Infrastructure for Quantum computing

- HPC capacity
- HPC-QC facilities
- Materials
- Nanofabrication facilities
  Experimental, pilots, (pre)-commercial
  what material platforms
- Control electronics
- Compilers?

Infrastructure for Quantum Communication

- Materials

- Nanofabrication
  Experimental, pilots, (pre)-commercial

- Networks
  metropolitan and back-bone networks,
  Fieldlabs / industrial environments
  QKD or entanglement-based?

- Satellites & HUP's

- standards

Infrastructure for Quantum simulations

- HPC access
- Q.C. access
- Compilers, software languages

Infrastructure for Metrology & other

- Quantum innovation centers
  facilities & knowhow-support
  for SME & start-ups
  bringing together value chains (also for training industrial residents)
  for spin-out to other markets

- Quantum in Space
  Atomic clocks at ISS
  GEO, LEO, cube-sats
  Space-grade support components

- Time & Frequency Transfer (TFT)

Infrastructure – notes from break-out session (1)

- Nanofabrication facilities:
  more than bare wafers; both academic & RTO level; role of foundries to be clarified; budget for people & maintenance – beyond few years.

- Standardization: metrology institutes / European effort / Euramet / EU-wide acceptance

- Innovations centers: great for start-ups, education,…

- Communication networks: opportunities unequal across EU; network between all capitals; national-versus-EU responsibilities

Infrastructure – notes from break-out session (2)

- Photonics platforms good example; low loss waveguides; III-V materials; communication platform on available services
- Communication & Time-Frequency-Transfer communities need similar infrastructures (more general remark)
- Dedicated workshops on topic roadmaps
- Great overview of needs; we need a process to come to timing/priorities

Outcome from innovation break-out session

- How to exploit and preserve ideas of the proposals non selected in the ramp-up phase (make them available on the QSA website ?)
- Define semantics (research , innovation, dissemination)
- Give access to clean-room for external users
- Focus on a few promising applications leading to products
- Help spin-offs from academia to develop low hanging fruits
- Involve customers in the definition of industrial needs
- Can we define the selection process (avoid a EC only decision). To which extent can we inluence on the EC decision.
- Identify incubators, venture capital (e.g. pharmaceutical industry)
- Academic people should develop their ideas themselves (start-up), make it more attractive

Training & Outreach: QSA work statement

WHAT WE HAVE PROMISED TO THE COMMISSION

1. Outreach material, speaker and events
   1. Expert and speaker database
   2. Industry outreach exploration

2. Web portal set up (Ulm)

3. Press outreach including electronic media (VDI)

4. Reaching out to the workforce of tomorrow (aka Education)
   1. Collection of curriculae, materials, and best practices

