The European Programme in Quantum Technologies

QUANTUM FLAGSHIP

European Commission

Doru Tanasa

Policy Officer

HPC and Quantum Technologies Unit

European Commission

The EU Quantum Flagship

What is the **Flagship** and what we are doing on **Quantum Technologies?**

Summary and **success stories** from the ramp-up phase.

Envisaged activities in all the fields of QT and **upcoming calls and projects starting**.

EUROPEAN QUANTUM TECHNOLOGIES FUNDING ACTIONS

RESEARCH BASED

HORIZON EUROPE

HORIZON EUROPE
2021-2027

QU FLAGSHIP

Bring quantum **technologies** from the **lab** to the **market** and consolidate European scientific **leadership** in quantum research

- **FUNDAMENTAL R&D**
- **TECHNOLOGY SUPPLY**

Work Programme 2021-22
DESTINATION 4

DIGITAL AND EMERGING TECHNOLOGIES FOR COMPETITIVENESS AND FIT FOR THE GREEN DEAL

From Lab to Market

- **Pilot Lines & Testing Facilities**

ADVANCED DIGITAL SKILLS

Develop short term **training courses** and **Master programmes** in key capacity areas

European Chips Act

Bolster Europe's competitiveness and resilience in Semiconductors & **Quantum chips** including **Production Facilities & Quantum Fund**

INFRASTRUCTURES

DIGITAL DECADE

- 2025 – Europe's **first computer with quantum acceleration**
- 2030 - Europe to be at the **cutting edge of quantum capabilities**
- EDIC for quantum computing?

DIGITAL EUROPE

QUANTUM COMMUNICATION INFRASTRUCTURE (EuroQCI)

Build and **deploy** in the next decade a certified secure pan-European end-to-end QCI for **cybersecurity services**

- **QKD INFRASTRUCTURE**
- **TESTING OF CROSS-BORDER QCI LINKS**

DIGITAL EUROPE
DIGITAL SKILLS, CYBERSECURITY, SUPERCOMPUTING

QUANTUM COMPUTING INFRASTRUCTURE (EuroHPC)

Build and **deploy** an infrastructure for big data, artificial intelligence, high performance computing, among others

