QUANTUM
FLAGSHIP

QUANTUM COMMUNITY IN EUROPE

From a flagship to a fleet

20 SEPTEMBER 2022 | TOMMASO CALARCO | QUANTERA STRATEGIC CONFERENCE

QUANTUM FLAGSHIP

HELMHOLTZ QUANTUM

Universität zu Köln

JÜLICH Forschungszentrum

The EU Quantum Flagship

Consolidate and **expand** European **scientific leadership** and **excellence** in quantum research

Kick-start a **competitive** European industry in quantum technologies and position Europe as a **leader** in the future global industrial landscape

Make **Europe** a **dynamic** and **attractive** region for innovative **research**, **business** and **investments** in quantum technologies

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The Strategic Research Agenda Timeline

https://qrgo.page.link/45fPy

Community Consultations

Oberkochen, Germany
April 2018

Vienna, Austria
October 2018

Grenoble, France
February 2019

Helsinki, Finland
October 2019

May 2019

Timeline and draft structure to SAB
- SRA WG
- Innovation WG
- Education WG
- Gender WG

June 2018

Cross-checking by all WG and send to
- QCN
- QuantERA
- SEB
- COST
- EURAMET
- Photonics21
- …

July 2019

Finalise V1 with included SAB feedback

August 2019

Community consultation period
(via qt.eu)

Sep. 2019

Update SRA

Oct. 2019

- Send SRA to SAB
- Include feedback
- Last community feedback (in Helsinki)

Nov. 2019

SAB handed SRA to EC

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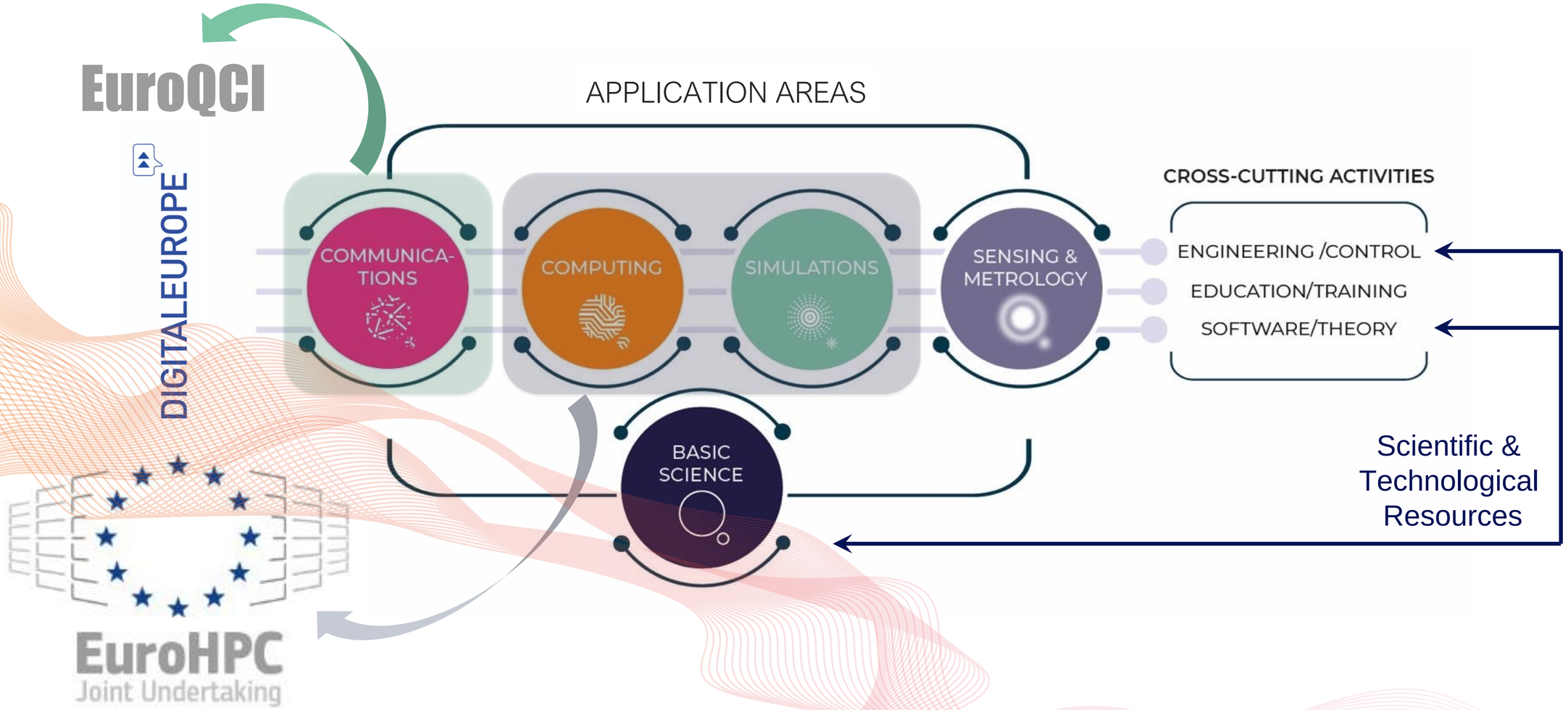
The Quantum Flagship
Strategic Research Agenda



