IQ ST | Integrated Quantum Science and Technology

uulm | Universität Stuttgart

Preparing the Quantum Technologies Flagship

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the strengths **of** Quantum Europe

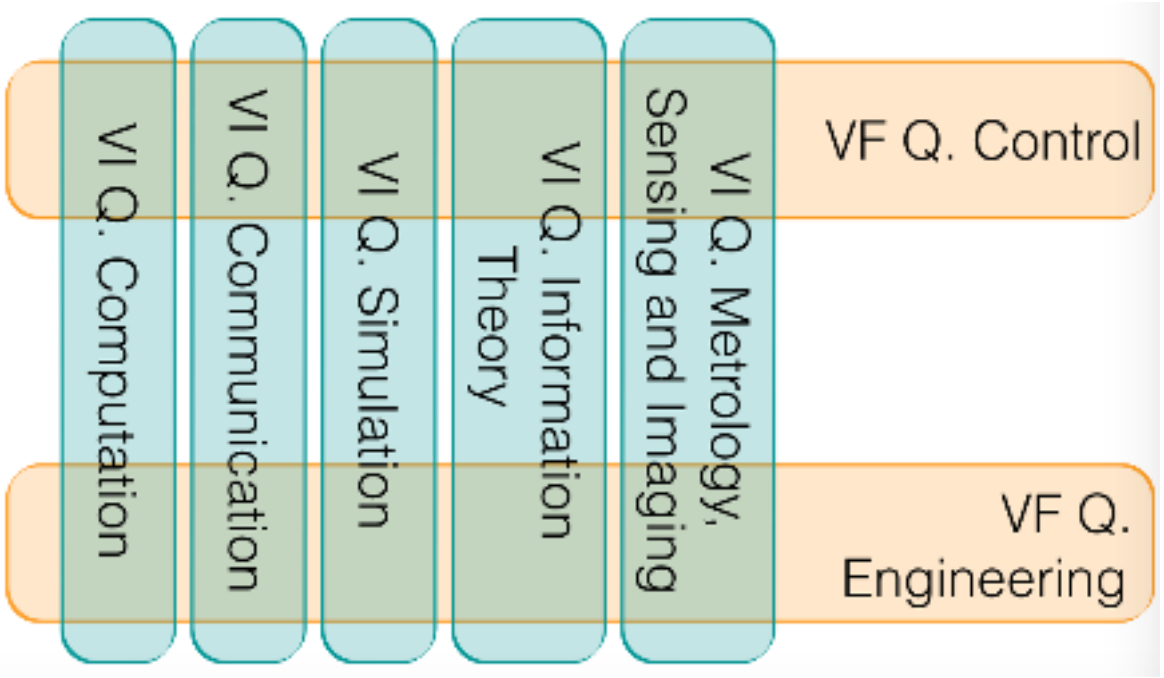
- Scientific Roadmap, Virtual Institutes, Strategy Board
- Member States involvement (national programs, QuantERA)
- Industry interest and investment; standardisation (ETSI)
- EC established Unit on QT and High-performance computing

The EU needs strong leadership now in order to stay at the forefront of the second quantum revolution, build on its scientific excellence and create a booming and competitive industry for future independence and prosperity.

- *Reinforce scientific leadership*
- *Establish leading engineering capability attractive to industry and investments*
- *Create a favourable innovation ecosystem*
- *Train a new generation of QT professionals and engage in dialogue with citizens*