This will happen over the next months

Please participate for a good start

Big event:
Vienna kickoff

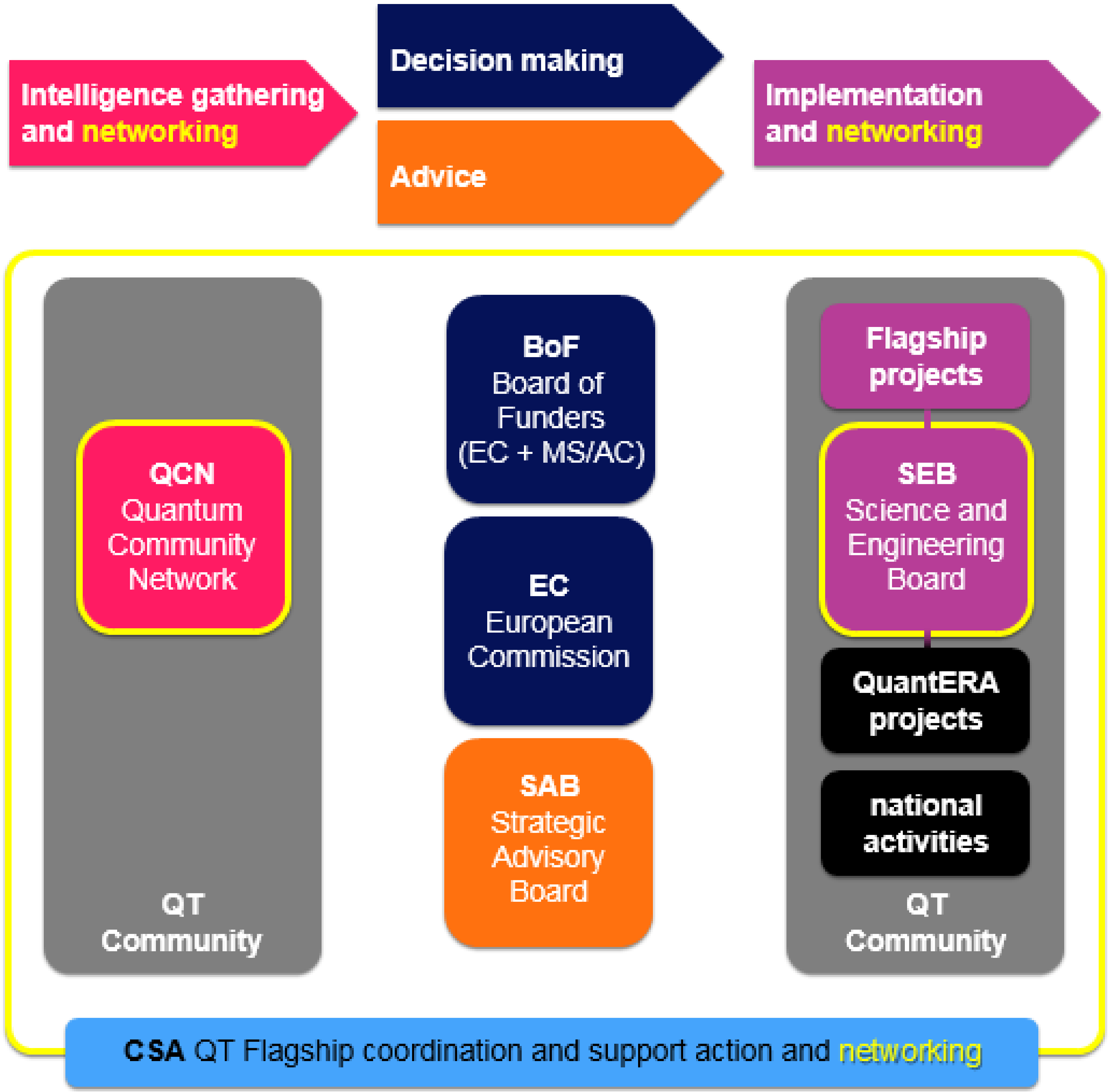
STARTING THE FLAGHSHIP PROPER

- Announcement of the first round of research projects
- Official start of the flagship
- Opportunities to network and coordinate
- Mark your calendars: **October 29/30** in Vienna
- Opportunity to reach out to industry

Starting together

Join us to celebreate quantum science and tell the world

QT Flagship Governance Structure



Board of Funders (BoF)
- Alignment of initiatives

European Commission (EC)
- Programme sponsor; project selection, funding decision