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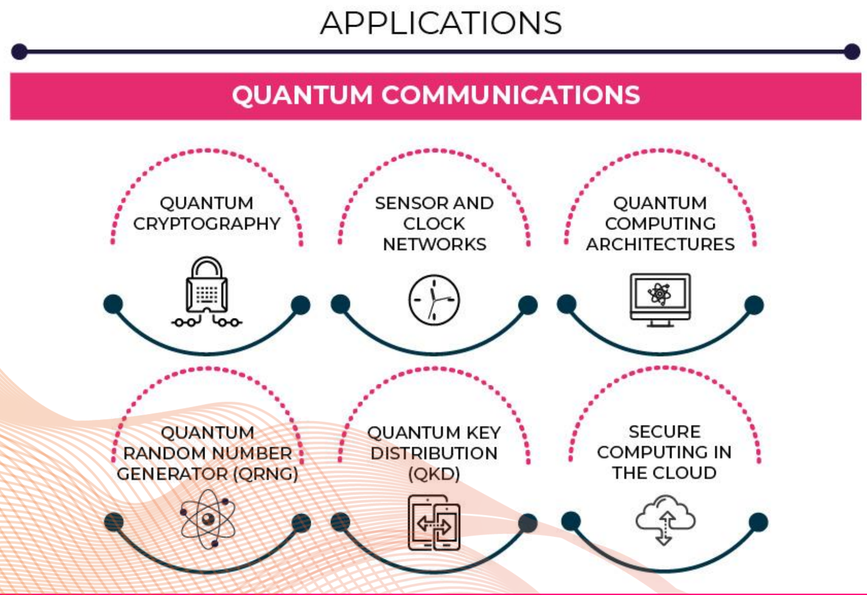
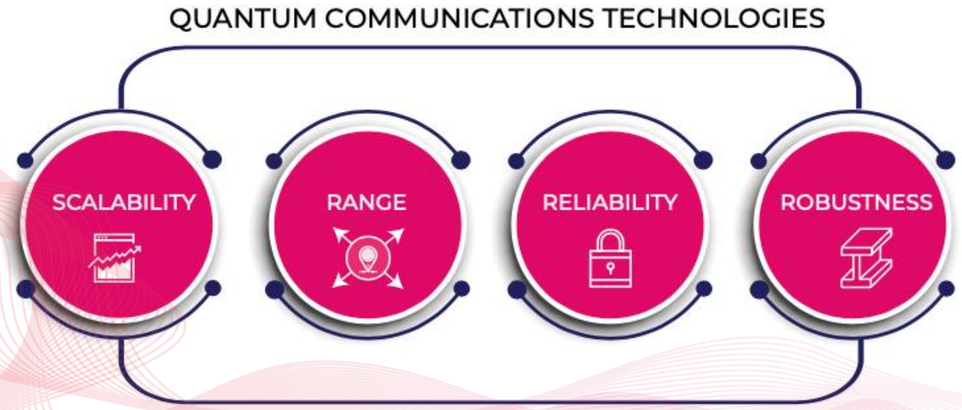
Quantum Communications



6-10 year vision

- Chain of physically distant quantum repeaters (quantum communication over at least 800km using telecom fiber)
- Quantum network node of at least 20 qubits
- Quantum network applications in platform-independent software in the quantum memory stage of netwrok development, or above
- Device-independent-inspired QRNG/QKD
- Entanglement generation using satellite links
- Open development infrastructure for education/engagement of future workforce/classical security/network professionals
- Progress towards robust supply chain

Quantum communication will build on the current digital infrastructure to distribute and connect quantum resources for improved security and functionality. This will address challenges such as the long-term security of health records, to connected quantum clock networks and eventually enabling secure connection to quantum computers in the cloud.



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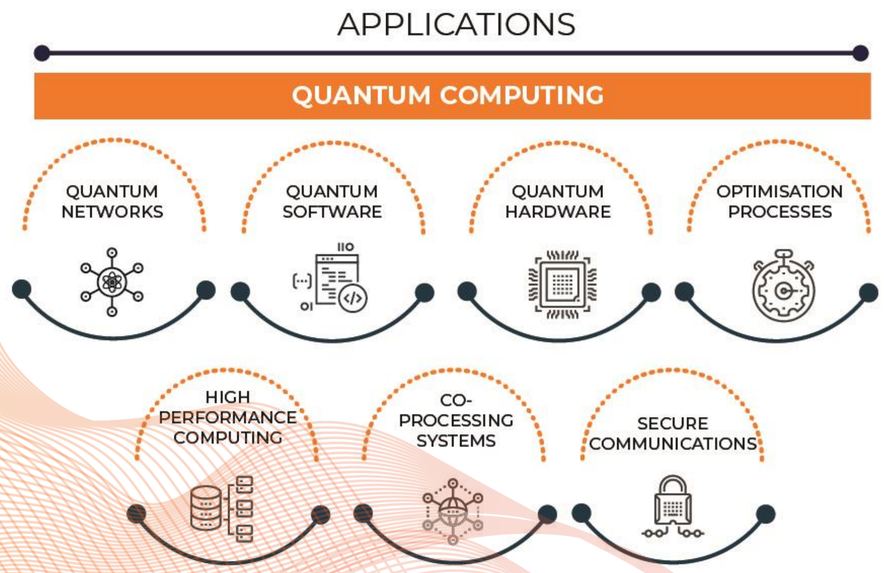
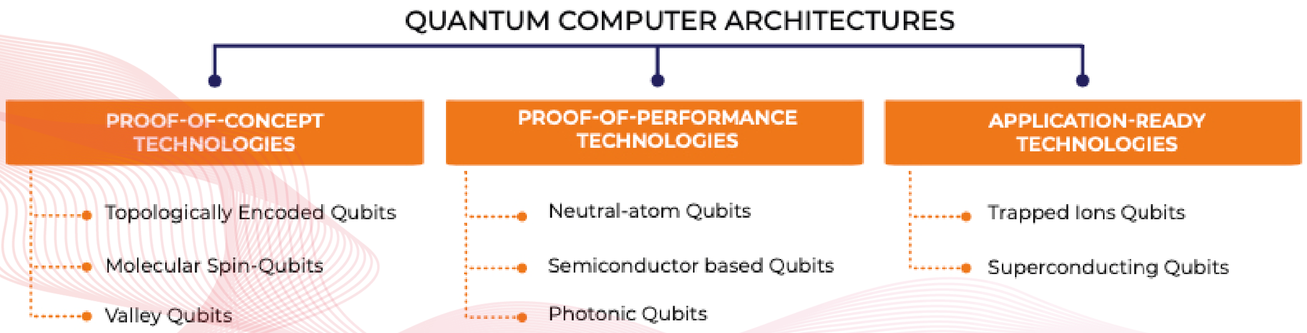
Quantum Computing