quantum technology

Virtual Institutes and Facilities



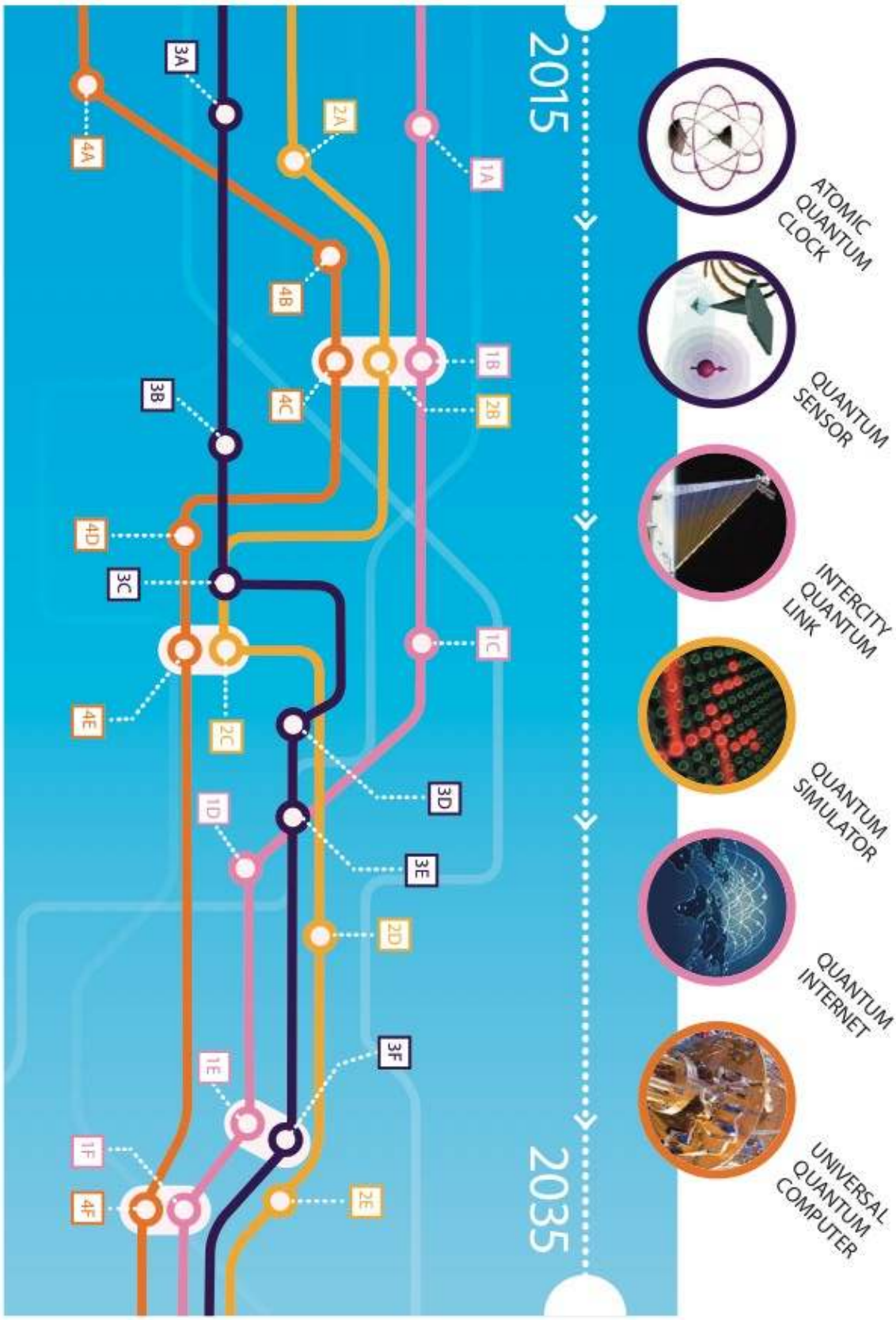
http://qurope.eu/vs

Directors: D. Esteve, N. Gisin, I. Bloch, I. Cirac, I. Walmsley, S. Glaser, C. Marcus