- **QT/HPC HYBRID**
- **QUANTUM SIMULATION/ COMPUTATION**

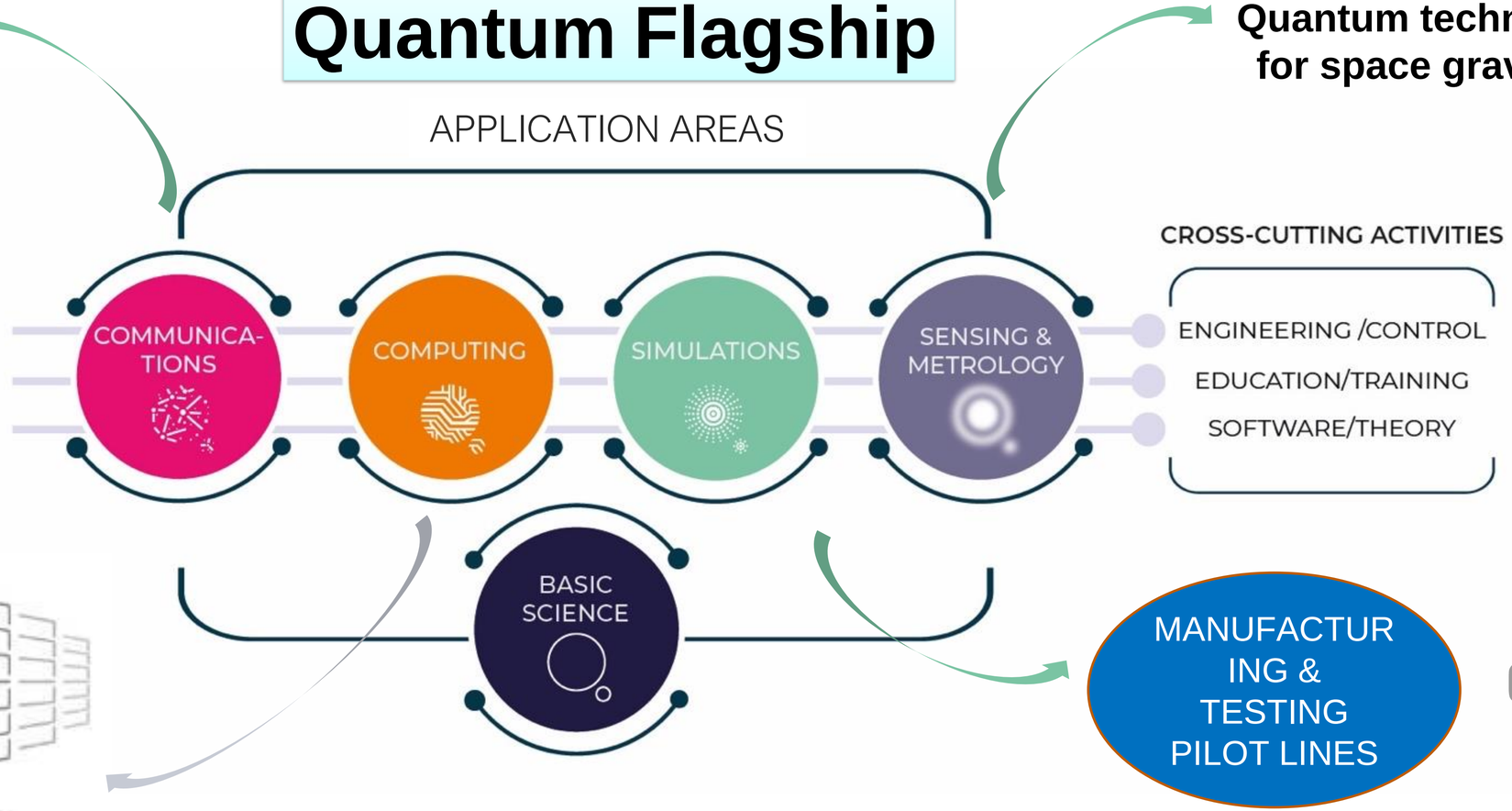
The Quantum Flagship

Structuring activities & efforts

EuroQCI

Quantum Flagship

HORIZON EUROPE - Quantum technologies for space gravimetry



EuroHPC Joint Undertaking

MANUFACTURING & TESTING PILOT LINES

Chips Act

The Ramp-Up phase

2018-2021 Projects

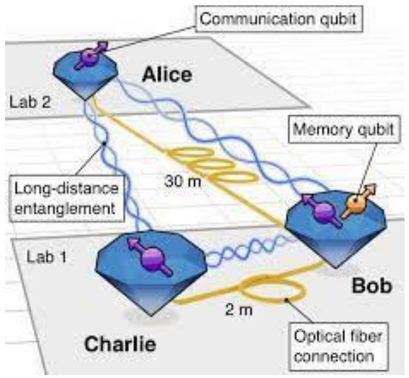
21 projects ≈ 150 M€

Communications	Simulation	Sensing	Computing	Basic science
For a Secure Digital Society and a Quantum-enabled Internet	Simulating Complex Systems for Advanced Design and Development	Bringing Accuracy and Performance to Unprecedented Levels	Computing Power to Overcome Currently Unsolvable Problems	Addressing Foundational Challenges for Development of Quantum Technologies
UNIQORN	Qombs	ASTERIQS	AQTION	PhoQuS
CiViQ	PASQuanS	iqClock	OpenSuperQ	SQUARE
QRANGE		Metabolics	QLSI	QMiCS
QIA		macQsimal	<NE|AS|QC>	S2QUIP
				2D-SIPC
				microQC
				PhoG

Quantum Flagship: Success stories from ramp-up phase (2021) (1/2)

Communication

World's first 3 node network and full stack multi-processor quantum network, and a state-of-the-art quantum repeater link



Computing

World record entanglement 24 qubits, 50 qubits prototype, 2 quantum computers 19" rack-mountable

AQT

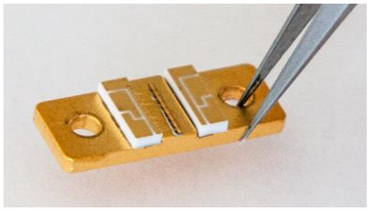
25 qubit chip processors with world-leading capabilities, global breakthrough in quantum error correction

IQM

Simulation

Atomic-based programmable quantum simulators, demonstrated practical quantum advantage (>200 qubits)