6-10 year vision

- Quantum processors fitted with error corrections
- Quantum algorithms with quantum advantage
- Establish/support foundries (integrated photnics, cryo and superconducting electronics), new instrument builders and software companies
- Research coordination
- Expanded suite of algorithms, compilers, libraries
- Automated system control/tune-up
- Integrated tool-chain and module libraries for integrated optics, cryo- and superconducting electronics
- Coordination of EU-wide joint efforts with other fields (material science, engineering, mathematics, computer science)
- Standardization
- Integration of industry/foundries
- Engage with EU infrastructure, large labs programs, RTOs

Quantum computers have the potential to solve tasks that we don't even dare dream of today and that classical computers can never solve. Completely new solutions for drug development, material design or areas such as financial services and transport will be possible.



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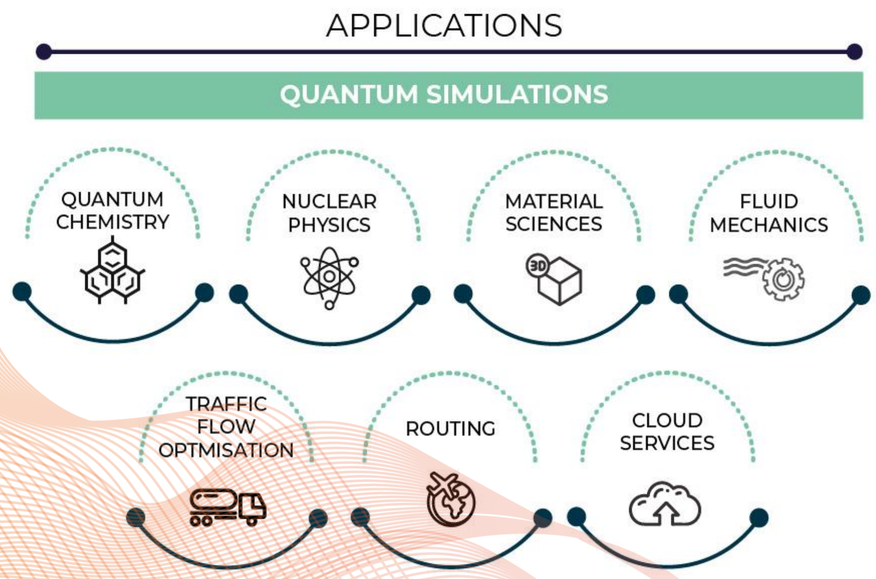
Quantum Simulations

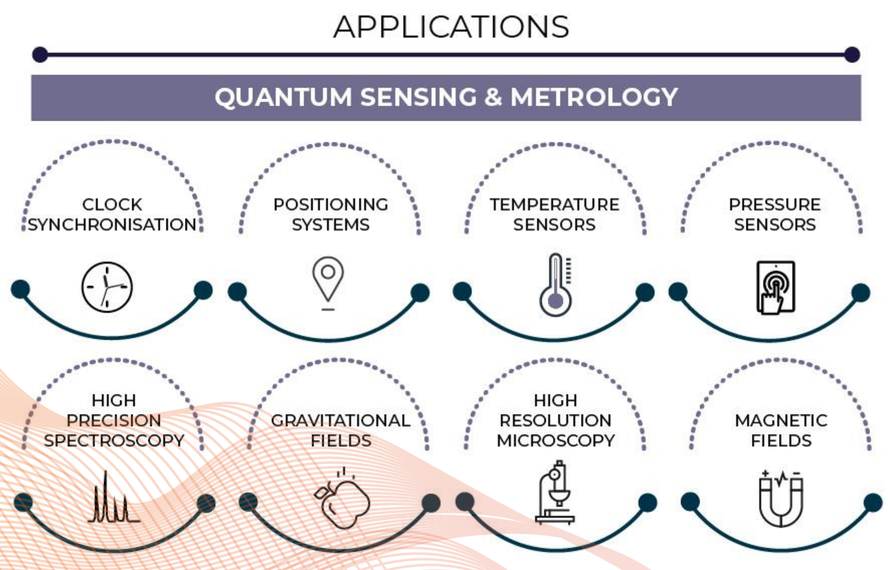


Quantum simulators promise novel insights into strongly correlated quantum matter and at the same time offer near-term perspectives of tackling computational problems on quantum devices without quantum error correction.