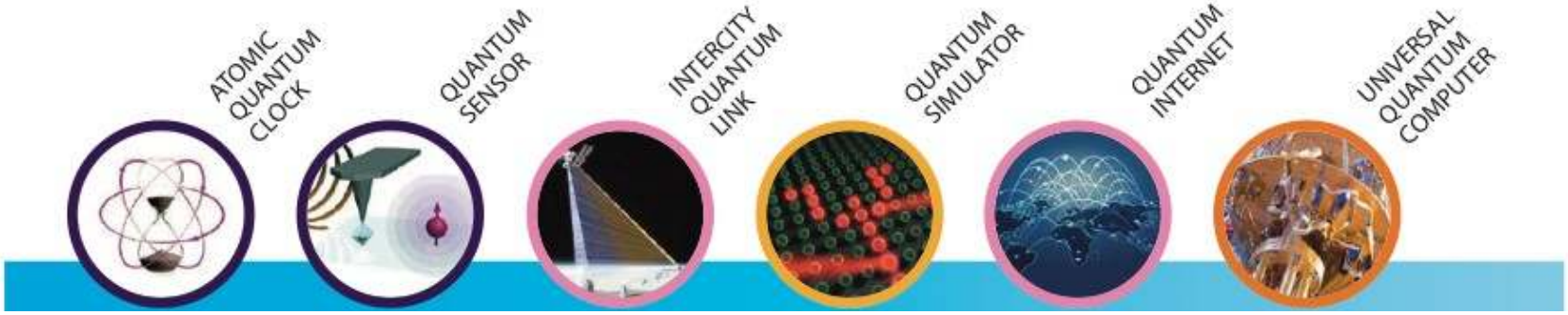
quantum industry in Europe

Quantum Manifesto, May 2016

Quantum Manifesto



Quantum Manifesto



	1. Communication	2. Simulators	3. Sensors	4. Computers
0 – 5 years	A Core technology of quantum repeaters B Secure point-to-point quantum links	A Simulator of motion of electrons in materials B New algorithms for quantum simulators and networks	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	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	C Quantum networks between distant cities D Quantum credit cards	C Development and design of new complex materials D Versatile simulator of quantum magnetism and electricity	C Quantum sensors for larger volume applications including automotive, construction D Handheld quantum navigation devices	D Solving chemistry and materials science problems with special purpose quantum computer > 100 physical qubit
> 10 years	E Quantum repeaters with cryptography and eavesdropping detection F Secure Europe-wide internet merging quantum and classical communication	E Simulators of quantum dynamics and chemical reaction mechanisms to support drug design	E Gravity imaging devices based on gravity sensors F Integrate quantum sensors with consumer applications including mobile devices	E Integration of quantum circuit and cryogenic classical control hardware F General purpose quantum computers exceed computational power of classical computers


Communication

Promises & challenges

- Promises
  - Protection against cyber attack
  - Trusted communication beyond complexity-based crypto
- Challenge
  - Acceptance by professional crypto community
  - Develop quantum repeater networks
  - Bring device independent quantum information processing closer to applications.

Interplay with industries

- Establish demonstration pilots
- Engage users to highlight benefits
- Standards and certification

European role

- Foster collaboration between modern and quantum cryptographers
- Build a European quantum backbone
- Maintain European leadership in quantum networks.

Simulation

Promises & challenges

- Promises
- Solve hard optimization and design problems
- Predict and optimize material properties
- Super conductors, protein folding, machine learning
- Challenges
- Classify which problems can be solved with quantum speedup.
- Technical related to device and infrastructure around the quantum simulator.

Interplay with industries

- Joint vision which problems to tackle
- Joint development with feed-back cycles for a technology infrastructure to support the field.

European role

- fund and encourage a broad range of research where we all learn from each other
- get quantum simulators in more hands as this could create critical mass and make it attractive for small businesses to build better devices for simulators.

Sensing/Metrology

Promises & challenges

- Improved precision and sensitivity (e.g. beyond SQL)
- New concepts for sensors and metrology (e.g. utilize the large information capacity of quantum systems)
- Applications in other fields of science, e.g. medicine, biology
- New applications "outside the classical box" (e.g. new solutions, new customers)

- Mitigating noise and decoherence (e.g. using error correction)
- Managing system imperfections (e.g. use feasible improvement; complexity/size vs. benefits/performance)

Interplay with industries

(and government)

- Collaboration necessary (e.g. synergy between basic science and technology: miniaturization (clocks), improved materials (NV))
- Government as intermediary (e.g. National Labs)
- Competition necessary (e.g. fair ecosystem, IP etc)

European role

- Funding innovation (e.g. intermediate TRL)
- Skills development
- Timeliness of Flagship (e.g. science ripe for exploitation; industry interest growing)
- Testing systems (e.g. clock networks for time standards)
- Support during 5-year period from idea to prototype

Computation

Promises & challenges

- Promises
  - Demonstrating quantum computer supremacy with 50…100 qubits in different implement.
  - New applications: quantum chemistry (catalysts), materials design, optimization, entering cognitive era
- Challenges
  - Need to educate people
  - Need collaboration of different disciplines
  - Scalability: qubit #, quantum error correction, control / read-out electronics
  - Interface flying & stationary qubits
  - Industry-quality & -scale fabrication

Interplay with industries

- Several institutes are collaborating with industry
- Concerted multidisciplinary effort needed
- Forming quantum engineers
- Perform know-how exchange

