The Flagship in Quantum Technologies of the European Commission

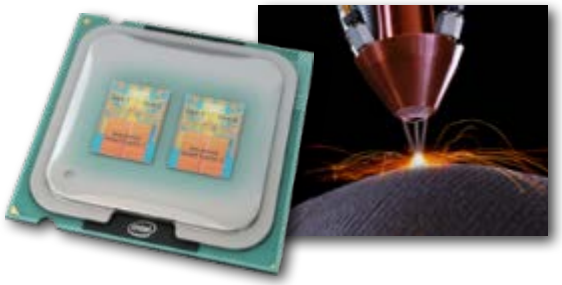
Tommaso Calarco

The Quantum Technologies Flagship Meeting
Stephen's Green Hibernian Club, Dublin
22 September 2017

The second quantum revolution is unfolding

First quantum revolution

- Discovery of fundamental laws of the microscopic realm
- Formulation of quantum mechanics

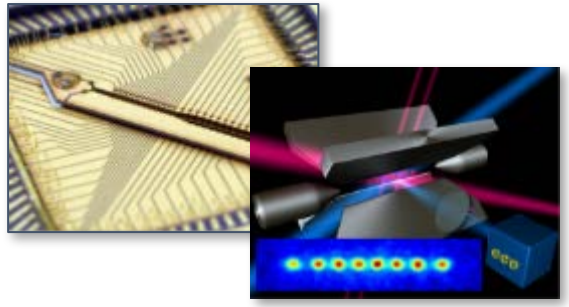


‘Bulk’ quantum technologies

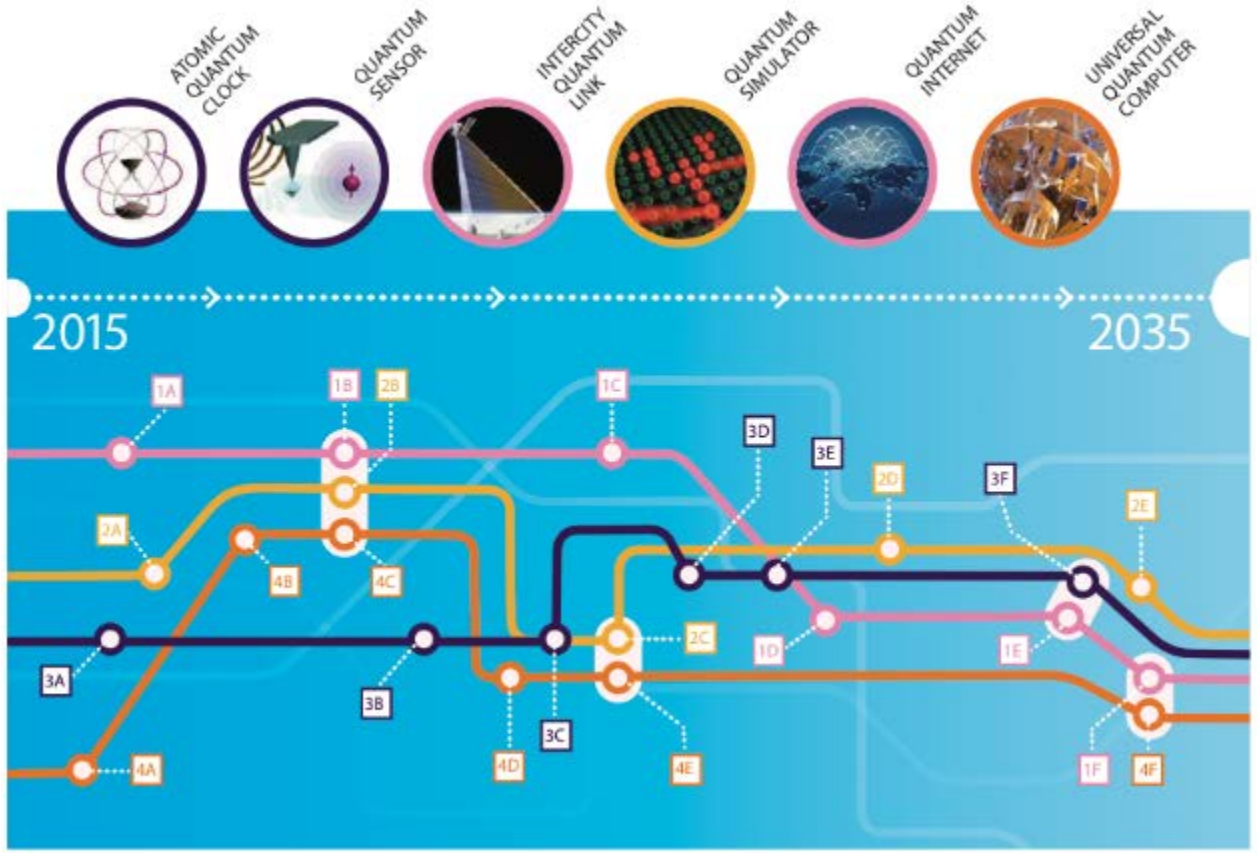
- Development of ground-breaking technologies such as transistor and laser
- Based on bulk effects, where many quantum degrees of freedom are manipulated at once

