Category	Name	Comment
Communication	Sigg	"Hardware" of QC such as networks and sources would fit into a facility program.
Communication	Joachim	One aspect of quantum communication is supertunneling i.e. the quest of extreme low decay long range tunneling effect very usefull for quantum communition between quantum chips.
Communication	Prati	The Quantum Communication sections open by stating that it consists of the transfer of quantum states. This statement is contradicted by the QRND content. indeed, the QRND consists of a local stream of binary digits. One should either change the definition of what does Quantum Communication include, or move the QRND to a different section. Notice that QRND are not cited in the short term goals.
Communication	Remacle	"Harvesting the potential of molecular quantum states and molecular quantum dynamics using short laser optical pulses can also open new avenues for Quantum Communication, in particular for the goal stated at the beginning of this section 'Quantum Communication is the art of transferring quantum states from one place to another'. We already demonstrated experimentally and analyzed theoretically exploiting controlled intramolecular quantum dynamics for quantum communication inside the different subunits of a modular single molecule. Intramolecular communication also present the advanatge to be very fast, on a fentosecond to picosecond time scale. One can also exploit selective intermolecular coupling using polarization properties. I suggest to add these directions of research on p8 in the 'grand research challenge section'. Exploiting controlled intramolecular quantum dynamics for quantum communication inside the different subunits of a modular single molecule using short optical pulses. Exploit selective intermolecular coupling using polarization properties."
Communication	Levine	different parts of the same molecule inherently can communicate with one another in so called intramolecular processses. Modular molecules , for example, proteins, are particularly good at this. Different molecules can communicate very fast and with very high fidelity with one another in so called intramolecular processes. We have demonstraeted experimentally how to employ both types of processes to concatenate logic units. Our papers on these have typically been published in higher impact journals.
Communication	Vitali	Optomechanical systems are the more promising candidates as quantum interfaces, especially for interfacing superconducting circuit-based quantum computers. This potentiality of optomechanical systems is much less stressed compared to the role of nano-optomechanical as quantum sensors.

Communication	Peev	"QRNG: The state of the art description includes RNGs that can be upgraded to meet stringent criteria and be considered True QRNGs. Others that counted in this category are just good physical RNGs employing some quantum effects but whose description cannot be reduced (presently) to prime principles. Long Term Secure Storage: This is a very fruitful concept that involves Quantum and post-Quantum (classical but ostensibly quantum safe) methods. This is very much OK from a pragmatic point of view but the authors appear to put fully the whole approach into the quantum technology domain. Clearer wording will be better. Standards and certification: These are indeed different things. One can address security certification (the development of approaches for a third party to verify the security of a System according to defined criteria) and functional standardization (allowing a QKD System to interoperate with other communication systems and simply fit in). These things are very needed but should not be be put under the same label (as in p.9 of p.8) Quantum Networks: The amount attention dedicated to trusted repeaters and prospective quantum repeaters is too high in proportion compared to switching networks (all possible types of) that can be widely used on the metro scale today. This approach requires, however, an upgrade of the majority of the present day, standalone Link-QKD-devices. By the way, from a purely abstract point of view, a QKD Network based on quantum repeaters is a switching network. QKD with high rates: This requirement goes through all the roadmap but the reason is never mentioned. Irrespectively of the key generation rate of QKD, it can never match the classical communication throughput and for this reason practical application of OTP on the full communication stream is impossible. Standard block ciphers are using little key even in the regime of very frequent key exchange (sub-second key renewal appears unreasonable). Subtle reasons for higher key generation rates might be discussed. But without such discussion the quest for higher and higher rates appears like a quest for records irrespective of any application perspective."
Communication	Martin	"* Page 6, point 8: This is rather unclear. e.g.: If somebody stores encrypted data using OTP (or even a decent AES) it will be safe from Q. computers. So, what is the exact meaning of this phrase? * Page 8, point 9: This mixes two very different ""standards"". Standards and certification is a rather complex issue, that deals mainly with protocols and security (and also physical construction), whereas putting a QKD system in a box of a standard size is (at least nowadays and thinking about ATCA blades) the simplest thing possible about physical construction. * Page 39: 2.1.6 Virtual Facilities. I can imagine a sophisticated facility offering the nano and micro fabrication, but, ""low losses"" connectors? Obviously I'm thinking in QKD networks, where low losses are key, but not crucial.

		We just use the best optical connectors available and that is it. Not even expensive. Maybe for other uses this is so crucial that they have to be built on purpose, but then this should be pointed out. * Page 42. End of the first paragraph. A mention is done to ""virtual and SW defined networks"". Virtual NW is a very standard thing in networking, that (although it can benefit from good crypto) is not a good case to highlight a possible ""quantum enhanced nw"". I think that this is intended to mean the new paradigm of ""Network Function Virtualisation"" that can be built on top of software defined networks. As it is, the wording is wrong. * Page 48. Goals. I think that a goal that is key to telecommunications infrastructure providers is a fully integrated QKD+classical communications network with fully compatible equipment in the sense that quantum and classical links could be seamlessly integrated and easily deployed in the same NW and be seen to the NW management as an additional resource. This is related to the Software Defined Networks and Network Function virtualisation, which are the paradigms that the NW operators are embracing right now. * Page 50: About one third into the first paragraph of ""Trusted Node Networks"". I think that the phrase ""This trust requirement could be overcome by using classical, or even post-quantum, encryption protocols on the nodes, thus realising a quantum-safe network."" does not make sense. What is its meaning? * Page 51 and 52: ""State of the art"". Not much emphasis is put in switching networks. This is an approach that is somehow middle ground between a trusted node NW and another composed by Quantum Repeater. Without a Quantum repeater this is the way to avoid the trust assumption implied in trusted node networks and, for sure, will be part of a future quantum network. They have been the subject of quite some research. I would like to point out to two of our works, in part because they were done together with Telefonica, the largest telco in Spain. The first reference is a network demonstrator that, to the best of our knowledge was the first fully switched network (2009) with the typical structure of backbone+access using conventional telecommunications equipment and demonstrating the coexistence of classical and quantum signals. We used CWDM equipment in the backbone and GPON technology (2.4 gbps) in the access NW. The archive reference is https://arxiv.org/abs/1006.1858 The second reference that I consider interesting is also the first addressable switched NW where any QKD emitter (Alice) in an access NW can address any other receiver (Bob) in another access NW (and crossing the backbone NW that links them). The demonstration used the same Telefonica testbed in Madrid and the reference is “Quantum metropolitan optical network based on wavelength division multiplexing,” Optics Express, vol. 22, no. 2, pp. 1576-1593, Jan. 2014 (arXiv:1309.3923). By the way, in several points in the manuscript it was mentioned that quantum networks were built in Vienna, Tokyo, Switzerland, South Africa, China... It would be worth, at least for its European provenance, that in 2009 there was also a Quantum