European role

- Develop framework for lean and goal-oriented collaboration between academics and industry
- Invest, believe, partner, develop value chain, as a team

Software/Algorithms

Promises & challenges

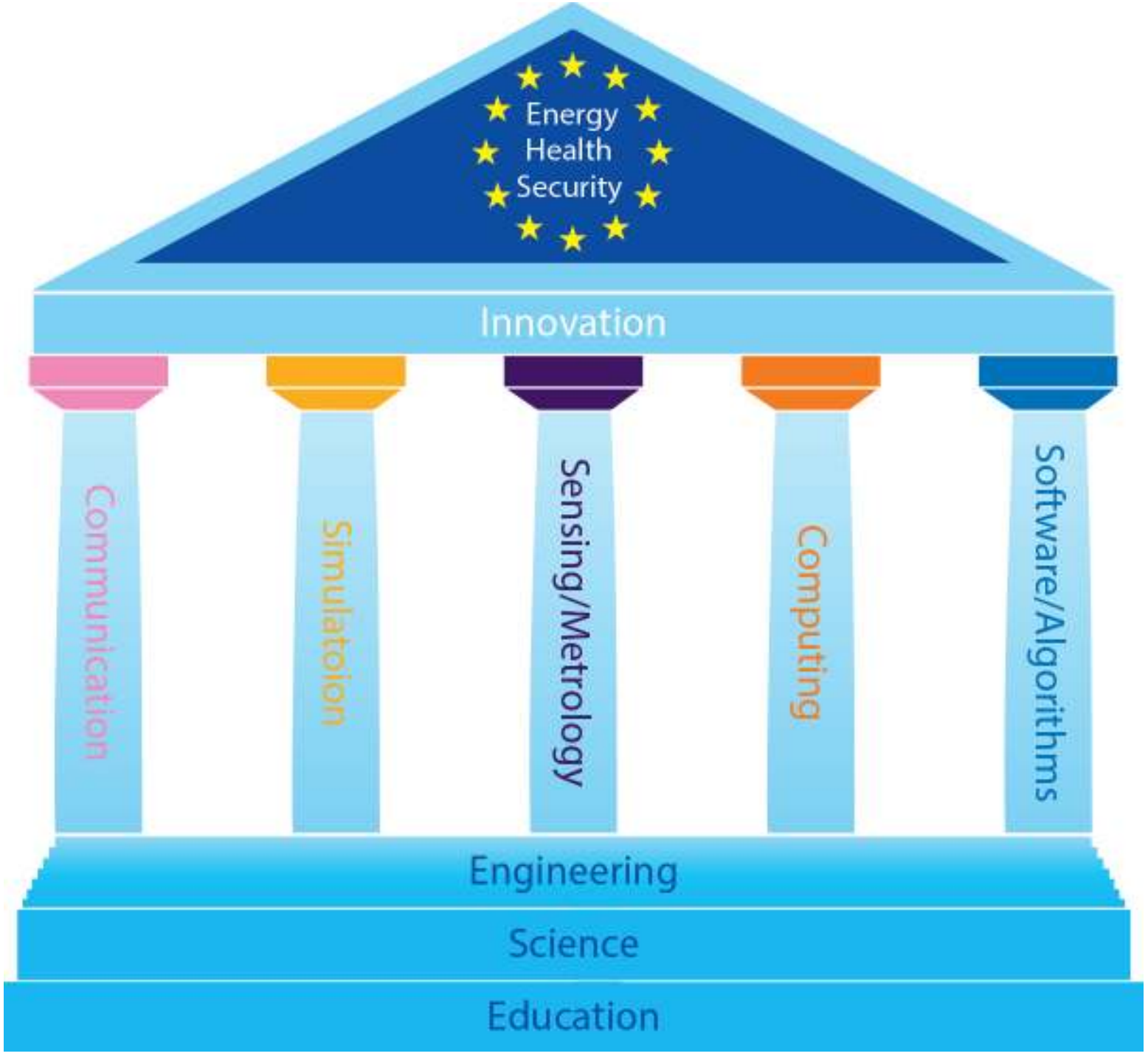
- Pr: Modelling material and chemistry compounds with few qubits.
- Pr: Helping to understand how nature optimizes.
- Pr: Applications beyond computing.
- Ch: Mapping algorithms to physical hardware.
- Ch: Develop a new way of thinking.
- ….