Second quantum revolution

- Technologies based on the manipulation of individual quantum states
- Make use of “strange” quantum properties, such as superposition and entanglement
- Secure communications, ultimate computing power, ultraprecise sensors



Quantum Manifesto was handed over to European Commission in May 2016



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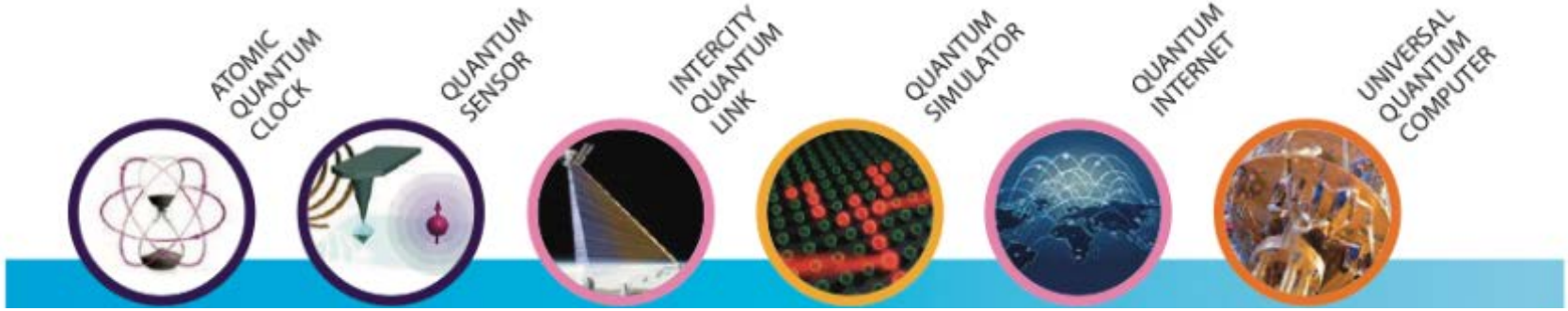
Quantum Manifesto



1. Communication

0 – 5 years

A Core technology of quantum repeaters

B Secure point-to-point quantum links

5 – 10 years

C Quantum networks between distant cities

D Quantum credit cards

> 10 years

E Quantum repeaters with cryptography and eavesdropping detection

F Secure Europe-wide internet merging quantum and classical communication

2. Simulators

0 – 5 years

A Simulator of motion of electrons in materials

B New algorithms for quantum simulators and networks

5 – 10 years

C Development and design of new complex materials

D Versatile simulator of quantum magnetism and electricity

> 10 years

E Simulators of quantum dynamics and chemical reaction mechanisms to support drug design

3. Sensors

0 – 5 years

A Quantum sensors for niche applications (incl. gravity and magnetic sensors for health care, geosurvey and security)

B More precise atomic clocks for synchronisation of future smart networks, incl. energy grids

5 – 10 years

C Quantum sensors for larger volume applications including automotive, construction

D Handheld quantum navigation devices

> 10 years

E Gravity imaging devices based on gravity sensors

F Integrate quantum sensors with consumer applications including mobile devices

4. Computers

0 – 5 years

A Operation of a logical qubit protected by error correction or topologically

B New algorithms for quantum computers

C Small quantum processor executing technologically relevant algorithms

5 – 10 years

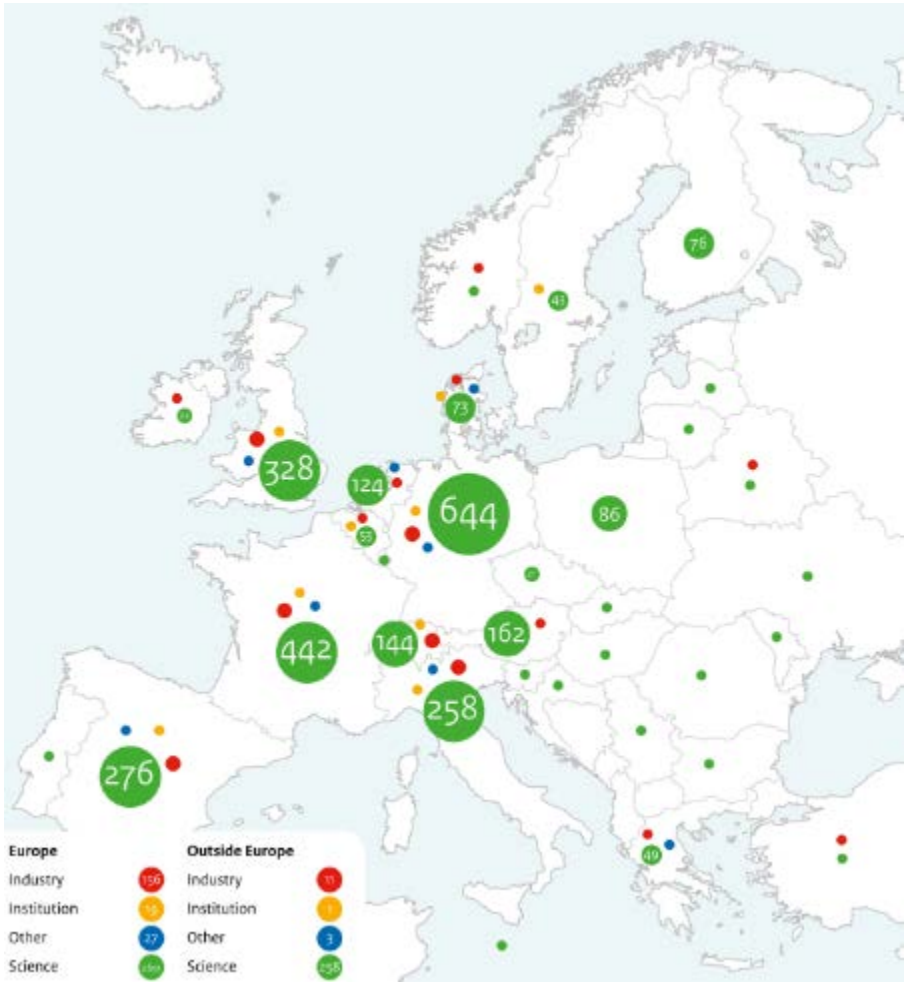
D Solving chemistry and materials science problems with special purpose quantum computer > 100 physical qubit