6-10 year vision

- Establish close link to end-users and develop more practical applications
- Programmable quantum simulators with higher degree of control
- Applications in quantum chemistry, complex quantum systems, material science
- Software development especially in relation to computer science
- Build a bridge between quantum software companies, research and industry, translating/mapping industry problems to the langauge of quantum simulation
- Develop industry targeted roadmap

Quantum Sensing and Metrology



The second Quantum Revolution will result in quantum sensors that outperform existing sensors in many aspects, such as size, operating environment, sensitivity, specificity, statistical or systematic uncertainty, traceability, calibration intervals, lifetime, power consumption, reliability, or security, unleashing a wealth of novel applications.

6-10 year vision

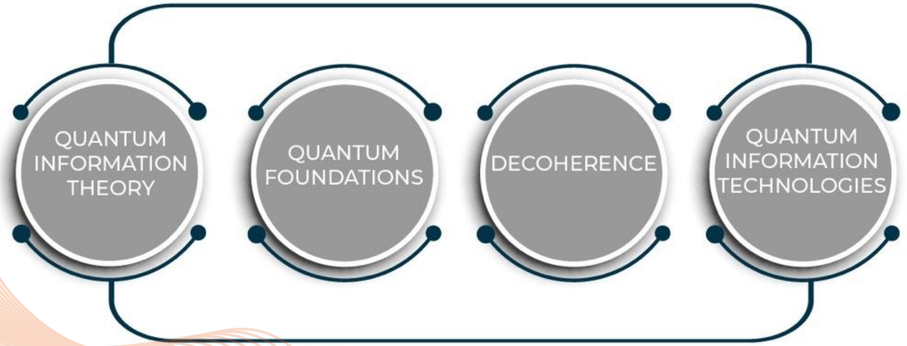
- Continued evolution of enabling techs and material engineering to increase TRL and promote quantum sensors to the market
- Quantum measurement standards for instrument self-calibration
- Establish foundries for key techs
- Fabrication of optically/electonically integrated lab-on-a-chip platforms based on functionalized materials (biomedical) or integrated atom chips (electric/magnetic fields)

- Prototypes: quantum enhnced measurement/imaging, entangled clocks, inertial sensors, opto-mechanical sensing devices
- Commercial products: magnetometers, supre-resolved and/or sub-shot noise microscopes, high-performance optical clocks and atom interferometers, quantum RADAR and LIDAR
- Networks of quantum sensors and space-borne quantum enhanced, sensors, including optical clocks, atomic and optical inertial sensors

Scientific & Technological Resources

6-10 year vision

SCIENTIFIC RESOURCES



Scientific resources

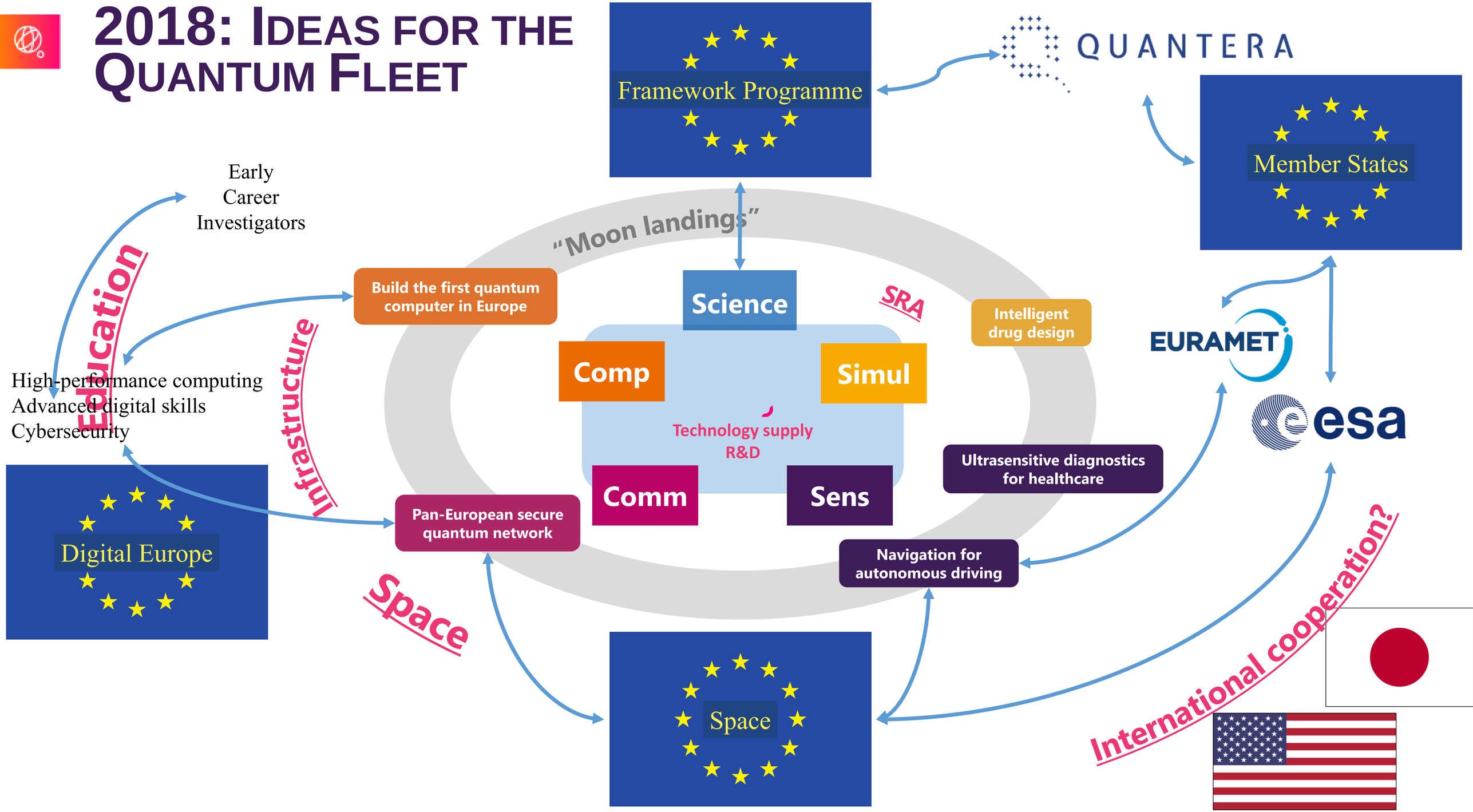
- Work towards opening up new avenues for potential growth in QT
- Scalable methods for certification of complex many-body and multi-partite quantum systems