PASQAL



Quantum Flagship: Success stories from ramp-up phase (2021) (2/2)

Quantum SW & Applications

Software

- ✓ Quantum natural language processing

Industry-relevant use cases:

- ✓ CO_2 recapture
- ✓ Drug discovery
- ✓ Financial applications

Machine Learning & Optimisation

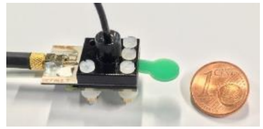
- ✓ Reinforcement learning for stock management
- ✓ Hard optimization problems for energy management

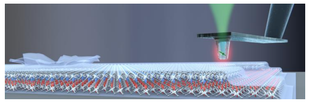
Quantum Sensing & Metrology

Metabolic Microscope x1,000 more sensitive than state of the art

Quantum polarizer enhancing MRI signal 10,000-fold at room temperature

Optical lattice clock off by only one second over the age of the universe





Skills & Start-ups

Skills: EU community of 5000+ scientists, engineers, innovators.

Quantum Flagship: 1600+ scientists, engineers, innovators

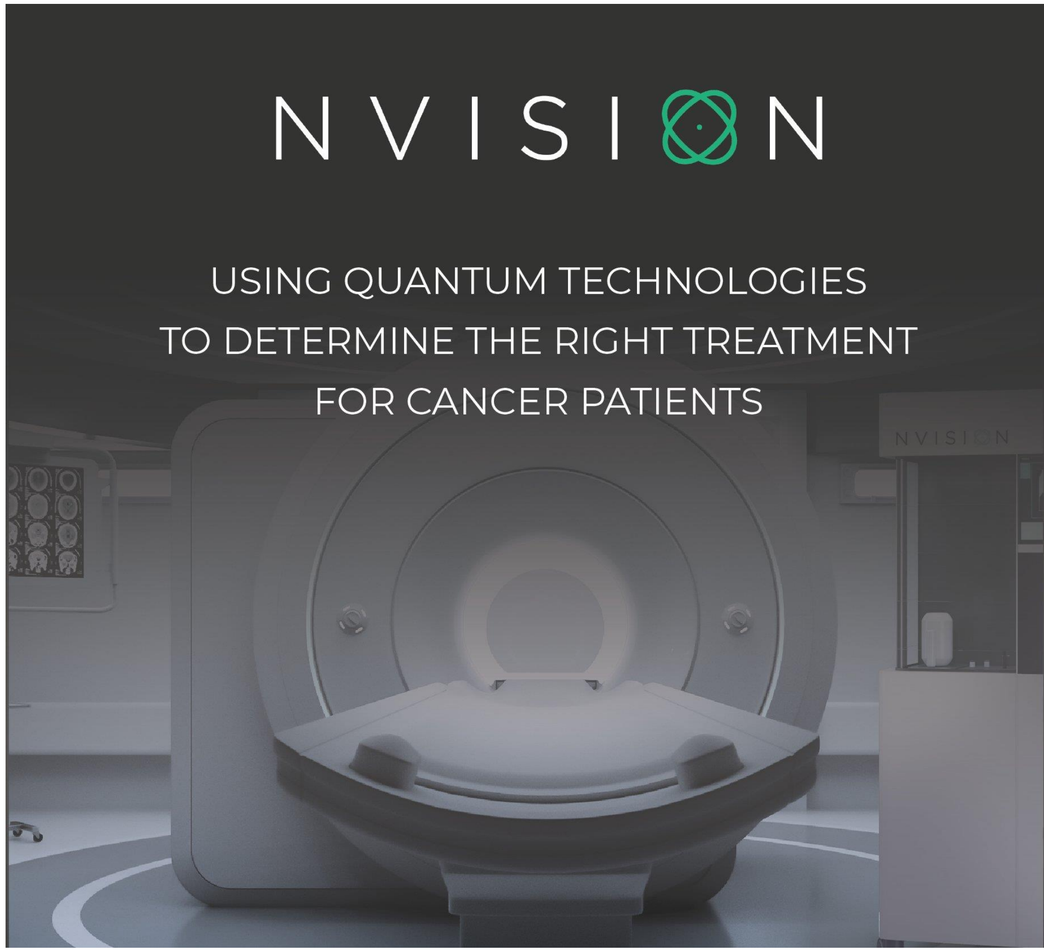
105 patents (64 granted) and commercialisation for 12 projects and standardisations (8 projects), 1500 publications, 2000 conferences