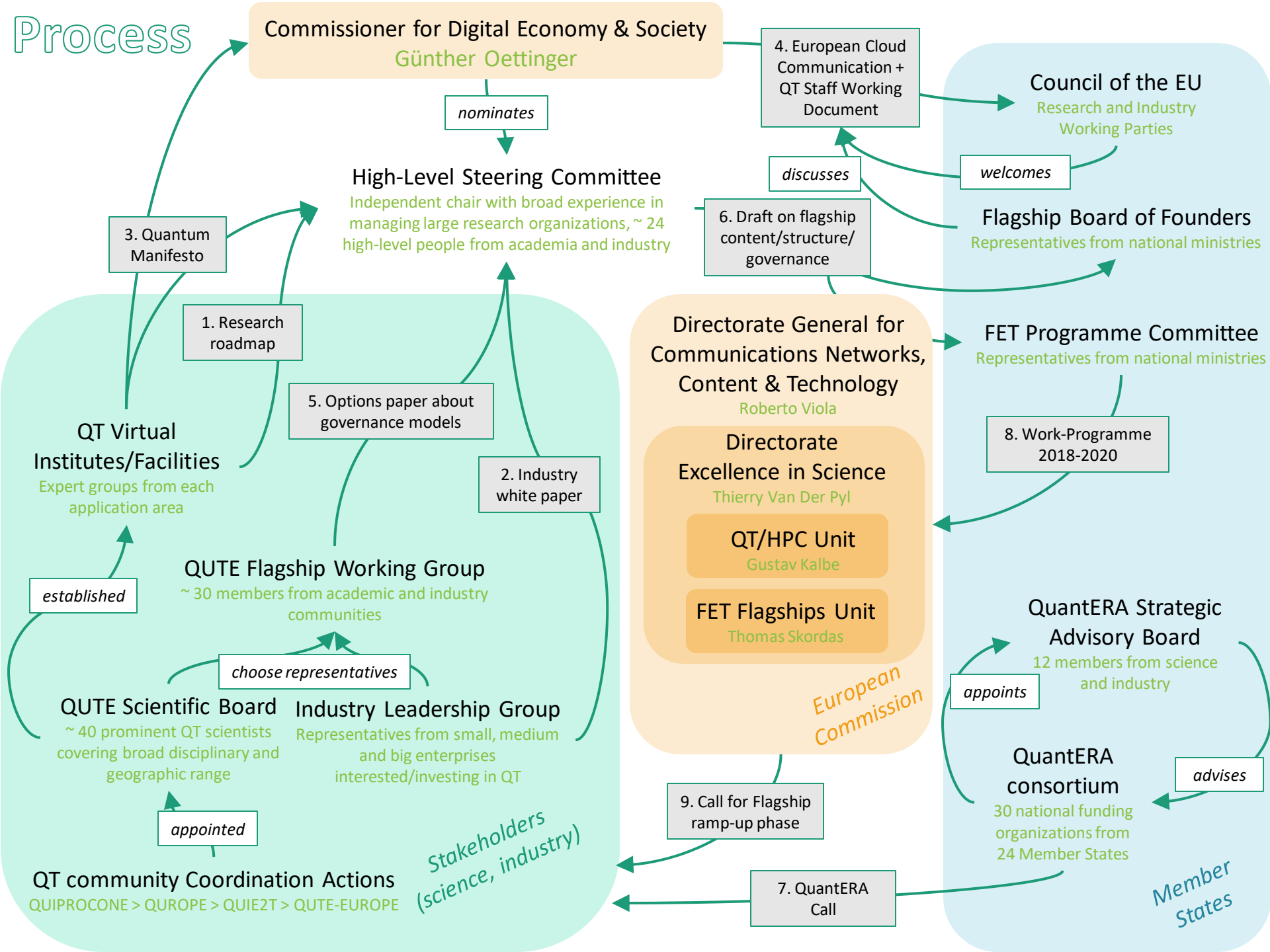
Interplay with industries

- Forums where academia and industry can learn the same language.
- Guidance on worthy problems.
- Inspiring classical solutions by "thinking quantum".
- Build system-blocks for people to play with.