Technological resources

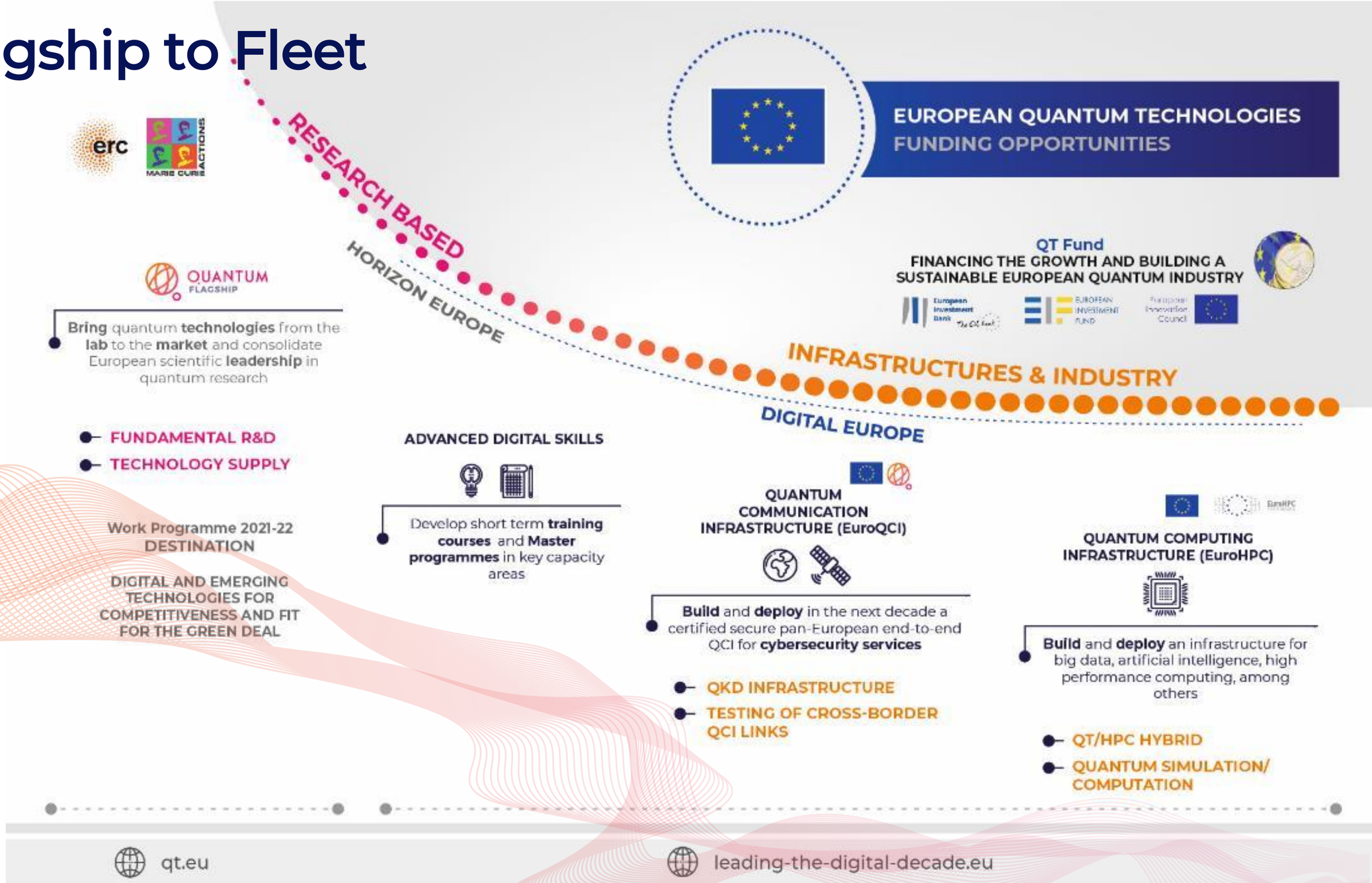
- Systems, manufactured at scale, fully integrating quantum devices with a range of classical (optical/electronic) devices
- Schemes to stabilise/control complex entanglement-based networks.
- Modular approach from simple to complicated control pulses in theory and improved pulse shaping in exps.
- Reliable strategies for the control of mesoscopic systems.

