Quantum Flagship:
Mid-term review and future activities

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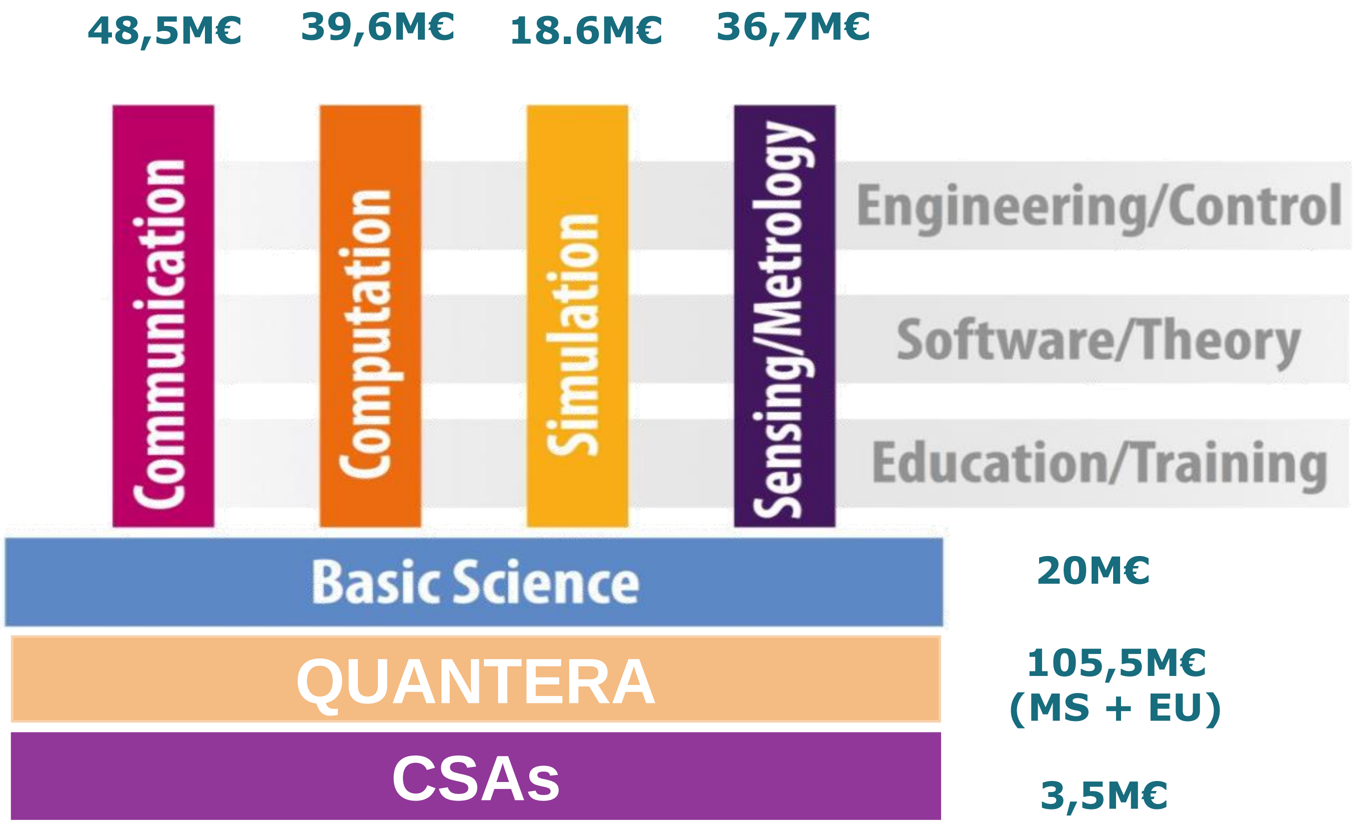
Ramp-up phase:

Oct 2018

+

Sept 2020



Total budget : ~ EUR 272,5 million

1400 scientists directly involved, 236 organisations (1/3 private)

Mid-term review: Objectives

- Check how projects are progressing towards Flagships overall objectives
- Summarises progress by individual projects and in the key research domains
- Outlines synergies between projects and presents other progress metrics (e.g. number of events organised, publications, patents)
- Available to download here (see also blog post by Thomas Skordas and Jürgen Mlynek here)
- ~ 25 experts involved in Review process

Mid-term review: Key figures

- 20 spin-off companies expected to be created
- projects have organised events attended by more than 12,000 quantum experts, some of them common
- 60 patent applications filed, 16 patents already granted
- 500 articles published, some articles shared between different 160 more under review, 50 articles collaboration results (more than one project involved)