> 10 years

E Integration of quantum circuit and cryogenic classical control hardware

F General purpose quantum computers exceed computational power of classical computers

More than 3600 supporters from academia and industry

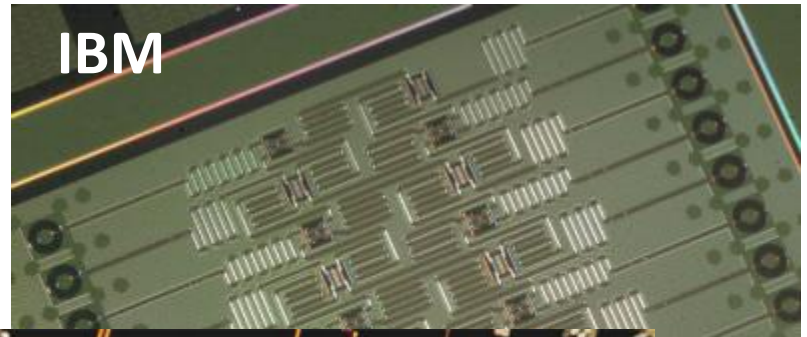


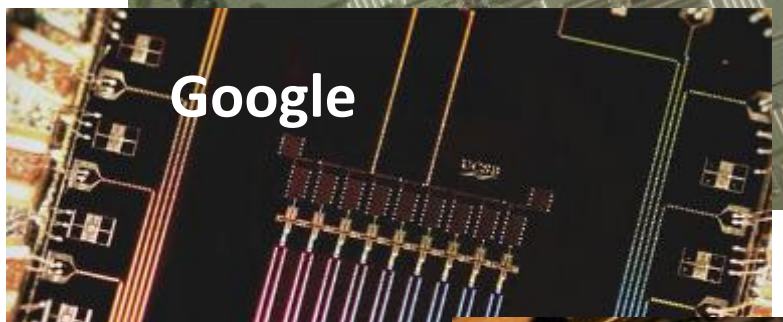
ASML
SAFRAN
AEROSPACE · DEFENCE · SECURITY
HUAWEI
IBM
intel
BOSCH
e2v
Bringing life to technology
Alcatel·Lucent
TOSHIBA
imec
THALES
SINGLE QUANTUM
IDQ
SIEMENS
NOKIA
Microsoft

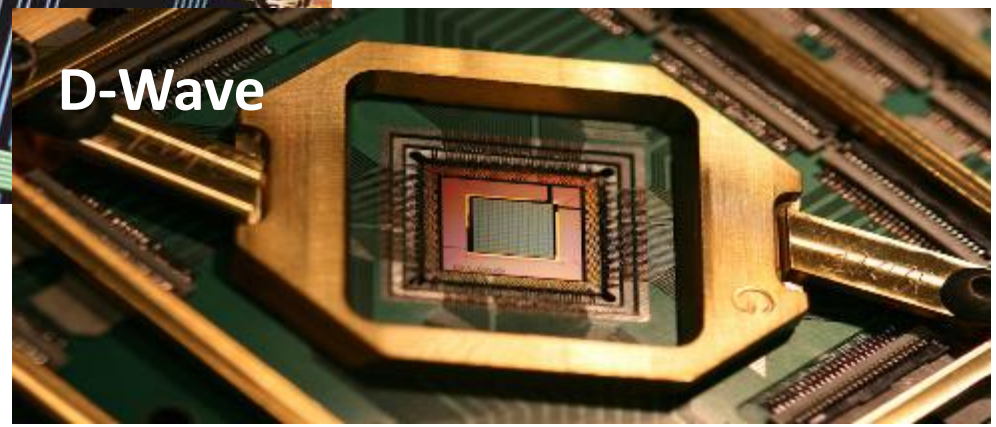
Lots of QT activity outside Europe

China: 2,000km
QKD backbone +
Micius satellite

Lots of QT activity outside Europe







North America:
Massive private investment in QC

QCWARE

1QBit

QXBranch

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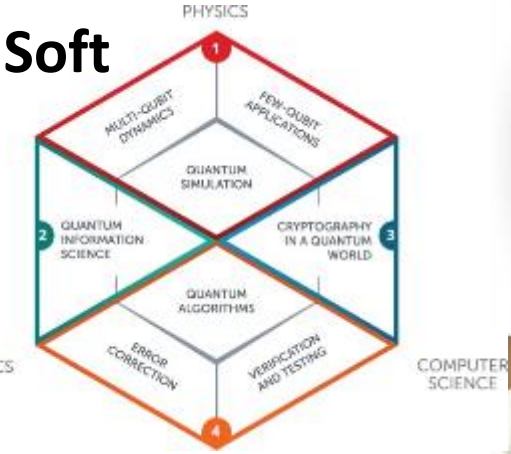
Five reasons why Europe will remain at the fore-front of quantum technologies