The Scientific and Technological Resources area can provide maximum flexibility for the attribution of scientific and technological resources: on the scientific side, it provides an “entrance door” for new ideas or themes, and on the technology side, it exploits synergies and sharing of resources.

2018: Ideas for the Quantum Fleet



From Flagship to Fleet



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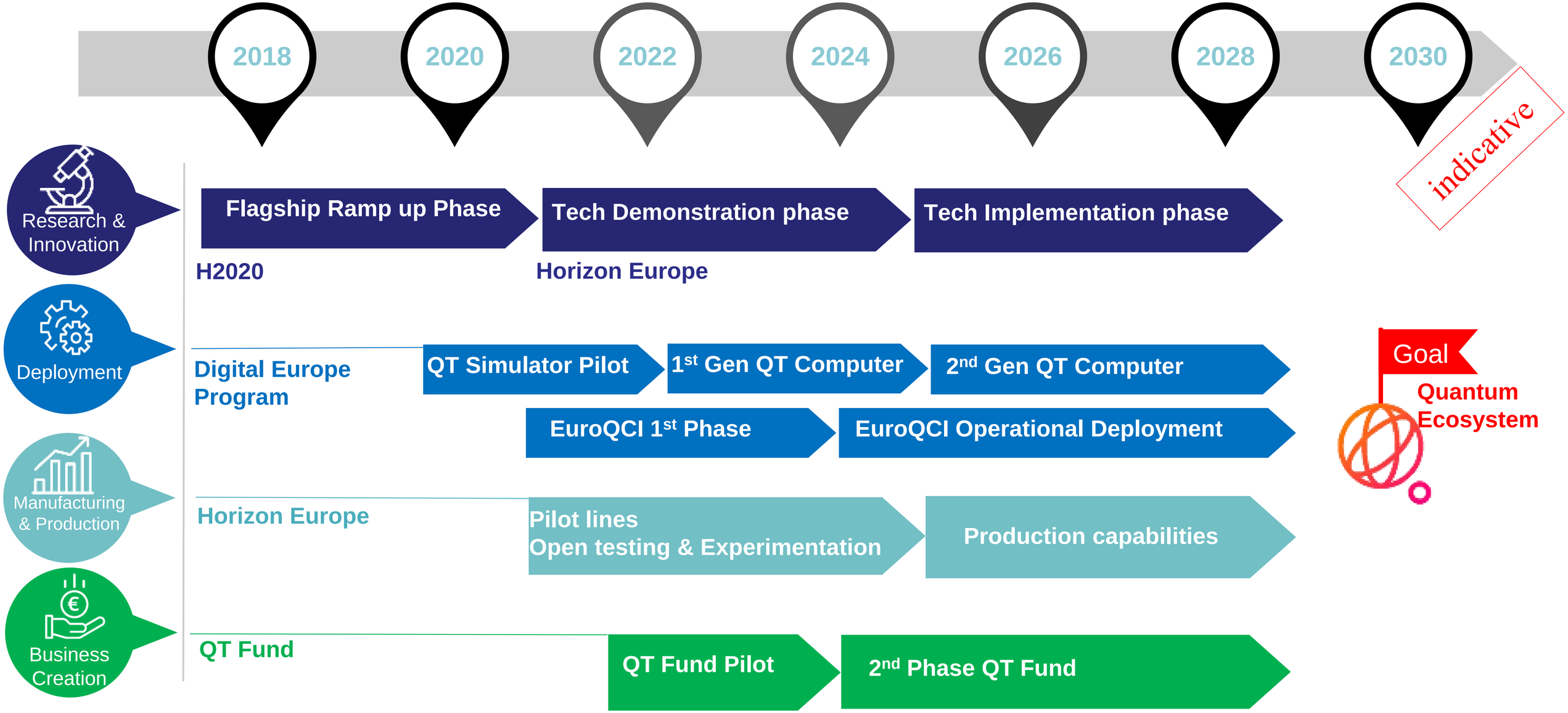
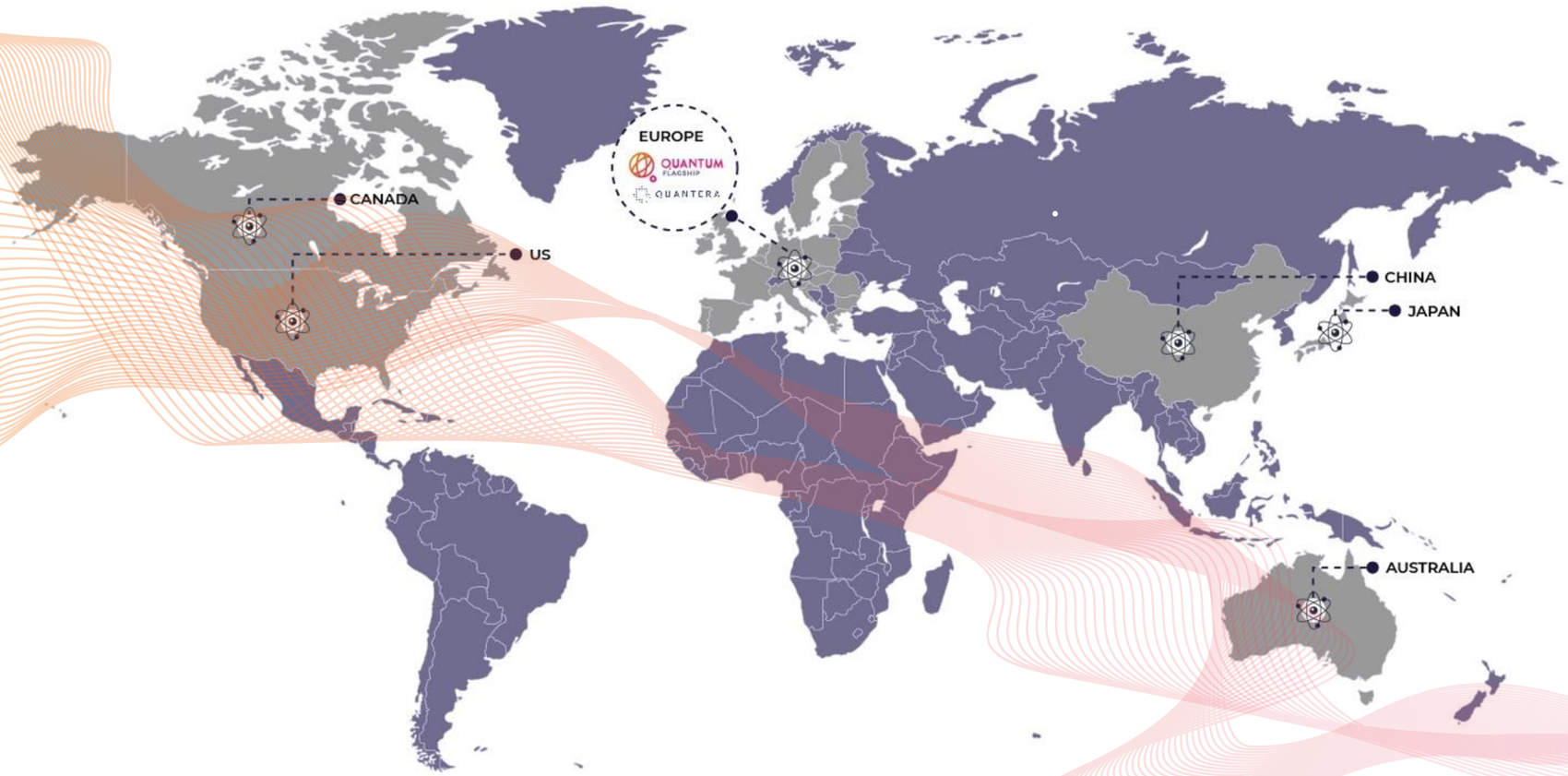
Europe's commitment to QT: Timeline