Mid-term review: Overview

- the Flagship projects are progressing towards the common goals for the application areas and the fundamental science domain set out in the Flagship's Strategic Research Agenda
- many projects are well ahead of state-of–the-art technology, some even world-leading in their field (e.g # of entanglements of ion-trap computing platform)
- are all well on track with only minor delays due to Covid19
- the Flagship has expanded and united Europe's quantum community, not least via major events in Vienna in 2018, in Grenoble and Helsinki in 2019, and in Berlin in 2020

Mid-term review: Communication

- world-leading advances in continuous variable QKD technologies
- break-throughs towards high efficiency quantum memory enabling storage and retrieval of photonic entanglement with 87 % efficiency, a world record.
- Long-lived solid-state quantum memory at single photon level with storage time of 20 ms, a 20-fold increase over the state-of the art.
- specified, modelled and validated construction technologies for different types of quantum random number generation

Mid-term review: Computing

Trapped ion technology (AQTION) achievements:

- ✓quantum computer demonstrator 10 qubits (first EU machine on the cloud)
- ✓operational prototype (racked) 50 qubits (cf. IonQ 32 qubits, Honeywell 15qubits)
- ✓world record entanglement of 20 ion-qubits

Superconducting technology (OpenSuperQ) achievements:

- ✓7-qubit machine (upgraded to 17-qubits) (c.f. IBM 53 qubits, previous machine was 17 qubits, Google 73 qubits)
- ✓Two-qubit gates fidelity of above 99% (c.f. IBM 96%, Google 99%)

Mid-term review: Simulation

- developed the next generation of atomic-based programmable quantum simulators (100 atoms in tweezer arrays, 50 ions in ion trap, 20 Rydberg atoms in arrays) – world-leading, reached practical quantum advantage (impossible to simulate with HPC)

- made progress towards demonstrating that quantum simulation can be useful for optimising real devices.

Spin-off of one simulation project will build a hybrid HBP/Quantum Simulator in the framework of EuroHPC

Mid-term review: Sensing and Metrology

- progressed towards the development of quantum sensors based on NV-diamond centres

- made advances in quantum metrology and sensing through MEMS (microelectromechanical systems) technology

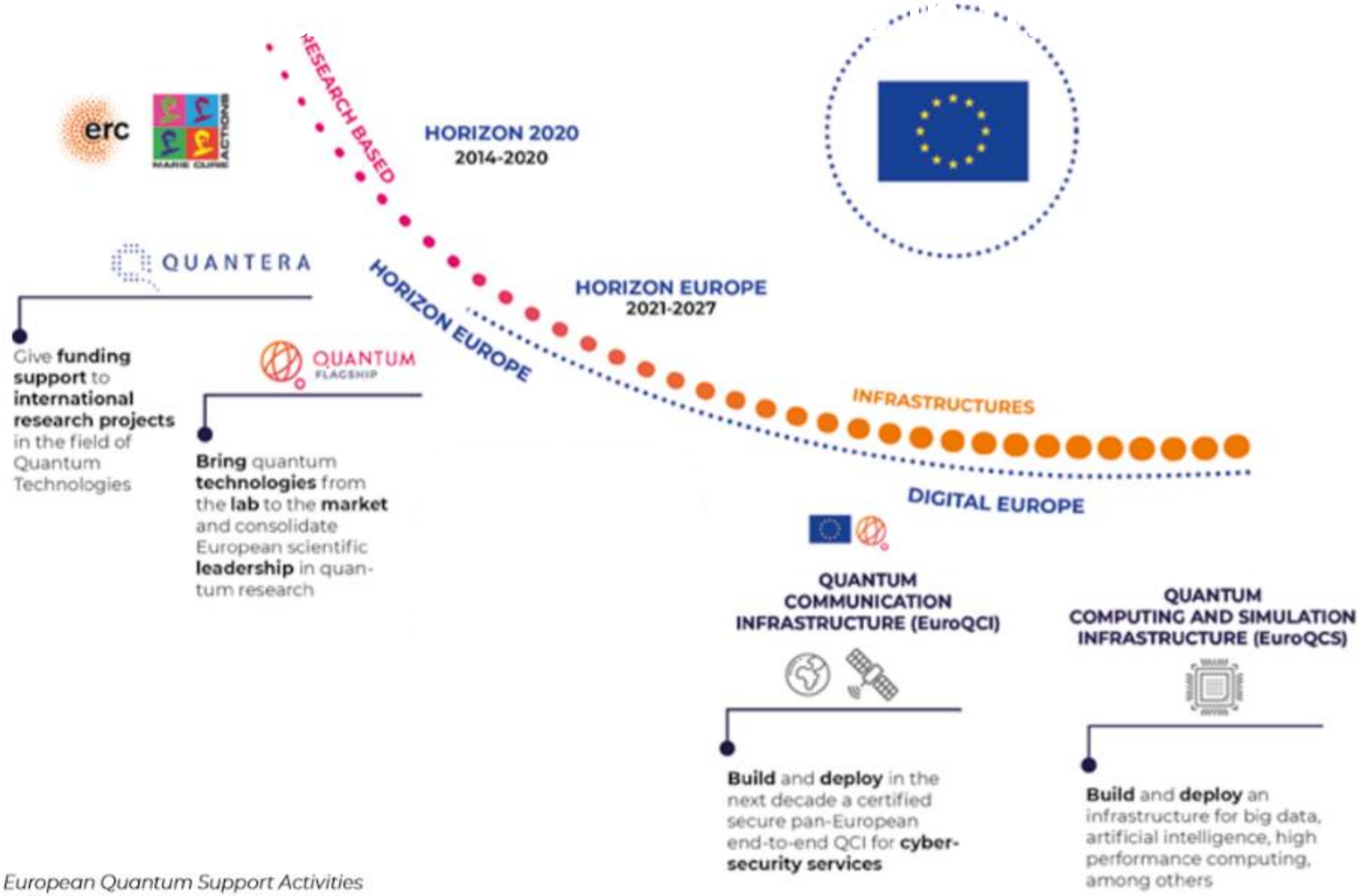
- demonstrated the brightest Sr beam in the world – to pave the way to the first continuous atom laser and the first superradiant optical clock