Start-ups as spin-offs (25)

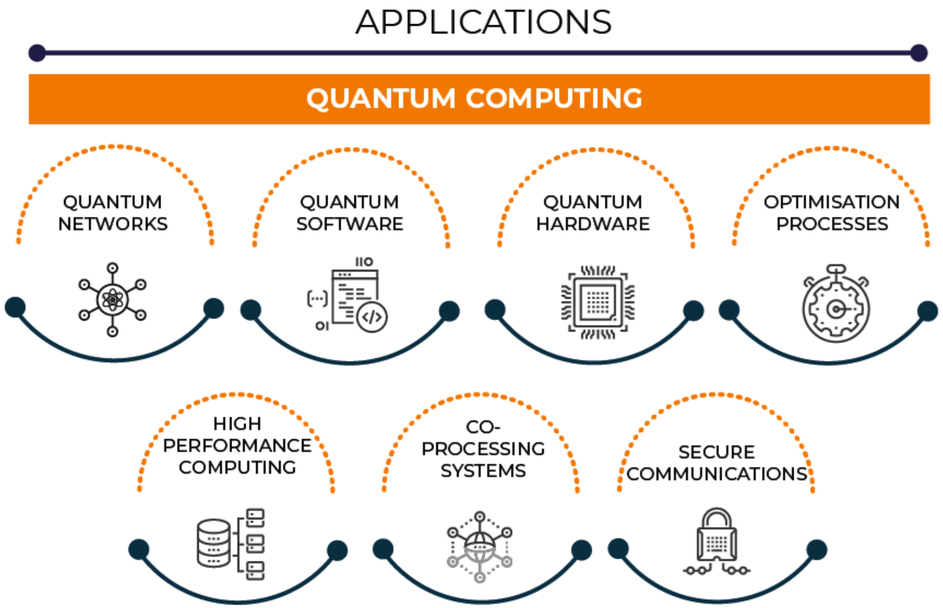
Master's in Quantum Technologies

Succes Story Highlight – NVision Imaging Technologies

- QuantumTech company from Germany (Ulm) (website)
- Partner in the MetaboliQs project (Ramp-up phase, Sensing field, 6.6M EUR)
- Won the Innovation Radar Prize (Nov 15th 2022) out of more than 300 applicants (news)
- Metabolic MRI is based on a hyperpolarisation platform, which is a promising technique for improving the sensitivity of magnet and chemical testing
- **Allows to reduce from months to days feed-back on cancer treatments** and can be employed with standard MRI scanners



