complex systems for advanced design and development

- ✓ Next gen atomic-based programmable Quantum Simulators
- ✓ **Practical quantum advantage**
- ✓ **Pan-European** hybrid **HPC/quantum infrastructure** (100 qubit analogue sims at FZJ and GENCI)

QUANTUM Sensing metrology

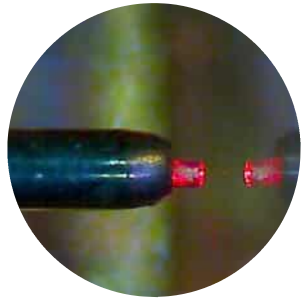
Bringing accuracy and performance to unprecedented levels

- ✓ **Diamond quantum sensors** (automotive, medical imaging)
- ✓ First **quantum sensors in space**
- ✓ New MEMS-based quantum sensors
- ✓ Next gen integrated/compact **optical quantum clocks**

QUANTUM Computing

Computing power to overcome currently unsolvable problems

- ✓ 50 qubit **trapped-ions Quantum Computer** (with low power consumption at 1.5KW) deployed and online
- ✓ **25 superconducting qubit device** with 99% 2-qubit gate fidelity built



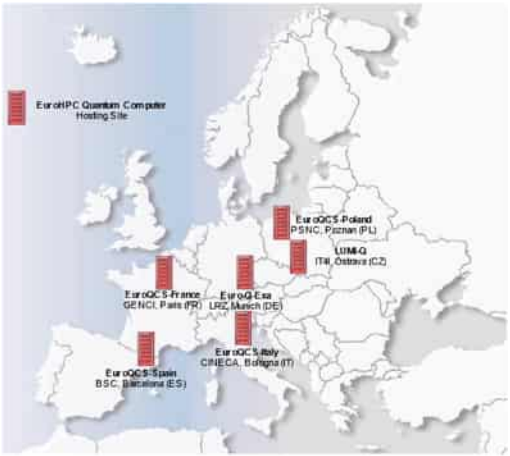
QUANTUM Basic science

Addressing foundational challenges for development of quantum technologies

- ✓ **World record** tuneability of **photon emitters**
- ✓ New single photon detectors
- ✓ High-fidelity quantum gates with microwave-driven ions
- ✓ Compact **entangled** photon-based **light sources**
- ✓ Detection and control of single rare earth ions

Quantum in Europe: Computing Infrastructure

	2019 & 2020	2021	2022	2023	2024	2025	2026	2027
Quantum Infrastructure	1st round **2 quantum simulators** interfacing with HPC systems	2nd round **6 quantum computers + quantum simulators** interfacing with HPC systems (17 participating states and € 100 M+ procurement budget)				3rd round new generation of **quantum computers + quantum simulators** most advanced platforms € 300 M)		



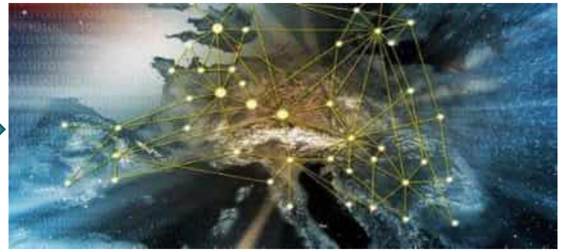
Objectives

- Build ecosystem, develop skills
- 2025 – Hybrid computing with a quantum accelerator
- 2030 – Cutting edge in quantum

Quantum in Europe: IRIS^2 and EuroQCI

EuroQCI space segment

EuroQCI terrestrial segment



under rescheduling!

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

- ESA & SES Astra Consortium funded – Eagle 1 launch in DEC 2025(?)

1st Generation - deployment of LEO satellites with EU technology

- A small number of satellites funded by ESA/EU
- Exchange quantum keys between different sites on EU territory interconnected LEO satellites + ground stations + terrestrial systems

2nd Generation - deployment of a fully operational system integrated with IRIS^2 for secure connectivity