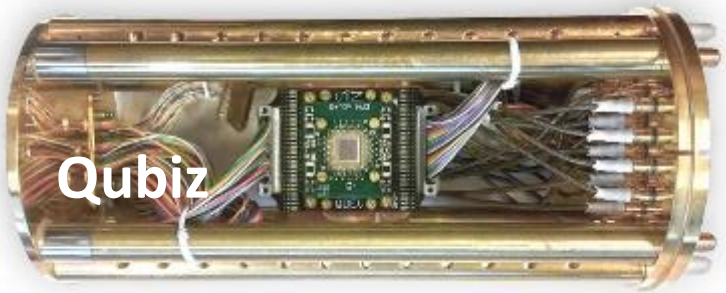
1. **World-leading experts with a global network of collaborators**
2. Strong supply chain
3. Vivid QT start-up scene
4. Broad interest from industry
5. Strong committment from governments and funding agencies

World-Leading experts

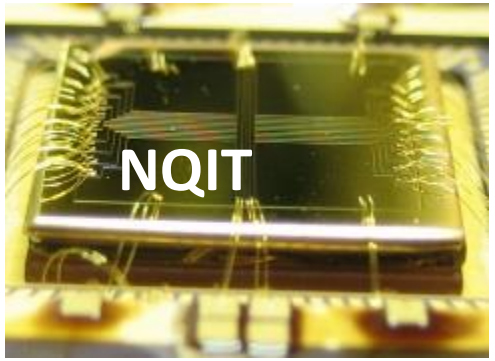
Blatt group



QuSoft



Qubiz



NQIT

Qutech

Bloch group

Haroche group

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Wallraff group

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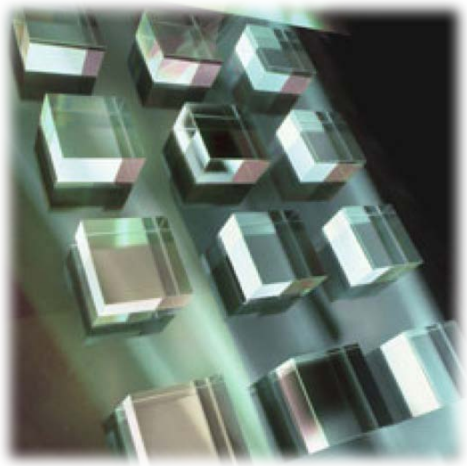
Strong supply chain

Attocube

Zurich Instruments

Menlo System

ASML



Element Six

Toptica

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Vivid QT Start-up scene

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High interest of European industry in Quantum Technologies