European Commission

Mid-term review: Basic science

- discovered a multitude of novel 2D opto-electronic materials
- achieved world record tune-ability of photon emitters
- developed new single photon detectors
- developed and implemented high-fidelity conditional quantum gates with microwave-driven ions
- made progress towards the fabrication of compact entangled photon-based light sources (photon guns)
- advanced nanofabrication of 2D materials to enable reconfiguration of photonic circuits using MEMS
- detection and control of single rare earth ions (REI) as qubits (cerium, erbium)

Quantum Technologies in the EU



European Quantum Support Activities

European Commission

Quantum technologies in the next MFF (2021-2027)

Under Negotiation

2021 - 2027

Digital Europe Program

- Supercomputing, quantum-computing infrastructure
- QT/HPC hybrid

Horizon Europe QT FLAGSHIP

- Technology supply
- Fundamental R&D

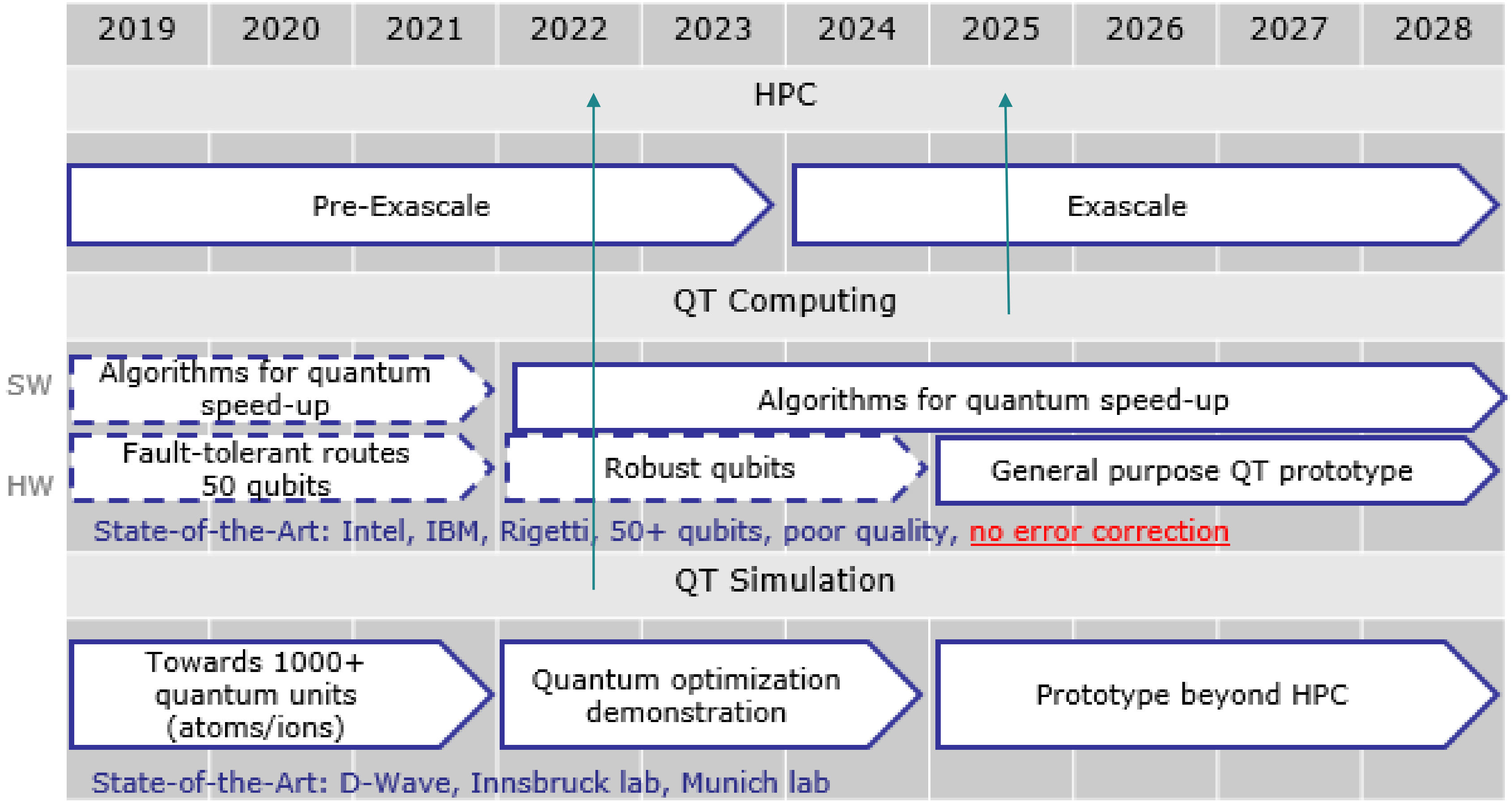
Connecting Europe Facility (CEF2)