		NW in Madrid and that it was funded by a private Telecommunications company (Telefonica) The two references mentioned above (and some other concerning entanglement distribution) were done in that NW (a promotional video from Telefonica can be found at http://www.gcc.fi.upm.es/en/videos.html)"
Communication	Liscidini	"It has been pointed out that the use of integrated photonics could boost main applications in quantum communication, lowering the cost and reducing the size of the devices (e.g. for satellite communication). Yet, in Sec. 2.2.6 we find little about SFWM in Silicon devices and their challenges. While there have been a number of results in the use of integrated devices to generated entangled photon pairs, it could have been mentioned that their use for the generation of multipartite states is extremely immature and is worthy of investigation. The use of continuous variable or several degrees of freedom to encode more information in photons seems promising to increase the transmission bit rate. Yet, the document could have pointed out that this requires also strategies to characterize the sources of such complex photons states. This could have been mentioned in the section 2.2.6 C. Challenges. Similarly, Sec. B State-of-the art could have mentioned that recently there has been a number of works that aim at developing such efficient methods, from Reduced Density Matrix Tomography to Stimulated Emission Tomography (e.g. B. Fang, “Fast and highly-resolved capture of the joint spectral density of photon pairs,” Optica 1, 281 (2014)). In this regards, these techniques seem very promising thus mention this or other similar works here might be useful to help the community to identify possible approaches to solve this challenge."
Communication	Couteau	standardisation for single photon sources and detectors is missing in the document, Novel single photon sources: defects in 2D materials, defects in large band-gap semiconductors (such as ZnO or GaN), single plasmons, light-matter interaction at the nanoscale
Communication	Stefanov	"The document states ""Several groups are currently working on fibre QKD systems that encode in polarisation, phase, photon number and time-bins, ..."". It forget to mention however energy encoding as realized by [Matthieu Bloch, Steven W. McLaughlin, Jean-Marc Merolla, and Frédéric Patois, ""Frequency-coded quantum key distribution,"" Opt. Lett. 32, 301-303 (2007)] with weak coherent pulses or with entangled photons as for example in: - Frequency-bin entangled photons, L. Olislager, J. Cussey, A. T. Nguyen, P. Emplit, S. Massar, J.-M. Merolla, and K. Phan Huy, Phys. Rev. A 82, 013804; - Creating and manipulating entangled optical qubits in the frequency domain Laurent Olislager, Erik Woodhead, Kien Phan Huy, Jean-Marc Merolla, Philippe Emplit, and Serge Massar Phys. Rev. A 89, 052323

		- Shaping frequency-entangled qudits, Christof Bernhard, Bänz Bessire, Thomas Feurer, and André Stefanov Phys. Rev. A 88, 032322"
Communication	Paternostro (on behalf of COST "Quantum Technologies in Space")	"page 8: add the bullet point: ""Space-based capabilities for Europe-wide and intercontinental QKD"" page 43: add the bullet point: ""Matching current capabilities in putting quantum optics sources and satellites mounting QKD devices in space for Europe-wide and intercontinental quantum networking. The current world leader in this regard is China, which launched its first quantum satellite in 2016."" page 48, Section E: add the bullet point ""Launch a European satellite with quantum-optical and QKD capabilities.""""
Communication	Hakonen	-Single photon detection at microwave frequencies could be pursued with the use of novel materials (for example, 2d materials).
Communication	Macucci	"On Page 6 item 8 is not fully clear: what is meant by quantum-proof cryptography? Is it quantum cryptography, in which case it could not be a replacement for the current cryptography. Why is it referred to stored data? References on this would be useful. On Page 49, ""Secure access to the first quantum computer mainframes"" sounds a bit weird: quantum computers with shared access will most probably be used for research purposes, for which there is no particular need of secure access. Goverment agencies willing to use quantum computation to break encryption schemes will most likely have their own quantum computer."
Computation	Joachim	"Quantum control is not only to apply to quantum systems structured in qubits. Other quantum system with no qubit inside can also be controlled in a quantum way like in the Quantum Hamiltonian Calculator approach or like single molecule-motor which can be driven quantum mechanically"
Computation	Campbell	Broadly, I was happy with this section on my area of expertise. For quantum computers to actually work they must be fault-tolerantly built using logically encoded qubits. I was glad that the relevant experimental and theory goals in this regard were explicitly mentioned. The quantum computing introduction on page 5&6 was brief compared to overviews of other Virtual Facilities. As such, the bullet points could have been more detailed.
Computation	Bertels	the link with application domains and thus algorithms is not developed enough. we should strive for application specific devices rather than generic quantum computing technology which may be beyond the capabilities of the flagship, especially given the lack of focus and choices up front.