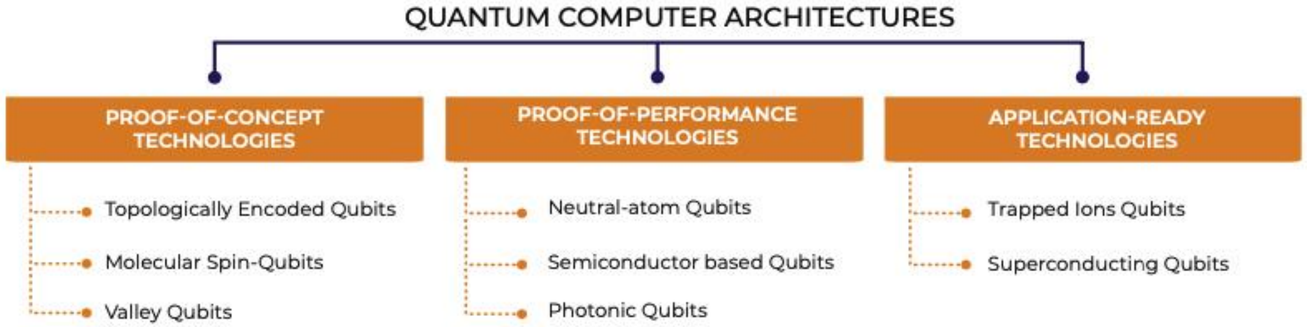
Quantum Computing



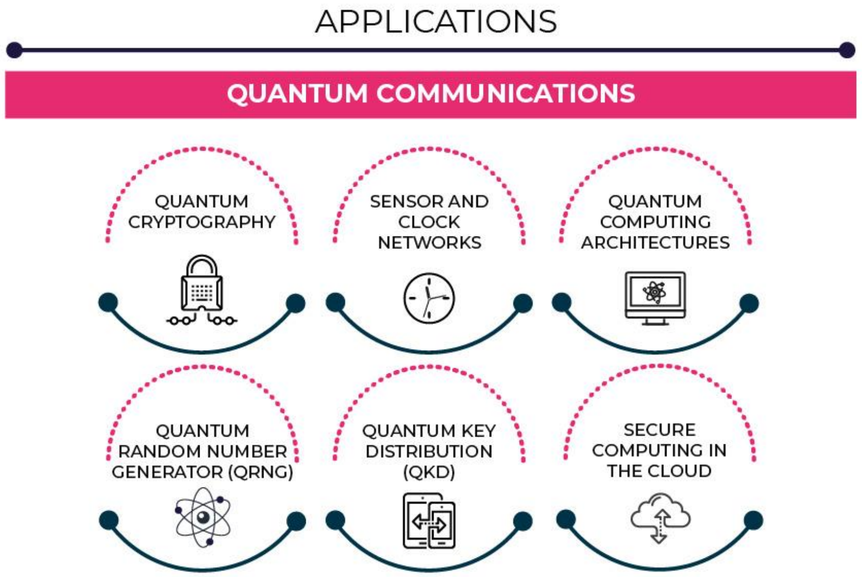
Quantum computers have the potential to solve tasks that we don't even dare dream of today and that classical computers can never solve. Completely new solutions for drug development, material design or areas such as financial services and transport will be possible.

6-10 year vision

- Quantum processors fitted with error corrections
- Quantum algorithms with quantum advantage
- Establish/support foundries (integrated photonics, 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



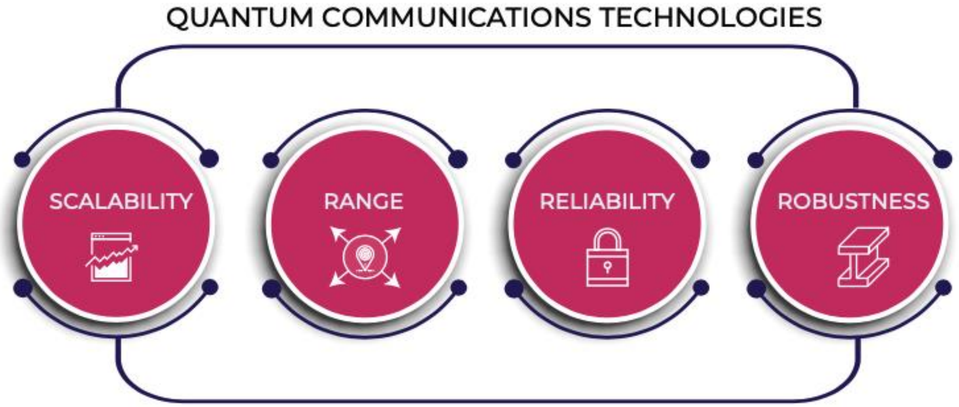
Quantum Communications



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.