- Testing of cross-border QCI links

EuroHPC

- Supercomputing infrastructure
- Quantum computing (part of new mandate)

Roadmaps (quantum computing/simulation and EuroHPC)



EuroQCI: A Terrestrial and a Space segment

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

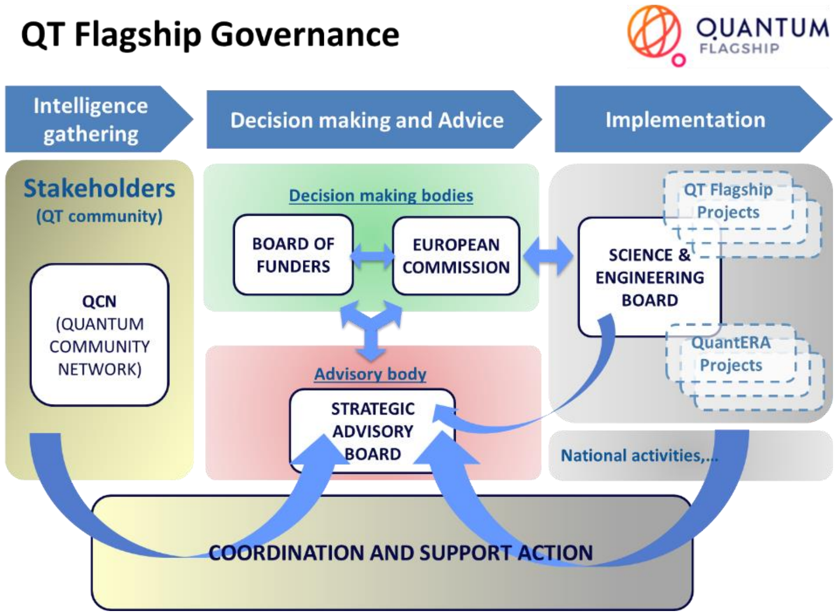
- Protection of government data & communications, telecommunications networks, data centres, critical infrastructure (energy, finance, etc.)
- Securing EU space systems, etc.

The Quantum Flagship in the next MFF: targets

- build quantum computers of at least 500 qubits by 2025, and develop built-in quantum error-correction
- support efforts to link a chain of physically distant quantum repeaters enabling quantum communication over at least 500 kilometres, and demonstrate a quantum network node of at least 20 qubits connected to a quantum network
- develop networks of quantum sensors and of high-precision space sensors, and quantum chips for specific applications
- build an advanced experimental and testing infrastructure, where European Research and Technology Organisations (RTOs) and other open innovation labs can enable an industry transition towards quantum technologies and large innovation capacity building
- continue supporting basic science and basic technology developments

Governance structure modifications needed

- Renew expert group in 2021
- Include activities under EuroHPC and QCI
- Include industrial consortium (QUIC) : industry players (start-ups, SMEs and large industry) are organising themselves around the European Quantum Industry Consortium



Current governance

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