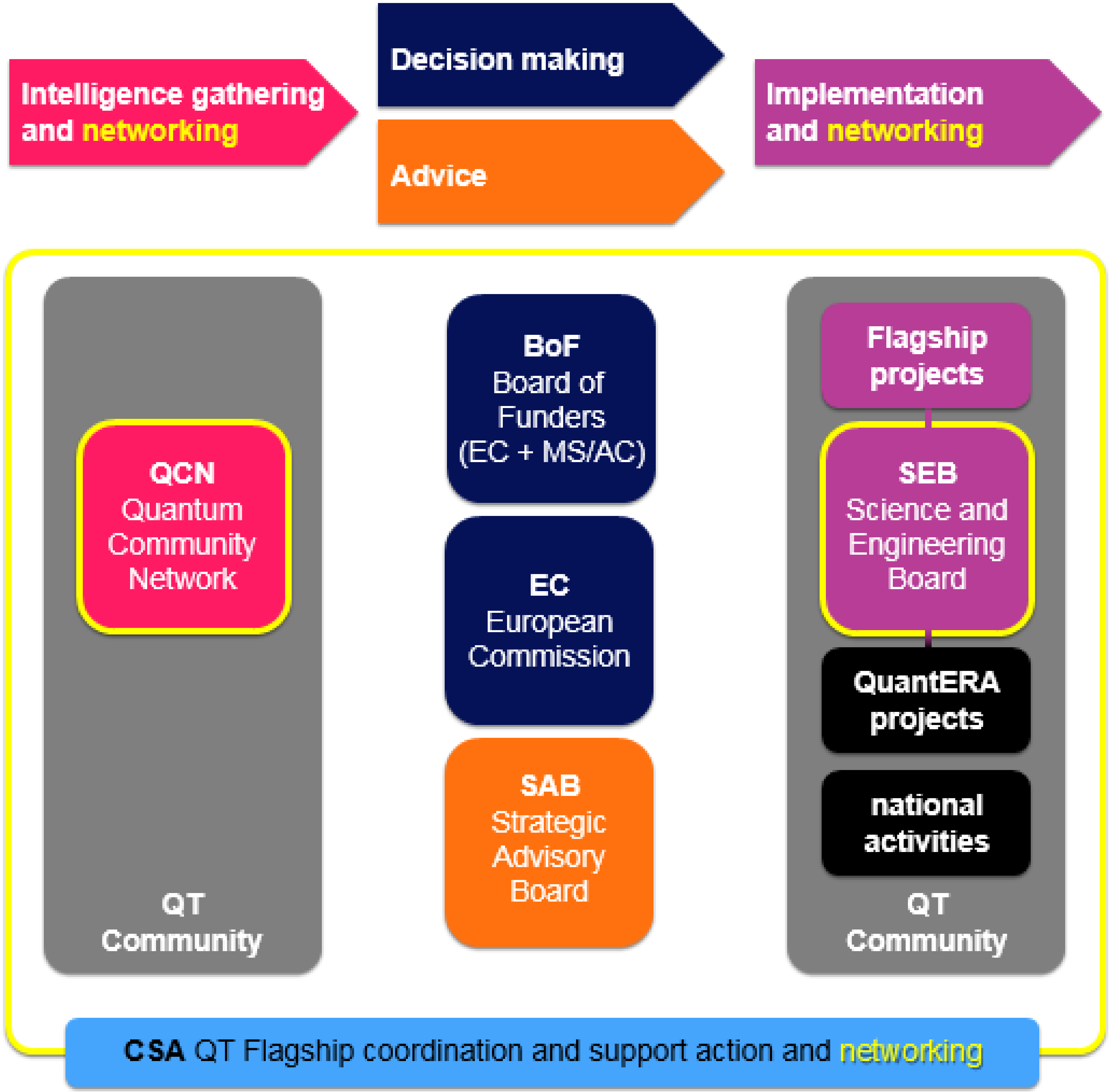
Strategic Advisory Board (SAB)
- Monitor progress of FS
- Propose Strategic Research Agenda (SRA)

Science and Engineering Board (SEB)
- Coordinate FS R&I activities
- Identify collaboration opportunities, joint developments, sharing of infrastructures among projects

Coordination and Support Actions (CSA)
- Enable networking of stakeholders
- Liaise with QT initiatives at national/regional level
- Manage communication platform and information repositories
- Organize workshops, conferences
- Organize benchmarking of QT projects
- Promote, disseminate, maximize outreach
- Identify education and training offers/needs

Quantum Community Network (QCN)
- Identify, engage, involve relevant national stakeholders
- Help coordinate the interaction and program harmonization between the FS and national initiatives

QT Flagship Governance Structure



Major results from break-out session

QT Flagship deviates considerably from former flagships

- no core project but open competition via calls
- community-backed SRA as input for FS calls
- EC QT unit launches calls based on QT FS SRA
- EC QT unit organizes evaluations

QT FS Governance Structure proposal

- is intended for ramp-up phase (in H2020)
- will be further developed for FP9

QT Flagship is open to whole QT Community

- Everybody is invited to community meetings
- Industry and other diciplines are involved

CSA provides services to all boards and actors of the FS

SAB members must not be project investigators (conflict of interest) but must be senior experts in QT

Quantum Science in Space

Photons	
Scientific goal	Long distance entanglement. Tests of spacetime models
Why in Space	Large gravitational differences, velocities
What is needed	1. Develop/launch quantum hardware 2. Three small satellites in LEO Q-system 3. Spacecraft for space Q-correlation
3-year Horizon	1. Model optical communication payload 2. Build and fly the small-satellite system 3. Conceive the measurement protocols
10-year Horizon	1. Implementing a satellite mission 2. Implementing a satellite mission 3. Develop and test the mission
How much	1. 15M€ (3yr) and 20M€ (10yr) 2. 20M€ (3yr) and 80M€ (10yr) 3. 5M€ (3yr) and 100M€ (10yr)

Atom Clocks	
Scientific goal	Tests of GR, Lorentz invariance, dark matter
Why in Space	Large gravitational differences, velocities
What is needed	1. Optical clock on ISS 2. Network of minisats with frequency links
3-year Horizon	1. Engineering model of space optical clock 2. Feasibility of frequency links on minisats
10-year Horizon	1. Space mission 2. Working network of minisats
How much	1. 20M€ (3yr) and 100M€ (10yr) 2. 6M€ (3yr) and 20M€ (10yr)