Industry members of the Steering Committee

Dr. Cyril Allouche

Jaya Baloo

Ing. Paolo Bianco

Dr. Michael Bolle

Dr. Fabio Cavaliere

Dr. Guido Chiaretti

Dr. Daniel Dolfi

Dr. Norbert Lütke-Entrup

Dr. Graeme Malcolm

Dr. Iñigo Artundo Martinez

Dr. Markus Matthes

Dr. Grégoire Ribordy

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Atos

Jaya Baloo
kpn

Ing. Paolo Bianco
AIRBUS DEFENCE & SPACE

Dr. Michael Bolle
BOSCH Invented for life

Dr. Fabio Cavaliere
ERICSSON

Dr. Guido Chiaretti

Dr. Daniel Dolfi
THALES

Dr. Norbert Lütke-Entrup
SIEMENS

Dr. Graeme Malcolm
M SQUARED

Dr. Iñigo Artundo Martinez
VLC PHOTONICS

Dr. Markus Matthes
ASML

Dr. Grégoire Ribordy
IDQ

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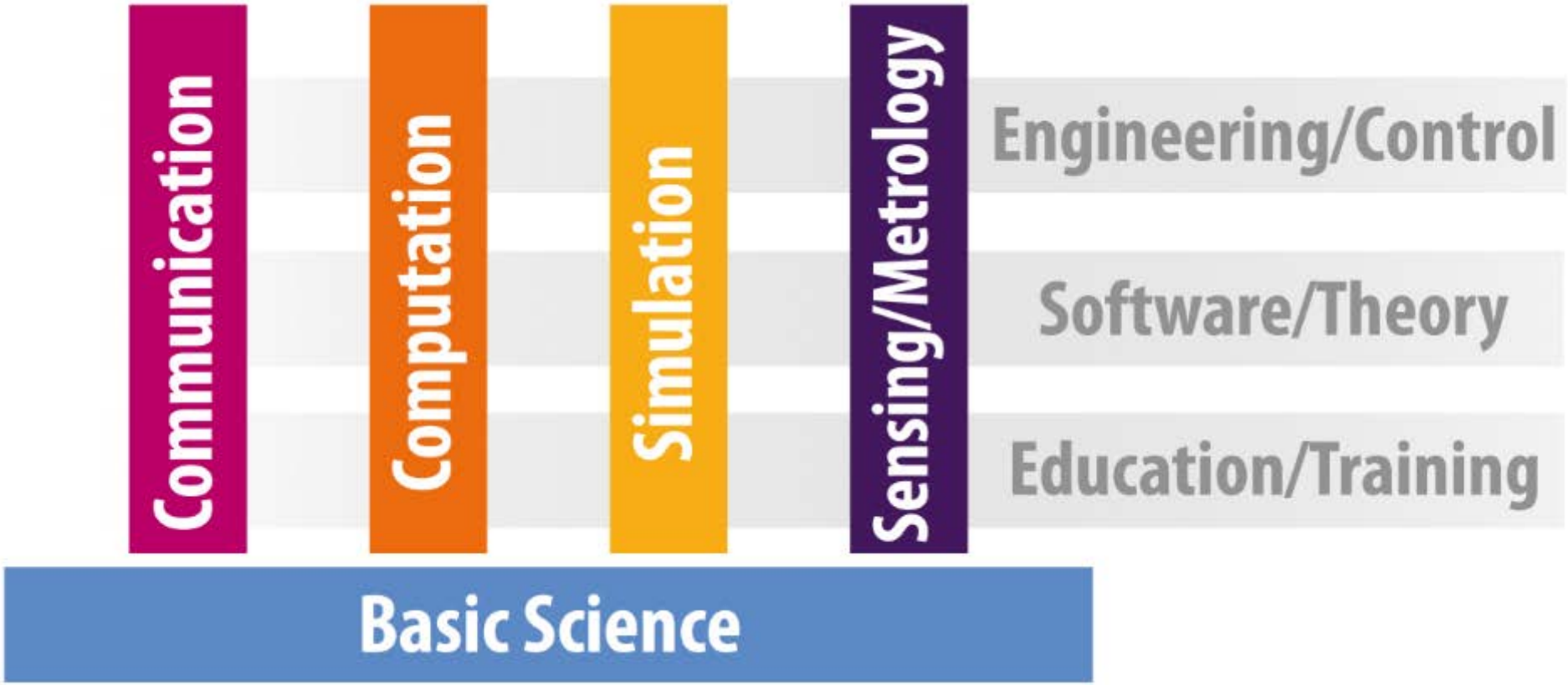
HLSC final report just published

https://tinyurl.com/qt-report

Structure of Flagship Work Programme



Qcomm in the HLSC Report

Quantum communication milestones

- **In 3 years,** development and certification of QRNG and QKD devices and systems, addressing high-speed, high-TRL, low deployment costs, novel protocols and applications for network operation, as well as the development of systems and protocols for quantum repeaters, quantum memories and long distance communication;

- **In 6 years,** cost-effective and scalable devices and systems for inter-city and intra-city networks demonstrating end-user-inspired applications, as well as demonstration of scalable solutions for quantum networks connecting devices and systems, e.g. quantum sensors or processors;

- **In 10 years,** development of autonomous metro-area, long distance (> 1000km) and entanglement-based networks, a "quantum Internet", as well as protocols exploiting the novel properties that quantum communication offers.

Academic and industrial work promoting standardisation and certification should be addressed at every stage.

Qcomm in the WP

Quantum Communications: Development of state-of-the art network devices, applications and systems (memories, quantum repeaters, network equipment, high throughput miniaturised quantum random number generators, etc.) for quantum communication mesh-networks. Proposals should target cost-effective solutions, devices and systems compatible with existing communication networks and standard cryptography systems, as well as device-independent protocols. Each proposal should address aspects like engineering, protocols, certification, software, algorithms. Actions should include validation of the proposed solution, proof of its suitability for the targeted application and benchmarking with respect to relevant targets set by the CSA in this area.

Qcomp in the HLSC Report

Quantum computing milestones

- **In 3 years**, fault tolerant routes for making quantum processors with more than 50 qubits will be demonstrated;
- **In 6 years**, quantum processor fitted with quantum error correction or robust qubits will be realized, outperforming physical qubits;
- **In 10 years**, quantum algorithms demonstrating quantum speed-up and outperforming classical computers will be operated.

Qcomp in the WP

Quantum Computing Systems: The development of open quantum computer experimental systems and platforms, integrating the key building blocks such as quantum processors (>10qubits) with limited qubit overhead, control electronics, software stack, algorithms, applications, etc. Work should address the scalability towards large systems (>100 qubits), the verification and validation of the quantum computation, fault-tolerance and solving a concrete computational problem to demonstrate the quantum advantage. Projects should foresee benchmarking activities. Benchmarks will be identified by the CSA for all the platforms selected in this area.

Qsim in the HLSC Report

Quantum simulation milestones

- **In 3 years**, experimental devices with certified quantum advantage on the scale of more than 50 (processor) or 500 (lattices) individual coupled quantum systems;
- **In 6 years**, quantum advantage in solving important problems in science (e.g. quantum magnetism) and demonstration of quantum optimisation (e.g. via quantum annealing);
- **In 10 years**, prototype quantum simulators solving problems beyond supercomputer capability, including in quantum chemistry, the design of new materials, and optimisation problems such as in the context of artificial intelligence.