Computation	Kashcheyevs	High-precision control of dynamic semiconductor quantum dot [Rep. Prog. Phys. (2015), doi:10.1088/0034-4885/78/10/103901] offers a potential "flying qubit" solution to the electronic semiconductor qubits (Section 2.1.4) [e.g, Nature Nano. (2015), doi:10.1038/NNANO.2014.275] and addresses many of the same engineering challenges [e.g, Phys. Rev. App. (2015), https://doi.org/10.1103/PhysRevApplied.4.044009]. Additional synergy is the near-term technological relevance for quantum metrology of small currents and high-fidelity charge read-out.
Computation	Luis	"The European scientific community working on the application of artificial magnetic molecules in future electronics has coordinated itself through the support of a COST action on Molecular Spintronics (MOLSPIN). A document describing the interest and potential of these materials for quantum technologies has been signed by more than fifty leading scientists. This ""Molecular Quantum Manifesto"" is available at the web of MOLSPIN. This document has provided a solid basis for the edition of the scientific roadmap. Changes that we propose here are aimed to update and improve the section that describes the state of the art in the research of molecular spin qubits and its future potential for quantum computation. These comments represent a consensus of contributions from all groups active in this field, which are associated to MOLSPIN work group on ""Molecular spins for quantum technologies. We strongly support the Flagship initiative and are firmly convinced that we can contribute to its success. 2.1.5 Impurity spins in solids and molecular spins A. Physical approach and perspectives Storage and processing of information can be carried out using individual atomic and molecular spins in condensed matter. Systems falling into this category include dopant atoms in semiconductors like phosphorous or deep donors in silicon or color centers in diamond, nitrogen or phosphorus atoms in molecules like C60, rare earth ions in dielectric crystals and unpaired electrons at radiation induced defects or free radicals in molecular crystals. The main attraction of spins in low-temperature solids is that they can store quantum information for up to several thousand seconds [1], on the other hand certain spin systems are shielded well enough from their environments such that room temperature operation seem feasible. Specific systems have been selected based on criteria like: dephasing time, optical access, single quantum state readout, and nanostructuring capabilities. Most of these systems are scalable in principle, technical progress in single quantum state readout, addressability and nanoengineering are in progress. Another solid basis for quantum information processing is provided by molecular spins and relies on artificial molecules engineered with features suitable for qubit encoding and entanglement. The composition and structure

of these molecules are well defined, with basically no dispersion in size and shape, and can be tailored with atomic precision using the virtually limitless possibilities of chemical synthesis. Current research activity focuses on the control of the coherent spin dynamics in molecular spin clusters, single metal ions and radicals, which implies understanding and minimizing decoherence through proper molecular design and processing methods. While experiments performed on bulk molecular ensembles still represent fundamental test beds, the manipulation of single molecular spins has been achieved thanks to advances in the controlled grafting of molecules on surfaces and the development of techniques for the coherent control and readout of single spins.

B. State-of-the-art

Impurity spins

Atomic and molecular spins in solids have received considerable attention as qubits. Already Kane's [1] proposal has underlined the basic challenges and opportunities of such systems in quantum computing. In the meantime, a number of related systems like dilute rare earth ions, colour centres, random deep donors in silicon with optically controlled spin and defects in wide and narrow band gap semiconductors have underlined their potential usefulness in QIP [2]. Most approaches use electron or nuclear spin degrees of freedom as quantum bits. The specific advantages of spin systems includes long coherence times [3] and access to highly advanced methods for precise manipulation of quantum states. The experimental techniques that have made liquid state NMR the most successful QIP technique in terms of precise manipulation of quantum states so far are currently being transferred to solid-state systems. These systems may be able to overcome the scalability problems that plague liquid state NMR while preserving many of the advantages of today's liquid state work. Large scale quantum simulator based on nuclear spin in diamond was proposed recently [4]. Robust control of solid state quantum registers allowed to realise repetitive error correction protocols [5].

Optically active defects (colour centres) also were used to realise high fidelity entanglement via optical channel and using magnetic dipolar coupling [6,7]. Dense ensembles of colour centres were shown to be promising candidates for building quantum memories for superconducting qubits [8].

In detail, the following landmark results that have been achieved:

- Magnetic resonance on single defects detected by charge transport and single spin state measurements by optical techniques;
- Multipartite entanglement of single defects based on magnetic dipolar coupling
- Quantum teleportation between distant colour centres based on optical channels;
- Quantum error correction;

		• Accurate preparation and readout of ensemble qubit states. Arbitrary singlequbit operations characterised by quantum state tomography with a fidelity >99,9%; • The preparation of Bell states with electron and nuclear spin ensembles as well as a three qubit Deutsch-Jozsa algorithm has been achieved. Molecular Spins Quantum dynamics of molecular spins has been deeply studied by a number of fundamental works in the last decade. Decoherence and dephasing mechanisms have been widely investigated in bulk molecular ensembles and even single molecules: low-temperature intrinsic coherence times exceeding ten microseconds have been reported [9,10], approaching ms in nuclear spin-free environments [11]; similarly, the switching rates for one-qubit and two-qubit gates are estimated to be on the order of nanoseconds. Recent important achievements are: • Synthesis of specific molecules that provide promising test-beds for scalable schemes and whose properties are chemically tunable by design [9-12]. • Observation of spin coherence and coherent Rabi oscillations on electronic spin ensembles at room temperature [10,11,13]. • Strategies to protect spin states from decoherence, based on a fine engineering of molecular states and levels, have been theoretically proposed and experimentally tested [14]. • Demonstration that the quantum spin dynamics can be largely preserved in molecules grafted to surfaces, provided that the molecular structure and interface are properly designed [15]. • Demostration that the nuclear spin of an individual metal atom embedded in a molecule can be read out electronically and coherently controlled via either magnetic or electric fields [16]. • Demonstration of spin entanglement between and within molecules [17] and first experimental tests of universal two-qubit logic gates [18]. • Proposals for the implementation of the Grover's algorithm in high spin molecules [19] and the use of molecular spins as quantum simulators [20]; experimental demonstration of Grover's algorithm on two spin qubits. • Ensembles of molecular spin qubits can be coherently coupled to a superconducting microwave cavity that acts as a 'quantum bus' [21]; the possibility of achieving the strong coupling regime with single molecules has also been put forward [22]. C. Challenges Impurity spins

		The strength of defect centre QIP in solids are the long coherence times of spins even under ambient conditions and the precise state control. Depending on the system, electrical as well as optical single spin readout has been shown (fidelity of more than 95 %). Substantial progress in the nano-positioning of single dopants with respect to control electrodes has been achieved. On the other hand, nanopositioning and creation yield of defects is still a major challenge (which has seen dramatic progress for phosphorus in silicon and colour centres in diamond). However there are schemes, based on deep donors in Si and optically active defects in diamond, where nano-positioning is not crucial. For defects in silicon, instead the randomness is exploited so as to make maximum use of spatial and spectral selection to isolate qubits and their interactions. For colour centres in diamond, long distant entanglement can be realised based on optical coupling. Molecular Spins The bottom-up approach used by (supra-)molecular chemistry offers simple and relatively cheap processes for the fabrication of nanosized magnetic molecules exhibiting multiple functionalities like switchability of magnetic states with light or electric fields, resonances at RF-MW radiation, etc. A key challenge is to exploit the control on and the sharp definition of eigenstates and eigenvalues in magnetic molecules for the development of new quantum algorithms and scalable schemes. D. Short-term goals (0-5 years) Impurity spins Impurity systems form a bridge for transferring quantum control techniques between atomic and solid state systems. Close interaction between the atomic physics and solid-state communities is a key ingredient for achieving this. • Defects in diamond heads towards generation of coupled defect centre arrays and incorporation into photonic structures. For this, advanced nanoimplantation techniques as well as production of photonic cavities need to be improved in order to achieve long coherence time of defects in nanoengineered material; • For rare earth crystals, short term goals include faster gate operations using pulses developed by optimal control theory, demonstration of two-qubit gates and the development of single ion readout capabilities for scaling up to several qubits; • For the scheme based on deep donors in Si or diamond, short term goals are demonstrations of all the key steps of fabrication, preparation, readout, and manipulation. Molecular Spins. The main short-term goals can be summarised as follows:

		• Engineer new molecular structures for the optimisation of the coherent spin dynamics and for the implementation of elementary quantum gates, simple algorithms and simulations; • Set-up reproducible and high-yield procedures for the preparation of single/(arrays of) molecular spin qubits and their integration into solid-state devices with positional and orientational control. • Develop robust and high-fidelity techniques (based on electronic junctions, scanning tips or superconducting resonators,…) to read-out and coherently control spins in individual molecular and supramolecular structures. • Develop new computational schemes exploiting the rich and tuneable level schemes of molecular clusters and study of different molecular functionalities (f.i. light-induced switching, spin control by electric fields, …) useful for specific tasks in complex architectures of QIP. • Exploit molecular features for possible applications in quantum sensing. E. Medium-term goals (5-10 years) Impurity spins • The medium term perspectives for phosphorus in silicon are the demonstration of single spin readout and two qubit operations. Major efforts are concentrated in the US and Australia; • Few-qubit device could be built on the basis of N@C60 by integrating nanopositioning of molecules with single-spin readout devices and control electronics; Molecular Spins • Development of suitable molecular devices and protocols for the implementation of quantum error correction codes. • Read-out and coherently control small (up to 10 qubits) molecular registers. F. Long-term goals (>10 years) Impurity spins • Coupling of defects in wide band gap semiconductors to an optical cavity mode allowing to reach high cooperativity. Implantation of defects with nm accuracy in registry with control electrodes. Optical addressing of single defects within dense defect arrays using optical super-resolution techniques and magnetic field gradients; • For rare earth ions, efforts should be joined with crystal growth research (inorganic chemistry) to create appropriate materials for larger scale systems. Techniques should also be developed for entangling remote systems to achieve full scalability;

		• Few-qubit (up to perhaps 20 qubit) devices based on deep donors in silicon or silicon- compatible systems seem possible. Such devices should be linked into larger groups by flying qubits based largely on technology known from other fields. Achieving higher temperature is also of importance here; • Large scale (>100 qubits) quantum simulators based on implanted colour centres and optically initialised self-assembled nuclear spins in crystal lattice Molecular Spins • Development of scalable and noise-resilient devices able to read-out, control and communicate >20 molecular spin qubits • Realization of quantum simulators based on supramolecular structures able to solve problems relevant for quantum physics and quantum chemistry, and to simulate quantum processes in biology. G. Key references [1] B. Kane, "A silicon-based nuclear spin quantum computer", Nature 393, 133 (1998) [2] R. Hanson, D. Awschalom. ""Coherent manipulation of single spins in semiconductors"" Nature 453, 1043 (2008), P. Neumann et al. ""Multipartite entanglement of single spins in diamond"", Science 320, 1326 (2008) [3] E. Yablonowitch, H.W. Jiang, H. Kosaka, H.D. Robinson, D.S. Rao, T. Szkopek "Optoelectronic quantum telecommunications based on spins in semiconductors", Proc. IEEE 91, 761 (2003) [4] Cai JM, Retzker A, Jelezko F, Plenio MB. A large-scale quantum simulator on a diamond surface at room temperature. Nature Physics 9:168-173 (2013) [5] Waldherr G, Wang Y, Zaiser S, Jamali M, Schulte-Herbruggen T, Abe H, et al. Quantum error correction in a solid-state hybrid spin register. Nature 506:204 (2014) [6] Dolde F, Bergholm V, Wang Y, Jakobi I, Naydenov B, Pezzagna S, et al. Highfidelity spin entanglement using optimal control. Nature Communications 5, 3371 (2014) [7] W. Pfaff, B. Hensen, H. Bernien, S. B. van Dam, M. S. Blok, T. H. Taminiau, M. J. Tiggelman, R. N., Schouten, M. Markham, D. J. Twitchen, R. HansonUnconditional quantum teleportation between distant solid-state qubits, Science 345, 532–535 (2014) [8] C. Grezes, B. Julsgaard, Y. Kubo, M. Stern, T. Umeda, J. Isoya, H. Sumiya, H. Abe, S. Onoda, T. Ohshima, V. Jacques, J. Esteve, D. Vion, D. Esteve, K. Mølmer, and P. Bertet, Multimode Storage and Retrieval of Microwave Fields in a Spin Ensemble, Phys. Rev. X 4, 021049 (2014) [9] C. J. Wedge, G. A. Timco, E. T. Spielberg, R. E. George, F. Tuna, S. Rigby, E. J. L. McInnes, R. E. P. Winpenny, S. J. Blundell and A. Ardavan, "Chemical Engineering of Molecular Qubits", Phys. Rev. Lett. 108, 107204 (2012).