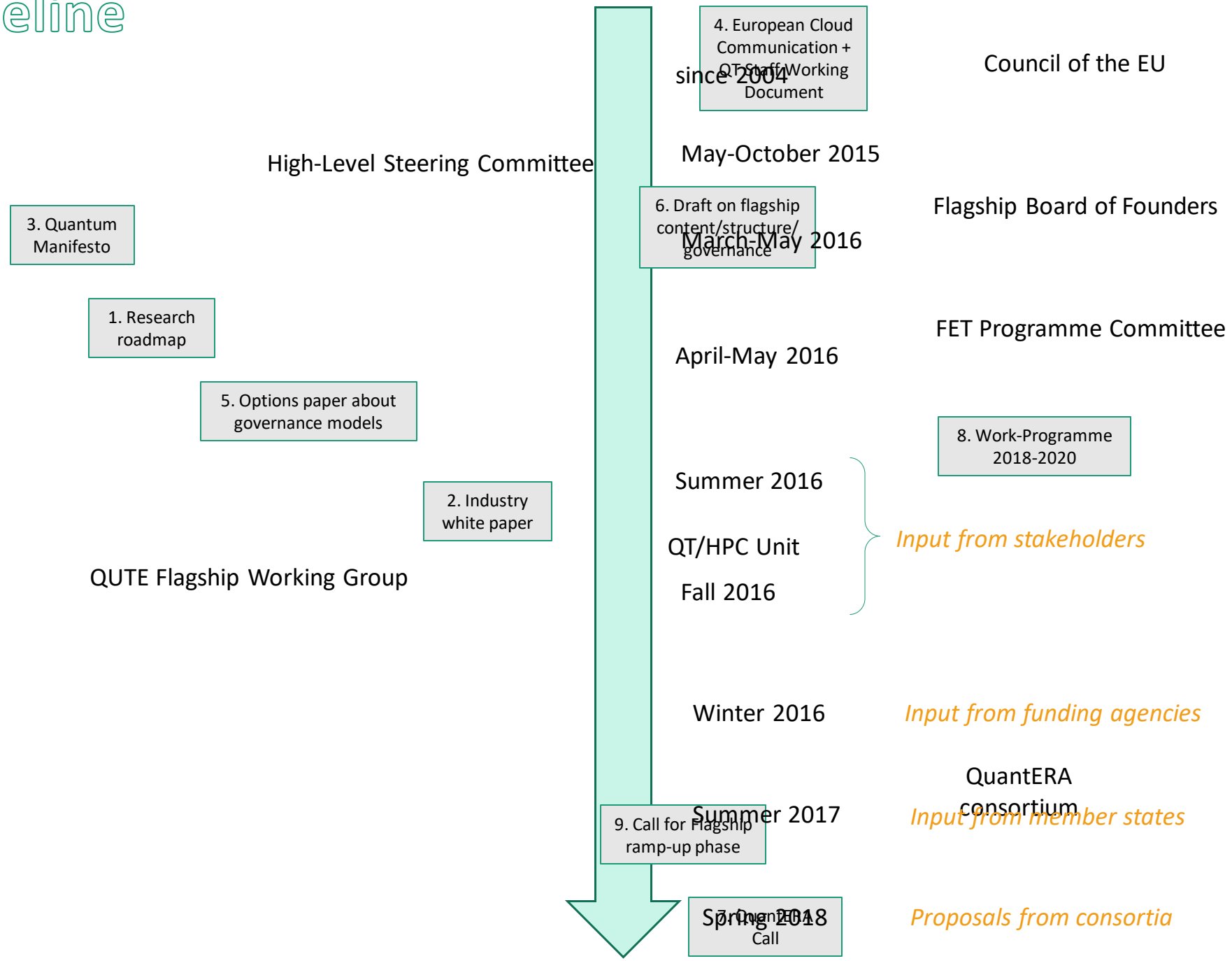
European role

- Science crosses borders. If you close the door there is more left outside than inside.
- Europe does not need to lead on hardware if it can lead on software.
- Funding is the start of collaboration.