Qsim in the WP

Quantum Simulation: Proposals should aim at delivering operational demonstrators, based on existing physical platforms that have shown a clear perspective to achieve more than 50 interacting quantum units and / or full local control. They should work towards demonstrating a certified quantum advantage for solving difficult scientific or industrial problems (e.g. material design, logistics, scheduling, machine learning, optimisation, artificial intelligence, drug discovery, etc.). The proposed solutions need to include the development of protocols, validation schemes and control, simulation software, system configuration and optimisation. Work should address the scalability towards larger systems with more qubits. Projects should foresee benchmarking activities related to real life applications. Benchmarks will be identified by the CSA for all the platforms selected in this area. Hybrid architectures are also to be considered under this area when relevant.

Qsens in the HLSC Report

Quantum sensing and metrology milestones

- **In 3 years**, quantum sensors, imaging systems and quantum standards that employ single qubit coherence and outperform classical counterparts (resolution, stability) demonstrated in laboratory environment;
- **In 6 years**, integrated quantum sensors, imaging systems and metrology standards at the prototype level, with first commercial products brought to the market, as well as laboratory demonstrations of entanglement enhanced technologies in sensing;
- **In 10 years**, transition from prototypes to commercially available devices.

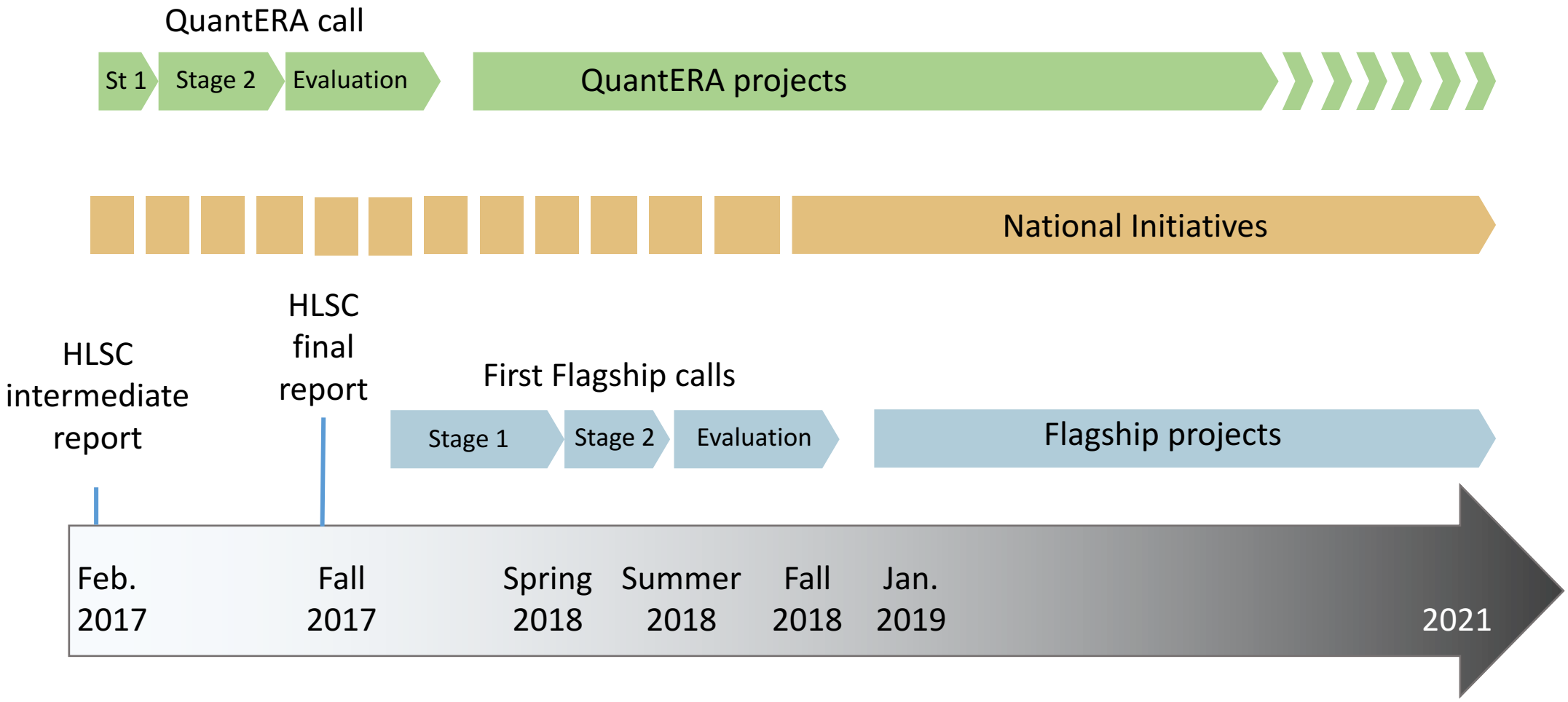
Qsens in the WP

Quantum Metrology and Sensing: Quantum sensors for specific application areas such as imaging, healthcare, geo-sciences, outdoor and indoor navigation, time or frequency, magnetic or electrical measurements, etc. … as well as novel measurement standards, making use of the advances in controlling the fundamental quantum properties. It is expected that the work will lead to practical sensing devices, imaging systems and quantum standards that employ quantum coherence and outperform classical counterparts (resolution, stability) targeting TRL 3 and 4 and showing potential for further miniaturisation/integration into industrial systems.