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Computation	Glattli	we may mention the rapidly developping field of electron flying qubits which has been possible with the advent of well designed and controlled electron interferometers performing with electrons all unitary operations available to photons. Although not mature for applications, the goal is to exploit new entanglement schemes possible thanks to the Fermi statistics (and not possible with photons (bosons)). Crucial steps have been : the advent of mature Single Electron Sources (G. Feve Science 2007, J. Dubois Nature 2013) which allowed Hong OU Mandel electron correlations (Bocquillon Science 2013, J. Dubois Nature 2013) and to perform Electron Quantum Tomography (T. Jullien, Nature 2014). Note that the activity on Single Electron Sources finds natural links with quantum current standards metrology although the goal are differents. There is a well structured and sizable Electron Quantum Optics community mostly based on European Labs and several ERC grants have been given to leaders of this community. A special Issue on "single-electron control in solid-state devices" is going to be published where about 20 laboratories have contributed.
Computation	Sigg	Here is the best of the document given a description of the Quantum engineering facility. But Q-computing with molecular system and also topologically stabilized systems are sub optimal.
Computation	Prati	There are some issues in this section. First, many researchers in the field would disagree that the trapped ions method is the most promising together with superconductive qubits, as the first achieves 15 qubits with no clear path towards millions required for quantum computation, while the second shows 500 interacting qubits (see Google/Santa Barbara groups) and is highly scalable. Second, there are two sections covering the same topic, i.e. dopants cited as semiconductor quantum dots in Section 2.1.4 and Impurities in Section 2.1.5. The two sections refer to exactly the same experiments of dopants in silicon, the first time grouped with semiconductor qubits, the second time with single impurity/molecule. The two sections partially contradict each other in the short, middle and long term perspectives. As final remark, the number of citations of 2.1.4 is very small, despite the importance of the semiconductor qubits in terms of scalability and the tens of Nature/Science papers published in the last 5 years.
Computation	Remacle	"I agree with the general definition of quantum computation at the beginning of section 1.1 :' A quantum computer is a device that harnesses some of the basic laws of quantum mechanics in order to solve problems in more efficient ways than classical (standard) computers.' However, there are alternative ways to implement this

		goal exploiting the quantum properties of molecules that do not rely on encoding the information in qubits and operating on them with quantum logic gates. We developed an alternative approach 'computing by observables' in the MULTI FET project that present similar advantages over classical computations. This approach relies of optical addressing by short laser pulses and quantum molecules dynamics and allows computing in parallel all the outputs of a logic function pf multivalued variables for all possible sets of inputs, and to read the outputs optically in parallel. One can tune which function is computed tuning the parameters of the laser pulse and also the coupling between the different subunits of the molecule. [1] B. Fresch, D. Hiluf, E. Collini, R. D. Levine, and F. Remacle, Proceedings of the National Academy of Sciences 110, 17183 (2013).[2] B. Fresch, M. Cipolloni, T.-M. Yan, E. Collini, R. D. Levine, and F. Remacle, The Journal of Physical Chemistry Letters 6, 1714 (2015).[3] T.-M. Yan, B. Fresch, R. D. Levine, and F. Remacle, The Journal of Chemical Physics 143, 064106 (2015). Following this line of research, I suggest to add a direction of research on p6 in the 'specific directions of research' section: Exploiting molecular coherence and the high density of information that can be encoded on quantum molecular states (not necessarily by decomposition into qubits) and molecular quantum dynamics for implementing massively parallel quantum computations using optical addressing by coherent laser pulses. Using molecules opens new avenues for scalability (more information inside each unit), for accessing high rates of processing, less need for interunit communication."
Computation	Levine	Our work on molecular logic devices is very much within the scope of quantum computing, section 1.1. We had several rounds of EC FET Open support for our work and consistent experimental demonstrations and theoretical developments. Our approach takes advantage of the high density and high connectivity of molecular energy states and the extremeely fast, fs scale, rates of molecular processes. We need devices that accept input from the classical world and that deliver corresponding output. So we call the logic that we do 'computing by observables' It is internal quantum dynamics that accept classical meauserments as input.
Computation	Bajoni	I believe there are achievements that are needed but not stated. High efficiency and very low loss optical filters beyond the state of the art are needed for the goals set for LOQC, but are not mentioned. The section on superconducting circuits refers to microwave/optical interfaces, and this goal requires an effort to develop efficient wavelength conversion and generation of entangled photon pairs with large frequency mismatch.
Computation	Samuelsson	Electron quantum optics offers unique opportunities for generation, coherent control and detection of flying electron qubits in semiconductor systems [e.g. Samuelsson et al, Phys. Rev. Lett. 92, 026805 (2004)]. Together with the close connection to quantum electronic metrology, with on demand generation of single and pairs of

		electrons, the strong European topic of electron quantum optics should be a key part of a quantum technology flagship.
Computation	Kataoka	"This comment may be relevant not just to the quantum computation part of this document, but also to other sections (such as quantum control and quantum metrology). There is a field of experimental and theoretical study, so-called "electron quantum optics," that is not mentioned in this roadmap document. Perhaps this is because that this field of research has not (yet) targeted specific QT applications. However, the field has been developing advanced technologies, such as electron quantum-state tomography [Jullien et al, Nature 514, 603 (2014)] and multi-particle interference [Bocquillon et al, Science 339, 1054 (2013)], that are strongly relevant to the scope of the QT flagship. Another important point is that this field has a strong European presence. Many key players (both in theory and in experiment) are based in European institutes, therefore there is a basis to form a strong consortium. There will be a special issue on "single-electron control in solid-state devices" contributed by the community (organised by Rolf Haug and Janine Splettstoesser) being prepared for publication soon in Physica Status Solidi (b)."
Computation	Liscidini	"I agree with all the contents and directions of this part, and I found particularly important having mentioned "search for problems where quantum computers will be required." Yet, it seems to me that the importance of this point could have been emphasized even more, especially in the case of quantum computation for which there are different technological approaches that aim at building a quantum computer. Indeed, the kind and the "size" of a problem are usually strongly connected to the choice of the technology to solve it. Thus, identifying such problems and their dimensions in terms of qbits is of primary importance to establish the most suitable "quantum technologies" to solve them. Another point that could have been clarified a bit more is related to the development of Quantum Interfaces to connect different computing units. While it is clear that in this case photons will play a major role, it would be important to understand the necessary transmission bit rate (which may be larger or smaller than that required for secure and effective quantum communication). Again, this would be useful to identify the right approach and discard those solutions that are clearly not suited to the task. As other quantum "tasks", quantum communication would largely benefit of cost-effective solutions. This has been pointed out along the entire roadmap. In this regards, I think that the role of silicon photonics could be emphasized a bit more. Indeed, in Sec 2.1.2 Quantum Computing with Linear optics there are no references to