International Cooperation

Quantum technologies have a huge potential for innovation that may revolutionise the information economy. Europe can play a leading role through strategic international cooperation to develop competitive collaborations that represent a win-win for Europe and the field.



InCoQ FLAG

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Quantum Computation & Simulation Infrastructure

Classical quantum simulation hardware in HPC

Quantum testbed facilities for hardware developers

Quantum computation and simulation hardware (ion traps, super-/semi-conducting qubits, spin qubits, phtonic circuits, neutral atoms)

Quantum application database (verification/validation, algorithms, apps)

European Commission

Quantum Communication Infrastructure

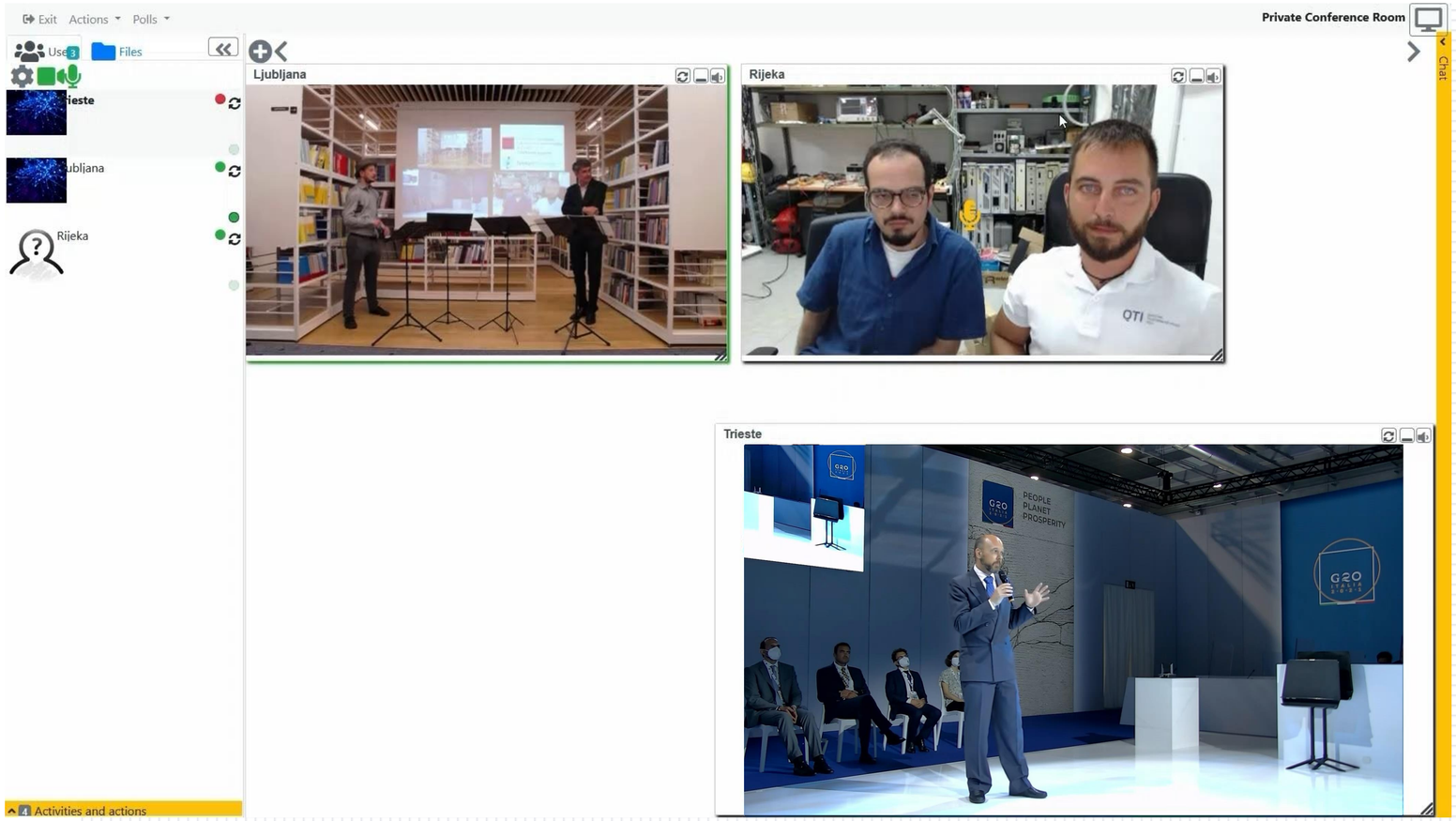
Integrate quantum cryptography into critical communication systems