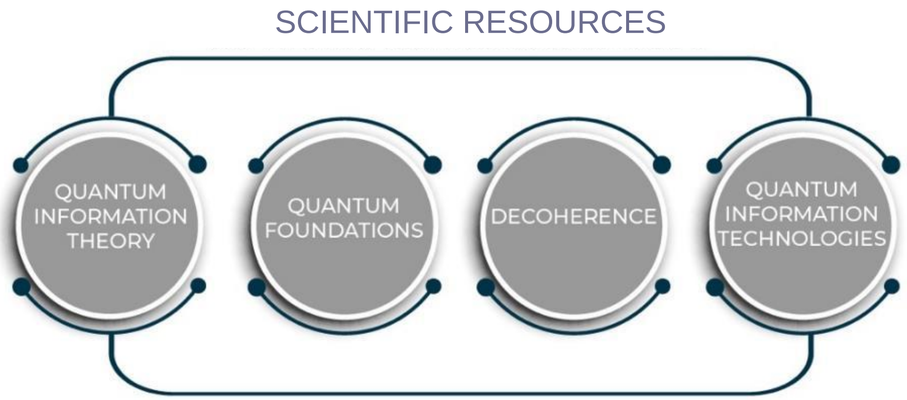
6-10 year vision

- 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



Basic Science
Scientific & Technological Resources

6-10 year vision



Scientific resources

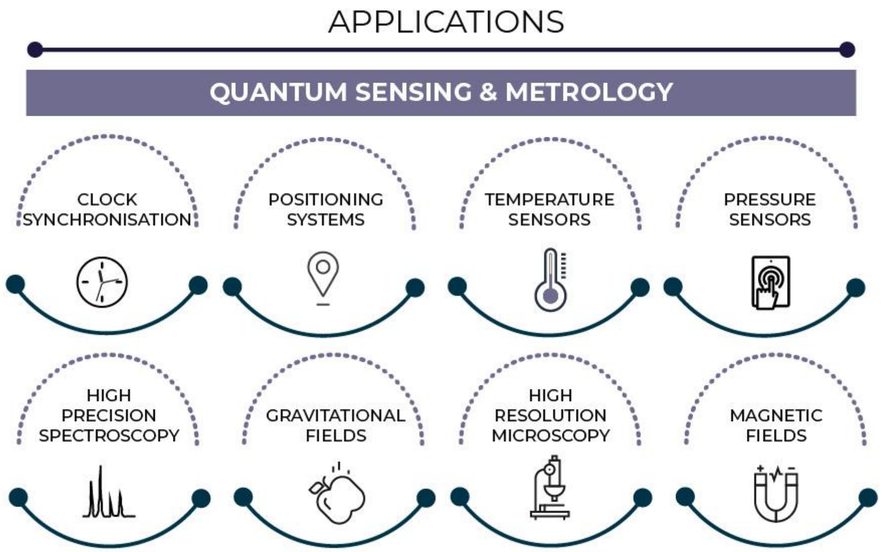
- Work towards opening up new avenues for potential growth in QT
- Scalable methods for certification of complex many-body and multi-partite quantum systems

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.

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.