		Integrated source of non-classical light based on SFWM (e.g. D. Grassani, et al. ""A micrometer-scale integrated silicon source of time-energy entangled photons,"" Optica 2, 88 (2015))."
Computation	Kröll	"Regarding section 2.1.5 (Impurities/Rare-earths) Page 35: A coherence time in impurity spins of more than 6 hours have now been experimentally observed. We suggest to add this more recent result to citations 1 and 3. The reference is: Nature 517, 177 (2015) Page 37 (first section, line 6): Replace ""For defects in silicon,"" with ""For defects in silicon as well as for rare-earths,"" Under short term goals, for rare-earths, replace ""two-qubit gates..."" with ""few-qubit gates..."" New medium term bullet point: * For rare-earth ions, efforts should be joined with crystal growth research to create appropriate materials for larger scale systems. Couple few qubit systems to high cooperativity cavities for interfacing with flying qubits and for connecting spatially separated qubit systems. New bullet point for long term goals (replacing old long-term goal for rare-earths): * For rare-earth systems, to simultaneously realize all required properties for demonstrating scalable quantum computing in one system, including long coherence, fast gates, and connectivity."
Computation	Couteau	Missing keywords: nanophotonics, Quantum plasmonics, Hybrid system metal-dielectric, antennas-waveguides, multiscale nanophotonics

Computation	Hensinger	"On p. 22 of the document, it would be useful to mention that there is an alternative approach to scaling up trapped-ion quantum processors. It is also possible to scale them up utilizing ion transport between quantum computer modules. This approach may be simpler to engineer. It would therefore make sense to mention this approach in the roadmap as well. I like to propose to replace the sentence: 'Nevertheless, there are well-defined approaches for scaling up ion trap quantum processors using microfabricated traps and photonic interconnects [2]. With the following sentence: 'Nevertheless, there are well-defined approaches for scaling up ion trap quantum processors using microfabricated traps and photonic interconnects [2] or alternatively using microfabricated traps and ion transport connecting quantum computer modules [26].' Please add: [26] B. Lekitsch et al., "Blueprint for a microwave trapped-ion quantum computer", arXiv:1508.00420 [quant-ph] (2016)"
Computation	Mihailovic	"Challenge: Ultralow-energy (ULE) ultrafast (UF) low–temperature (LT) memory. A huge and well known obstacle to large scale implementation progress of superconducting computing based on JJs is the absence of low- temperature memory technology (see for example ref. [1]) A solution is close to hand [2,3], which promises to significantly enhance scalability of QC circuits using superconducting Josephson junction devices by eventually allowing on-chip integration of LT UF-ULE memory. State of the art. The current approach to control of JJ qubits uses DACs, but data is brought through CMOS memory which has very high energy consumption. New solutions. A new technology [2,3], currently in early stage of development jointly by IJS/Nanocenter (Slovenia) and Hypres (USA) is based on switching between topologically protected states in dichalcogenide charge-ordered materials integrated within RSFQ qubit control DAC circuits. Demonstrators have shown sub-picosecond, low temperature operation and scalability, promising switching energies of atto-Joule per bit with 50 nm feature size. The devices are hybrids in the sense that the memory works as a memristor matched to RSFQ devices and circuits. As such they are form the input channel for digital data, i.e. the classical- quantum interface.

		[1] Holmes, D. S., Ripple, A. L. & Manheimer, M. A. Energy-Efficient Superconducting Computing; Power Budgets and Requirements. IEEE Trans. Appl. Supercond. 23, 1701610–1701610 (2015)). [2] Vaskivskyi, I. et al. Controlling the metal-to-insulator relaxation of the metastable hidden quantum state in 1T-TaS2. Science Adv. 1, e1500168 (2015). [3] Vaskivskyi, I. et al. Fast electronic resistance switching involving hidden charge density wave states. Nat Comms 7, 11442 (2016)."
Computation	Feve	"Please note that this comment is not only relevant to the quantum computation part but also to other sections. In recent years, a new approach to transport in quantum conductors has blossomed, by transposing concepts initially developed for quantum optics to electron transport. This opening field, called ‘electron quantum optics’, unfortunately does not appear in the Roadmap document. Indeed, the field deals with quantum control and manipulation of single excitations in condensed matter systems, particularly relevant to this QT Flagship initiative. A number of tools such as electron tomography or two-particle interference have been theoretically developed and experimentally demonstrated. They rely on time-controlled single electron sources, and consequently have strong connection to electrical quantum metrology and sensors. Besides, the tools developed in particular for quantum Hall edge channels are in principle transposable to other topological systems, such as quantum spin Hall insulators, or edge states in topological superconductors. As such, they connect to the topic of topological phases and excitations. Finally, most of the leading groups in the field are based in Europe. The Flagship initiative would allow for closer collaboration between these groups, and consequently strengthen the european leadership in this emerging domain."
Computation	Paraoanu	Under "alternative QC architectures" one could mention QC with continuous variables, which can be done in optics and in superconducting circuits.
Computation	Náfrádi	"A major missing point, in my opinion, is that the quantum computation section does not plan the seed for the 3rd quantum revolution to come after the conclusion of the quantum manifesto project. The general narrative of the section is that in subsections 2.1.1-2.1.5 five different parallel technologies are identified with the common denominator, the proven ability to use them in quantum computation, and with well identified technological

		shortcomings. The defined long term goals address the identified technological shortcomings. Once all promised long term goals are successfully reached it will result in quantum computers working inherently in extreme environments like in ultra-high vacuum or ultra-low temperatures without any avenue to extend it to work conditions close to ambient environment. Consequently, it does not offer hands-on experience to the general population on quantum computation. Neither directions to reach that goal is foreseen. To fill this gap I propose the extension of section 2.1 by a 7th subsection where the vision on “Alternative QC architectures” and “Making more robust qubits” introductory sections are detailed. These fields are clearly less developed at present than other parallel technologies detailed in section 2.1.1-2.1.5, thus the long term goal here should be to reach few-qubit test-beds, however, with the added benefit of ambient condition operation or intrinsic error correction. In this front promising materials like conducting carbon nano-spheres and various topologically protected electronic states are already identified. Several DiVincenzo criteria are currently meet for these systems like: - The conducting carbon nano-spheres are largely uniform well characterized qbits. - The initialization of the qbits at room temperature was already demonstrated. - Long-enough coherence time was demonstrated at room temperature to encode coherent state several times. These directions with the additional goal to identify yet unknown systems for possible quantum computation would enrich and strengthen the present quantum technologies roadmap."
Computation	Hakonen	"-Adiabatic quantum computation could be developed to solve certain problems. The range would be enhanced by developing technologies to work at even lower temperatures than 10-20 mK. Lower T would enable to cope with smaller gaps (more qubits). - Development of cluster states at microwave frequencies. There are already works on this. - Generation of entangled spins by splitting Cooper pairs would yield a good resource for continuous variable quantum computation in solid state systems."
Computation	COST Action	The comment is available on request at cost-nqo@uni-siegen.de
Computation	Macucci	"On Page 20 the ""adiabatic quantum computer"" by D-Wave seems to be mentioned in too affirmative terms: at present we cannot tell for sure, but it is possible that it will turn out to be nothing but a scam. I would suggest to use some more careful wording, if the D-Wave machine will eventually be exposed as a false claim, also the Roadmap will receive a