Combine terrestrial and satellite components for wide coverage

Protection of data networks, clock synchronization, e-voting,...

Backbone infrastructure for the quantum internet

Tripartite QCI demonstration at the



https://www.youtube.com/watch?v=LLc_YP7FngI&t=466s

EUROPEAN QUANTUM INDUSTRY CONSORTIUM

...a private organization, asserting the common interests of the European QT Industry through advocacy...

June 24, 2020 – First telco
Nov. 10, 2020 – Second telco
Feb. 14, 2021 – Founding Assembly
Apr. 12, 2021 – 1st General Assembly
Apr. 14, 2021 – 2nd General Assembly

***

- **Ms. Laure Le Bars (SAP)** – President
- **Dr. Benno Broer (Qu&Co)** – Vice-President
- **Dr. Thomas Strohm (Bosch)** – Vice-President
- **Dr. Enrique Lizaso** (Multiverse Computing) – Treasurer

plus Governing Board (15 members)

103 members, from 20 countries

- **23 (22%) Large corporations** (Airbus, Bosch, E.ON, Thales, etc.)
- **63 (61%) SMEs** (TOPTICA, muQuans,)
- **16 (16%) RTOs/Academic institutions** (DLR, Fraunhofer IAF, UCM, etc.)
- **1 (1%) Industry Association**

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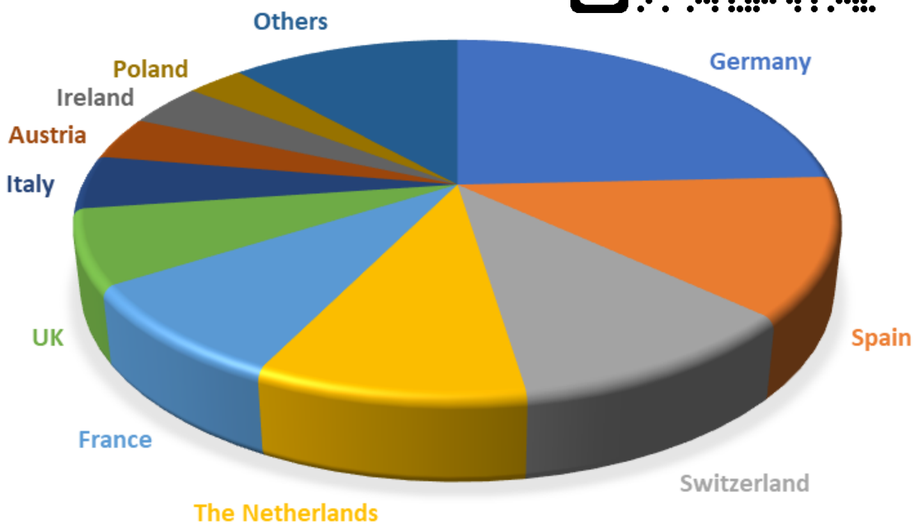
Procedure to appoint **Executive Director and Secretary** well advanced



Germany	25	Portugal	2
Spain	13	Finland	2
Switzerland	11	Israel	1
The Netherlands	10	Turkey	1
France	9	Slovenia	1
United Kindom	7	Lithuania	1
Italy	5	Greece	1
Austria	4	Denmark	1
Ireland	4	Czech Republic	1
Poland	3	Norway	1

Today's Quantum Fleet

QT fund

QUANTERA
ERA-NET Cofund in Quantum Technologies

MS Programmes

- ✓ France
- ✓ Germany
- ✓ Netherlands
- ✓ ……..

HORIZON EUROPE

QUANTUM FLAGSHIP

- ✓ Technology supply
- ✓ Fundamental R&D

QuIC
European Quantum Industry Consortium

DIGITAL EUROPE

Quantum Computing Infrastructure (EuroQCS)

- ✓ New regulation
- ✓ HPC-Qaccelerators
- ✓ QT/HPC hybrid

DIGITAL EUROPE

EuroQCI

- ✓ QKD infrastructure
- ✓ Testing of cross-border QCI links

CEF-2