Fundamental science in the WP

Fundamental science: Research and development of basic theories and components, addressing a foundational challenge of relevance for the development of quantum technologies in at least one of the four areas a.-d. described above, to improve the performance of the components or subsystems targeted in those areas. Proposals must clearly indicate how they support a challenge for one or more of these areas.

Timeline


QuantERA call
St 1
Stage 2
Evaluation
QuantERA projects
National Initiatives
HLSC intermediate report
HLSC final report
First Flagship calls
Stage 1
Stage 2
Evaluation
Flagship projects
Feb. 2017
Fall 2017
Spring 2018
Summer 2018
Fall 2018
Jan. 2019
2021

Frame conditions by EC and lessons learnt from running Flagship initiatives

New model:
No more core consortium, instead closely coordinated projects

Frame-conditions by EC:

- R&I projects selected, managed, evaluated according to H2020 rules (at least in ramp-up phase)
- Science & Engineering Board to coordinate between R&I projects
- CSA to coordinate all non-R&I activities
- An effective governance

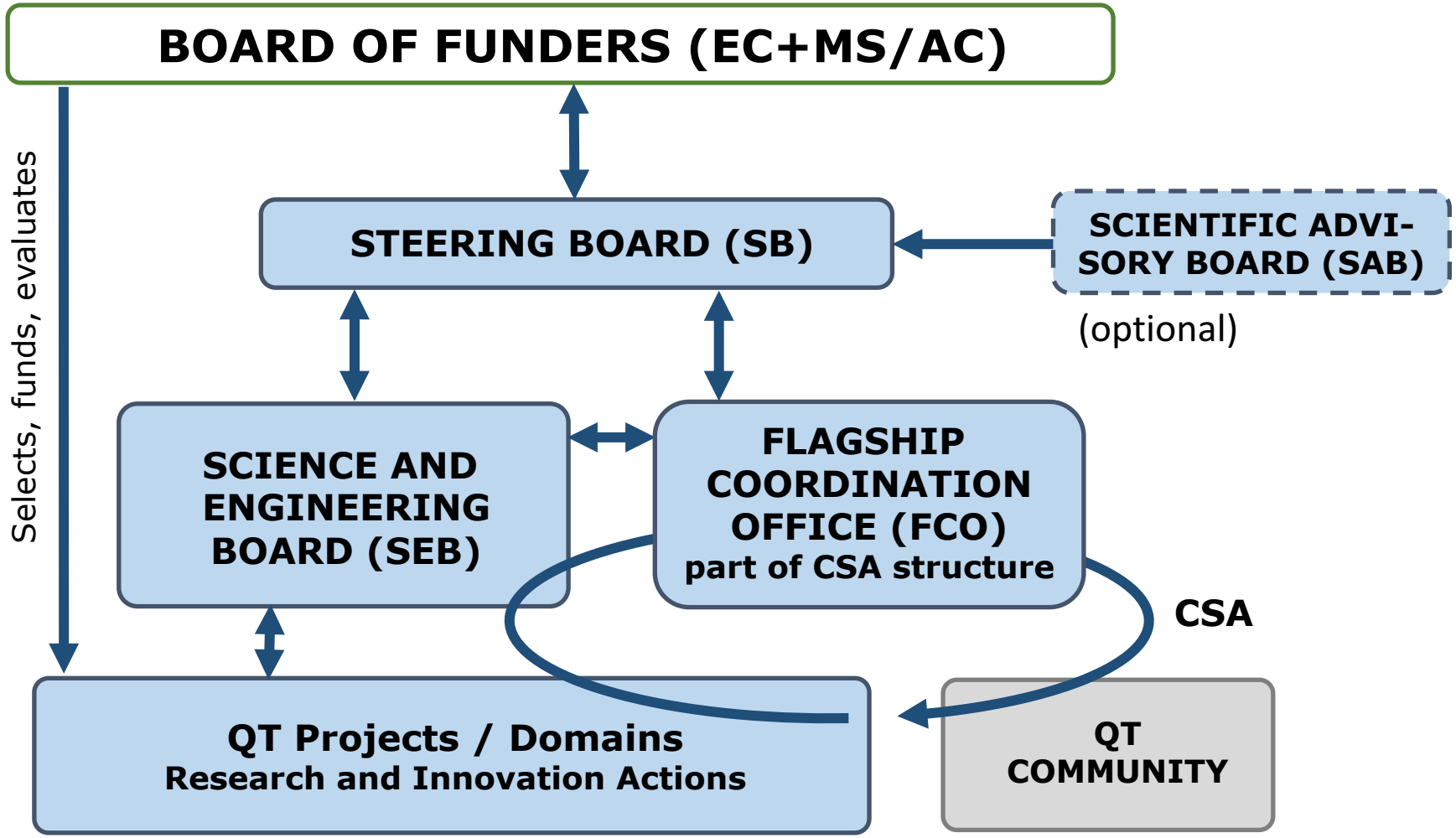
✓ **Adopt from running Flagships**

- Separation of strategic / coordination / operational level
- KPIs on program level
- Scientific Advisory Board

✗ **Change compared to running Flagships**

- New model with several projects
- A CSA for coordination of non R&I activities and community involvement