		blow in terms of credibility. Bruce Kane's paper appears as a reference both in Sec. 2.1.4 and in Sec. 2.1.5, but 2.1.4 appears to be about quantum dots and the implementation of qubits with electronic degrees of freedom, therefore it is something quite different from Kane's idea. Overall, Sec. 2.1.4 is written in a way that tends to partially overlap Sec. 2.1.5 (donor arrays are mentioned, which seem to be the subject of Sec. 2.1.5). On Page 96: The section on error correction for quantum digital computers is very short compared with others and with very little content, while a vast literature exists on the topic. It should probably be enlarged."
Computation	Ferrus	There are several issues in particular on the definition of the most promissing route for QIP (trapped ions). It is clear this is a matter of perspective as industries are mostly silicon-oriented which may not be necessarily be the case for academia. Although it is fair to mention it, one would need to weight proposals in terms of their applicability and large scale realisation. For this quantum dots are very promissing. This specific aspect has been recognised by the Australian groups, in particular Andrew Dzurak. Another comment concerns donors and impurities. Although in different sections, they are in practice the same. Overall, semiconductor qubits are under representated. This does not correspond to the level of research nor the direction industries are taking. A clear example is the CEA leti pursuing MOS type qubits or the Delft groups
Consensus Paper	Campbell	**Goals:** I strongly agree with the goals put forward in the consensus paper. **Values** I approve of the values put forward and would like to highlight the importance of transparency and openness. This consultation process is a good indicator that the flagship will operate in a transparent and open way. Although, it is unclear to me how these values will be ensured within the structure and organisation of the flagship. **Governance** I have found many researchers are put off EU grants due to the level of bureaucracy involved in both applying for and maintaining EU research programmes. I am sure that the community will appreciate any bureaucracy limiting mechanisms that can be built into the system of Governance.

		Structure and operation "I mostly agreed with this section. I was especially happy to see the importance of ""early career researchers"" mentioned. However, this point ought to be grounded in a specific commitment, e.g. a certain percentage of funding ring-fenced for early career researchers. Furthermore, there was a specific commitment to 50% of funding being industry led. I am very happy that the flagship is encouraging close collaboration between academia and industry. However, my initial impression is that 50% is a very large fraction of funding. I would ask if is this comparable to the percentage of industry leads in other big programmes? For instance, how does this compare with the UK quantum tech programme, which has a very significant industrial component. Furthermore, I worry that such commitments are vulnerable to abuse. There appear to be several ""quantum start-ups"" that acquire funding solely from research grants, but contribute no capital of their own. I fail to see the benefit of such companies other than they help funding bodies reach a target of funding that can nominally be said to be ""industry led""."
Consensus Paper	Melhem	**Values** Good, however useful to bring forward the needs to address at early stage the challenge of scalability and the development of critical components required for a Quantum Product by industrial enterprises and ensure quantum solution engineering needs are considered at the design stage **Other aspects** Ensure industrial organisations are engaged at an early stage in developing QT solutions by taking into consideration the need for 75-100% funding of cost of developing new QT products in a commercial environment
Consensus Report	Anonymous (upon request)	**Structure and Operation** "I found the sentence ""target at least 50% of the funding to be provided to support industryled projects that will support joint research and development type activities"" a bit strange. Why only specify a lower bound to the target funding percentage and why ""industry lead"" instead of ""collaborative"" projects? Is this really a necessary condition of the stakeholders from industry?"

Consensus Report	Buchmann	**Structure and Operation** I would like to propose a fundamental "double blind peer review" to better guarantee the goals and values of excellence across all fields.
Consensus Report	Bresson	**Structure and Operation** "Perhaps, it is a good point to clearly identify potential action concerning: - filling the technological 'valley of death' : increase TRL, encourage actions 'from lab. to applications', operational tests, … - identifying and/or creating potential applications for quantum technologies: market study, …"
Consensus Report	McGettrick	**General comments** I would only comment in general terms. I think the whole research area is / should be as important for "computer science" as it is for physics. I think, at many points, a little more emphasis should be made on the fact that ultimately we are designing quantum algorithms, i.e. software. More of this research should sit inside the computer science community. Indeed - though it is arguable - I think a better title for the whole project is "Quantum Computing Technologies", or "Quantum Information Technologies"
Consensus Report	Arrighi	**Value** Too much emphasis on academia-industry. The interested industrial actors are only a few. Not enough emphasis on the interdisciplinary: with Computer Science, Mathematics. **Governance** The fields of Computer Science and Mathematics MUST be represented in my opinion. Industry, on the other hand, is given too much space in a field it currently knows little about. To get them interested is one thing. To put them in charge is another. **Structure and operation** I would like to see a "minimizing paperwork" kind of point: lightweight processes; let us not spend more time evaluating each other's research proposals, than doing actual research.
Consensus report	Von Klitzing	**Value** The values are very well stated, especially the pan-european dimension is an important one. The size of the teams should be a separate point. **Structure and operation** It is very important that there is no core-consortium. It makes sense that there is no mobility requirement on the students to be funded. Care must be taken, however, that this does not mean that the money goes mainly to the students of the main players, for this would reduce the impact in terms of generating an Europe wide effect.