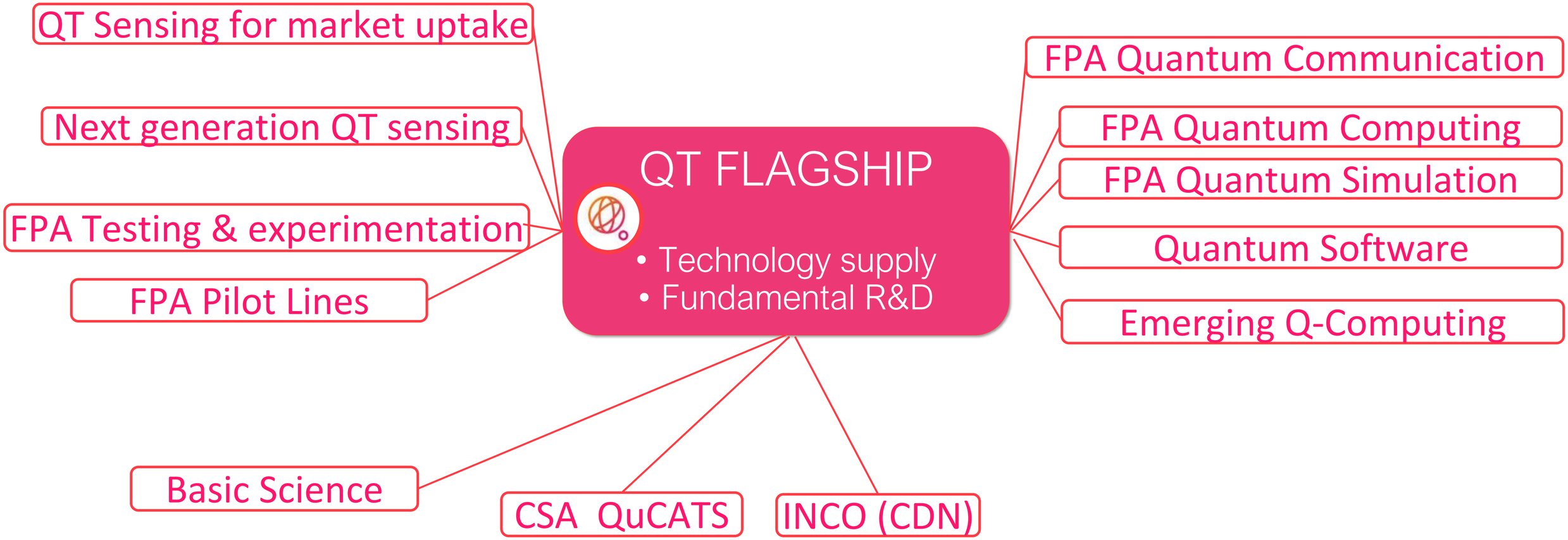
6-10 year vision

- 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 enhanced 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

Example Metabolics project
https://www.metabolics.eu/en/the-project.html
https://www.youtube.com/watch?v=W07HYSj-QDE

QT Flagship 2nd Phase: WP 2021 -2022

New Calls & FPA/SGAs



FPA/SGA Qu-Test

Quantum Computing

TNO VTT INRiM Fraunhofer cea PTB AIT imec LNE

Quantum Communication

AIT Fraunhofer INRiM VTT cea PTB imec

Quantum Sensing

Fraunhofer TNO INRiM VTT cea PTB AIT imec LNE INSTITUT d'OPTIQUE GRADUATE SCHOOL l'Observatoire de Paris | PSL

WP 2023/2024

- Horizon Europe info day – Cluster 4 (Quantum calls on 13/12 PM) (link to event)
- 4 Quantum calls in 2023:
  - HORIZON-CL4-2023-DIGITAL-EMERGING-01-40: Quantum Photonic Integrated Circuit technologies (RIA)
  - HORIZON-CL4-2023-DIGITAL-EMERGING-01-41: Investing in alternative quantum computation and simulation platform technologies (RIA)
  - HORIZON-CL4-2023-DIGITAL-EMERGING-01-43: Framework Partnership Agreement for developing large-scale quantum Computing platform technologies (FPA)
  - HORIZON-CL4-2023-DIGITAL-EMERGING-01-50: **Next generation quantum sensing and metrology technologies (RIA)**

EU QUANTUM TECHNOLOGY ROADMAP

2018 2020 2022 2024 2026 2028 2030

RESEARCH & INNOVATION

H2020 Horizon Europe

Flagship Ramp up Phase
24 Projects

Tech Demonstration Phase

Tech Implementation Phase

International Collaboration

QUANTERA

EU National Coordination

DEPLOYMENT

1st Entanglement
Quantum Network

QKD Infrastructure
Testing of Cross-Border QCI Links

Satellite integration
Full terrestrial deployment

Quantum Communications Infrastructure (EuroQCI)

EuroQCI 1st Phase

EuroQCI Operational Deployment

Quantum Computing Infrastructure (EuroHPC)

QT Simulator Pilot

1st Gen HPC/Q Computer/Sim

2nd Gen HPC/Q Computer/Sim Integration

EuroHPC HPC -
Quantum Simulator hybrid

QT/HPC Hybrid
Simulation/Computation

Digital Europe Programme

MANUFACTURING & PRODUCTION

ADVANCED DIGITAL SKILLS
Competence Framework

Pilot lines - Open testing & experimentation

Production capabilities

FPAs > Chips Act

Creation of QuIC
Industry Consortium

Quantum Sensing
& Metrology toolbox

BUSINESS CREATION

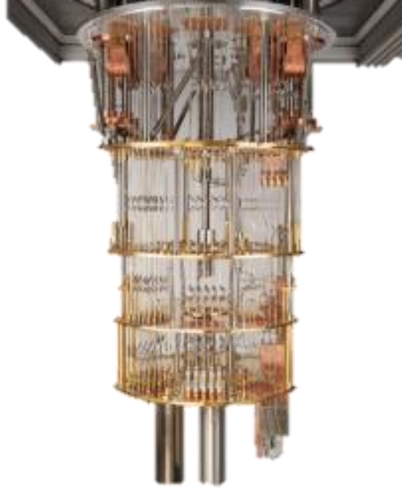
QT Fund

QT Fund - to support quantum startups in their development

QUANTUM ECOSYSTEM
The European Union is at the cutting edge of quantum capabilities

QUANTUM FLAGSHIP

European Commission



Thank you

more info in **qt.eu**

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