Governance model for the QT Flagship



Board of Funders – Program alignment and operation

Composition: EC + Representatives of MS/AC

Main tasks:

- Ensures alignment of programmes at different levels
- Oversees overall progress of the Flagship
- Discusses strategic views and options for the future development of QT in Europe

European Commission

- Prepares strategic positioning and options for the future development of QT in Europe based on Steering Board recommendations
- Prepares EU work programmes based on SRA
- Organises EU calls, evaluations, selects projects (including ERA-NETs) & issues grants/funding
- Prepares Flagship assessment based on agreed KPIs and monitors EU project execution
- Prepares strategic IN-CO activities

National/regional funding agencies

- Prepare transnational work programmes based on SRA
- Organise transnational evaluations and select transnational projects & issue grants/funding
- Monitor transnational project execution

Steering Board – Strategy planning & advice

Proposed composition:
~20 members from academia & industry & RTOs (+ SEB Chair and FCO Director as permanent invitees)

Appointed by: European Commission

Main tasks:

- Prepares & updates SRA
- Proposes KPIs for output and impact
- Oversees Flagship execution and reports to BoF on progress towards its goals
- Identifies gaps, provides recommendations for future to BoF

Interactions

- Interacts closely with both SEB and Flagship Coordination Office
- Delivers reports with programme options to Board of Funders (MS+EC)
- Logistical support provided by Flagship Coordination Office (funded via CSA)

Science & Engineering Board – Coordination of RIA

Proposed composition:
Coordinators of all EU-funded flagship projects (+ FCO Director as permanent invitee), elect among themselves a chair and six representatives for the Flagship domains and the cross-cutting topics Engineering/Control and Software/Theory

Main tasks:
- Oversees implementation progress of the Flagship's work plan
- Ensures coordination of the R&I activities between the different EU-funded projects
- Reports to the EC on overall performance and progress of the Flagship projects
- Proposes changes to the SRA taking into account scientific and technical advances/roadblocks

Interactions:
- Advises Steering Board with focus on RIA
- In close consultation with Flagship Coordination Office
- Interacts with the EC
- Interacts with all the Flagship's governance bodies, as needed

Flagship Coordination Office – Program coordination

Proposed composition: Key actors of QT community, selected via EU call for CSA

Main tasks:

- Coordinates QT community networking & outreach
- Supports international cooperation (IN-CO) and organises IN-CO events
- Enhances overall dissemination and outreach at the level of the flagship
- Organizes workshops, concertation events, education & training, etc.
- Coordinates IPR management, standardisation
- Gathers KPIs, project outcomes & results, and inputs from QT community for the SRA
- Supports Steering Board (secretariat, logistics,…)
- Organizes benchmarking

Interactions:

- Interface with EU, national, regional and transnational QT projects
- Provides input to Steering Board with focus on cross-cutting activities
- Constant communication and synergy with Science and Engineering Board
- Gathers data & analysis to Steering Board on portfolio and flagship progress
- Outreach to QT community at large / channels feedback from QT community

Proposed Key Performance Indicators for QT Flagship

Strategic goal	KPI
Foster collaboration	Number of co-written publications between academia and industry
	Number of new collaborations, stimulated through FS activities, leading to joint projects/publications/patents/funding
	Funding from MS leveraged, compared to funding from EC
	Number of academia/industry workshops + attendees thereof
	Size of the QT community: Number of entities in QT database, hosted by CSA
	Number and total months of secondments (from industry to academia and vice-versa)
Stimulate innovation	Funding from industry / venture capital raised, compared to public funding
	Number of patents filed
	Number of demonstrators (TRL 4) and prototypes (TRL 6) built
	Number of spin-offs founded + those surviving the first 5 years
	Average TRL advancement compared to time, number of personnel and funding
	Number of standards co-developed by Flagship
	Market share of European QT
	Number of jobs created by European QT industry
Ensure scientific excellence	Number of papers published and citations
	Number of invited talks at scientific conferences
	Project evaluation results
Train quantum aware workforce	Number of PhDs and master students graduated, funded by Flagship
	Number of trainings organized + academic and industrial attendees thereof
	Educational programs and material created
Outreach	Number of positive articles/mentioning in public media
	Website traffic + social media interactions
Gender diversity	Number of females in management / WP leaders / PhD students / …

Preferred by HLSC

FETFLAG-02-2017 call: Coordination and Support Action for Quantum Technologies

Specific Challenge: support the community in establishing the flagship initiative and its coordination with national activities in the field.

Expected Impact:

- A goal-driven, federated effort towards a challenging scientific and technological vision to generate European scientific leadership in Quantum Technologies, and a strong potential for longer term technological innovation and economic exploitation;
- Involvement and commitment from key stakeholders.
- Increased transnational collaboration on quantum technologies between the relevant European initiatives in the field;
- Spreading of excellence on quantum technologies across Europe;
- Increased awareness of European activities in Quantum Technologies.

Scope:

1. Establish a communication platform for all stakeholders;
2. Promote the objectives of the Flagship;
3. Facilitate connections between industry and academia;
4. Help shaping the Flagship Initiative during and beyond H2020;
5. Organize outreach events;
6. Facilitate dialogue between all stakeholders (policy, industry, academia);
7. Help the networking of respective national and international activities in the field.