Energy
Health
Security
Innovation
Communication
Simulation
Sensing/Metrology
Computing
Software/Algorithms
Engineering
Science
Education


Process
Commissioner for Digital Economy & Society
Günther Oettinger
nominates
High-Level Steering Committee
Independent chair with broad experience in managing large research organizations, ~ 24 high-level people from academia and industry
4. European Cloud Communication + QT Staff Working Document
Council of the EU
Research and Industry Working Parties
welcomes
discusses
Flagship Board of Founders
Representatives from national ministries
6. Draft on flagship content/structure/ governance
3. Quantum Manifesto
1. Research roadmap
5. Options paper about governance models
2. Industry white paper
QT Virtual Institutes/Facilities
Expert groups from each application area
Directorate General for Communications Networks, Content & Technology
Roberto Viola
Directorate Excellence in Science
Thierry Van Der Pyl
QT/HPC Unit
Gustav Kalbe
FET Flagships Unit
Thomas Skordas
European Commission
FET Programme Committee
Representatives from national ministries
8. Work-Programme 2018-2020
established
QUTE Flagship Working Group
~ 30 members from academic and industry communities
choose representatives
QUTE Scientific Board
~ 40 prominent QT scientists covering broad disciplinary and geographic range
Industry Leadership Group
Representatives from small, medium and big enterprises interested/investing in QT
appointed
QT community Coordination Actions
QUIPROCONE > QUROPE > QUIE2T > QUTE-EUROPE
Stakeholders (science, industry)
QuantERA Strategic Advisory Board
12 members from science and industry
appoints
QuantERA consortium
30 national funding organizations from 24 Member States
advises
Member States
9. Call for Flagship ramp-up phase
7. QuantERA Call

Timeline


since 2004
4. European Cloud Communication + QT Staff Working Document
Council of the EU
High-Level Steering Committee
May-October 2015
6. Draft on flagship content/structure/ governance
Flagship Board of Founders
March-May 2016
3. Quantum Manifesto
1. Research roadmap
FET Programme Committee
April-May 2016
5. Options paper about governance models
8. Work-Programme 2018-2020
Summer 2016
2. Industry white paper
QT/HPC Unit
Input from stakeholders
QUTE Flagship Working Group
Fall 2016
Winter 2016
Input from funding agencies
QuantERA consortium
Summer 2017
9. Call for Flagship ramp-up phase
Input from member states
Spring 2018
Proposals from consortia

High-Level Steering Committee

- 12 academic + 12 industrial members
- Advise EC on **Strategic Research Agenda**, **Implementation**, **Governance**
- No mere research: *industry participation* from the beginning
- Transparent, inclusive and broad method with respect to *input* generated *from the Quantum Technology Community*
- Consolidate *contributions from academia, industry and MS*
- First indications with main orientations: end 2016
- Final Report on all aspects of the Flagship: summer 2017

Defining the Research Agenda

- First priority: **Research Topics**, **Milestones**, **Timeline**
- Place Europe at the forefront of second quantum revolution
- Attractive to Stakeholders (Entrepreneurs / SME / Business)
- Areas: ***Communication***, ***Simulation***, ***Sensing/Metrology***, ***Computing***, ***Software/Algorithms***
- Common denominator and *clear EU added value* needed
- Good approximation of scientific basis for Research Agenda compiled in **Quantum Manifesto** and **QT Roadmap** (QUTE-EUROPE Coordination Action)
- Need for industrial perspective (how to create added value?)
- Address technology readiness levels

Governance Structure and Implementation Models

- Governance Structure **depends on clear Research Agenda**
- Goal: *simple* and *efficient* organisation
- Structure: *Projects*; *Scientific advisory board*; separation of science, day-to-day management, and strategic decision-making
- *Distinction* between Funding Agencies and Flagship Initiative
- Take into account experiences of *existing Flagship Initiatives*
- Possible sub-division into *Pillars/Hubs* according to Research Agenda, while maintaining *flexible pan-European organization*
- Listening to *input from industry/business* essential

Next steps

- ✓Next HLSC meeting: 10 November 2016 in Berlin.
- ✓***Participatory***, ***non-discriminatory consultation*** with the community, including business and industry
- ✓Opportunity to give input into the HLSC discussions for the ***broadest possible range of stakeholders***
- ✓*Community-wide workshop* with HLSC participation
- ✓Discussion sessions on
  - Governance and Structure
  - Industry
  - Scientific Roadmap (*Communication; Simulation; Sensing and Metrology; Computing; Software*)
  - Cross-cutting challenges (*Quantum engineering and control; Enabling Science; Theory, algorithms and protocols*)