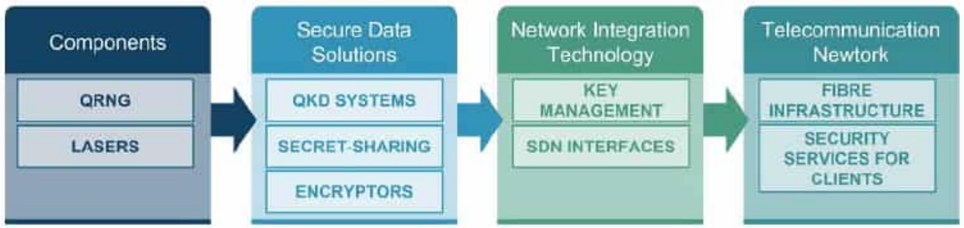
- Full coverage of user and security requirements

❖ 26 Member States deploy national QCIs as of JAN 2023

- **Aim**: Initiate MS in QKD use, test architectures, develop use cases, develop skills and prepare for full deployment
- 265 participants (incl. 34 SMEs), >60 use cases (finance, healthcare, defence, industry, research, etc.)

❖ 6 Industry projects for maturing EU QCI technologies:

- QKD systems ready for integration into telecom networks
- QKD modules (QRNG, optical components), key management software, encryptors, QKD protocols



Quantum Sensing in the EU

Sensors with increased sensitivity and precision able to capture many physical quantities (**magnetic field, radiofrequency field, gravitation, movement**…), or that can take measurements even in **harsh conditions** (e.g. high pressure and temperature)

Quantum Sensors	Applications
QT-enhanced MRI	• Heart and brain imaging, spectroscopy (molecular imaging)
Accelerometers	• Atom interferometry to measure accelerations (satellite-free navigation)
Gradiometers	• NV-centres to measures gradients, such as a magnetic field or gravity
Gyroscopes	• Position for automated driving or indoor navigation
Atomic clocks	• GPS that works even underground and inside, communication (radar signal amplification)
Gravimeters	• Environmental/infrastructure monitoring (volcanoes, CO_2 emissions) • Surveying (finding water basins and oil and gas reserves)
Other	• Measure temperature, electrical field, RF-field (wide-range frequency), ...

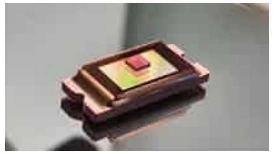

Quantum clocks


Quantum gyroscopes


Quantum gravimeters


Quantum accelerometers


Quantum gradiometers


Quantum NV centres


Quantum MRI scanners

European landmark achievements (2018-2021)

- ***Metabolic microscope*** x100,000 more sensitive than state of the art
- ***Quantum polarizer enhancing MRI*** signal x10,000 at room temperature
- ***Optical lattice clock*** off by only one second over the age of the universe
- ***Imaging sensors for THz waves*** with 1mm spatial resolution and acquiring of 20 000 frames / sec
- Some of the world's most advanced q. sensors based on ***NV centres in ultrapure diamonds*** (cryogenic scanning probe system, spectrum analysers with extended bandwidth, NV magnetometers under extreme pressure, etc)

NEXT STEPS

- ✓ **Miniaturization**
- ✓ **Chips Fabrication**
- ✓ **Testing & Experimentation**

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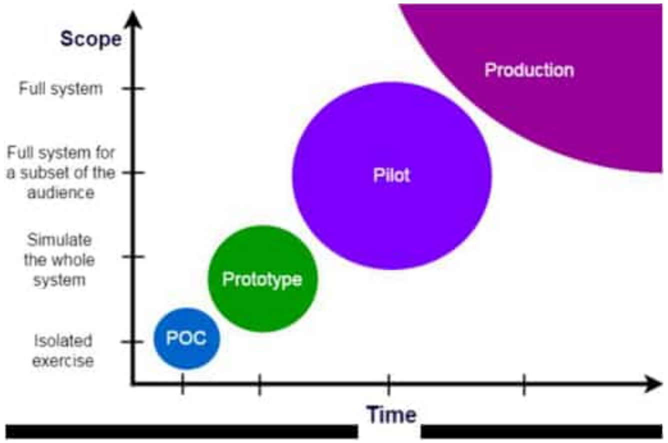
Quantum Flagship:
Fostering Industrial Uptake of QT

Deploying pilot production and testing capabilities for QT.

Key goals:

Qu-Pilot: Establish engineering methods and processes that are scalable at industrial level



Qu-Test: Establish a (open-access) network of QT testing and experimentation infrastructure for the needs of industry

Leverage EU facilities that offer such scalable methods, processes in pilot scale, and testing and experimentation services to all EU 27

→ Essential for the success of the European businesses enabling QT in all the application areas

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Thank you