Cold Atoms	
Scientific goal	Tests of GR and of the QM/GR interplay. Dark matter. Gravitational waves.
Why in Space	Long interrogation times
What is needed	1. Further technological demonstration 2. Compact accelerometer for space
3-year Horizon	1. Breadboard of space atom-interferom 2. Ultra-compact interferometer
10-year Horizon	1. "Technology demonstration" in space 2. Breadboard of the compact sensor
How much	1. 40M€ (3yr) and 90M€ (10yr) 2. 6M€ (3yr) and 20M€ (10yr)

Optomechanics and Matter-wave interferometry	
Scientific goal	Tests of large mass quantum coherence. Interplay QM/gravity
Why in Space	Long free time evolution (+100s)
What is needed	1. Targeted science case 2. Technology development
3-year Horizon	1. Theoretical modeling 2. Feasibility studies
10-year Horizon	1. Refined models 2. Drop tower-like experiments
How much	1. 2M€ (3yr) and 10M€ (10yr) 2. 10M€ (3yr) and 100M€ (10yr)

Total: 124M€ (3yr) and 526M€ (10yr)

Quantum Technology for Space

Optical Quantum Communication	
Which tech	Photon technology for quantum communication
Societal benefits	**Secure communication** (SC)
What is needed	1. Payloads to test LEO SC at high rate 2. Creation of secure network on ground 3. Implementation of GEO platforms 4. Implementation of GNSS platforms
3-year Horizon	1. Engineering & flight models 2. Telescope network on ground 3. Model of a payload for GEO SC 4. Model of a payload for GNSS SC
10-year Horizon	1. Operation in Space of the SC payloads 2. Operation using Space-ground network 3. Flight model of a payload for GEO SC 4. Flight model of a payload for GNSS SC
How much	1. 50+*40*M€ (3yr) and 260+*370*M€ (10yr) 2. 10+*20*M€ (3yr) and 40+*100*M€ (10yr) 3. 5+*10*M€ (3yr) and 50+*60*M€ (10yr) 4. 5M€ (3yr) and 80M€ (10yr)

Atom Clocks for frequency measurements	
Which tech, which app	High-precision clocks for clock-based gravimetry and time/frequency distribution
Societal benefits	**Understanding climate** **Precise navigation**
What is needed	1. Network of minisats with frequency links 2. Atomic clock on IIS
3-year Horizon	1. Demonstr. frequency links on minisats 2. Engineering model of space atom clock
10-year Horizon	1. Working network of minisats 2. High performance atomic clock in space
How much	1. 6M€ (3yr) and 20M€ (10yr) 2. 20M€ (3yr) and 100M€ (10yr)

Cold Atoms as sensors	
Which tech	High-precision sensors
Societal benefits	**Earth & Planetary Observation** Geodesy measurements Ocean circulation modeling Navigation
What is needed	1. Further technological demonstration 2. Compact accelerometer for space
3-year Horizon	1. Breadboard of space atom-interferom 2. Ultra-compact interferometer
10-year Horizon	1. "Technology demonstration" in space 2. Breadboard of the compact sensor
How much	1. 20M€ (3yr) and 75M€ (10yr) 2. 3M€ (3yr) and 10M€ (10yr)

Total: 119+*80*M€ (3yr) and 635+*530*M€ (10yr)

Italics = national and private investment

QTSPACE
QUANTUM TECHNOLOGIES IN SPACE

www.qtspace.eu

International Cooperation

- **Discussion Panel with EU – Japan – USA representatives**
- **„Do we share similar vision?”**

  USA– QT at preliminary state/pre-competitive fundamental science

  Japan – mixture of both

  EU – narrow to technology
- **Strategic programmes,** large investments at the national level (Q-LEAP Japan, Flagship in Europe, national programmes in the US)
- **Benefits:**
  Scientific cooperation itself
  Complementarity (avoid unnecessary duplication)
- **Findings:**
  International cooperation is well established at the academic level and could be enhanced
- **Challenges:**
  EC – the gap between fundamental research and technology is narrow, strategy on IP needed
  USA – we see the gap quite large
  EC - Excellent expertise in Europe - more funding required to create a „critical mass”/concentrate on large infrastructure
  USA – bottom-up approach, areas of cooperation should come from the research groups, whereas EU is more policy driven.
- **Next steps:** Effective communication (clear expectations discussed during joint workshops) and looking for a win-win scenario, if possible?