Consensus Report	Heusler	**Goals** Usually, about 0.1% of money or more is provided for the topic education, which is also of improtance for recruitment in industry. I miss statemants and plans in this direction. **General comment – other aspects to be included** A vision about acceptance of quantum technology in society, which is related to the topic of education, but also of outreach (beside school)
Consensus Report	Seravalli	**Value** I'd add a point on promotion of quantum-based devices to the whole community of EU citizens **Structure and operation** "Concerning point ""Funded industry participation within all the mechanisms of the flagship"", where it is declared ""target at least 50% of the funding to be provided to support industry-led projects that will support joint research and development type activities"" Could this ratio be tuned to the nature of the proposed projects, in order to avoid reduced financial support for disruptive, blue-sky projects (difficult to be led by industry)? For example, this could be done by differentiating such ratio on the basis of the call details (application-oriented vs. novel ideas). "
Consensus report	Koch	**Governance** A balanced representation should include gender. It is not clear to me whether this http://qurope.eu/content/qute-europe-sab is the Strategic Advisory Board. If it is, the status of gender balance (1 female among 34 members) is extremely disturbing..
Consensus report	Mitchell	**Value** very good. mention of the specific "quantum algorithms and protocols" in the otherwise general values is anomalous and should be removed. **Additional comments** Young people make an outsized contribution to disruptive innovation, I think everyone agrees on this. I would like to see some mechanism by which the Flagship can support extraordinary initiatives by young researchers. I do not mean fellowships so that they can work within a senior researcher's team on topics defined by the senior researcher, but rather a mechanism by which motivated young researchers can independently push their ideas toward the market. I am surrounded by young people who would like to take this route, but have no practical means to do so.
Consensus report	Denschlag	**Values**

		I miss an openness for new emerging topics and developments in quantum science and technologies **Governance** I miss some level of democratic measures: voting of some sort **Structure and operation** "a) I miss some level of democratic measures: voting of some sort. b) I think that that ""quantum control"" should be an independent pillar and not just an embedded activity. For example, controlling quantum dynamics in molecular compounds or in chemical reactions will potentially have a huge impact for our technological future. This should not be excluded from the quantum technology flagship. Restricting the flagship initiative only to promoting ""push-button"" devices such as the quantum computer is way of thinking that is too restrictive, I think."
Consensus report	Schumacher	**Additional aspects** European national metrology institutes (NMI) have a strong scientific position in the field of optical and electrical quantum metrology and are world leading scientific centers in parts of these fields. NMIs further have the important role of validation of new quantum standards by comparison measurements thereby creating confidence in new applications of quantum technologies. NMIs additionally represent an existing strong link between academic fundamental research and industry by offering services to industry and society which are already today directly derived from the application of quantum technologies (such as atomic clocks or Josephson voltage standards to name just a few). Due to this important role for the dissemination and application of quantum technologies it would be very wise to mention the role of the NMIs for quantum technology in the consensus paper.
Consensus Report	Pujals (this is a lawyer expert in IP)	**Structure and Operation** Also would be interesting the involvement of CEN-CENELEC and inclusiveness of SMEs and taking into account the global dimension of standard setting processes **Additional aspects** From my point of view it is crucial to set an specific program to generate, protect and aggregate IP in key Quantum Techs applications aimed at setting a patent pool for providing Freedom to Operate to the European industry. This will be key for them to accesing global markets. This programme must be set to manage strategically IP also in the context of standard setting and also to monitor global developments, allowing pan-European concerted decisions.

Consensus report	Prati	**Governance** "Overall, the Governance looks balanced and inspired by the principle of avoiding conflicts of interests. One possible concern arises from the connection of the inputs coming from the Virtual Institutes and Facilities, which belong to the 50% of the community of those providing a supply of new ideas and methods, with those of the community demanding such novel quantum technologies whose representatives, the small and large industries, provide in the funding scheme as the 50% of the beneficiaries. At this stage it is not clear which new ideas will be exploitable by the market by novel or existing actors. The role of existing supply chains in different technological areas should represent the bridge between supply and demand of ideas/research in the quantum technologies, so that they can act as seeds of what is going to become a ""pillar"" at a later stage of the funding scheme." **Structure and operation** It is a very good idea to adapt natural selection to those promising research activities that can bring ideas to market, forming the pillars to be funded at the steady state. It would be very important that "pillars" are intended as those activities supported by a complete supply chain from research to industries. Different schemes should be conceived in order to grant the formation and market exploitation of new start ups on one hand, and large industries on the other, which are already part of an existing supply chain, to be integrated with quantum technology research groups and technology transfer facilities, to grant the both new actors and existing industries may take benefit of the innovation. About the identification of applications in pillars namely: Quantum Sensors and Metrology, Quantum Communication Devices and Systems, Quantum Simulators, Quantum Computers: Hardware and Software, it looks that Quantum Imaging has been ignored while Quantum Simulators and Quantum Computers could be merged, and Quantum Sensors and Quantum Metrology could be split. **Additional aspects** In order to grant the successful participation of industries, a special attention has to be payed to the formation or the integration of vertical supply chains. The technology transfer process is of fundamental importance in order to connect fundamental research and industrial applications, so special tools should be conceived to assess such an intermediate layer connecting bottom and top layers of the supply chain.
Consensus report	Auzinsh	I would like to stress the importance of the pan-European dimension. In order to attract the maximum possible number of talented people and foster innovation, it is necessary to include also smaller, qualified players from all over Europe.

Consensus report	Poirier	Many NMIs (National Measurement Institutes) already collaborating in Europe in the frame of EURAMET have strong interests in the QT Flagship, however, they seem to be under-represented. NMIs are at the intermediate stage between academia and industry. NMIs can promote novel physics and participate in knowledge transfer in the impacting field of measurement science. They possess certain expertise, in device fabrication and measurement technologies, that they can offer to the community. They provide measurement traceability to the SI units with the highest accuracy.
Consensus report	Dür	**Additional aspects** "The acceptance of quantum technology in general public, and the recruitment of young researchers are important issues for success of the long-term aims defined in the quantum manifesto. It might be a good idea to allocate a small part of the budget not only to public outreach activities, but also to the development of teaching material for pupils and undergraduate students. While public outreach activities (public talks, special days for school classes etc.) are important on a shorter time scale, the development of teaching material can have a long-term influence and impact. Such teaching material includes visualisations, videos, apps, online courses and virtual experiments of the basic principles of quantum information theory and its technological applications (e.g. quantum cryptography, quantum computers), but may also include the development of a new quantum curriculum. This may lead to a new way of teaching quantum physics at high-school or undergraduate university level, where basic principles of quantum physics are discussed together with (or with help of) modern research themes and technologies. This should help to increase the acceptance of new quantum technologies among the general public, and at the same time get the best pupils and students interested in these emerging technologies, making sure that there is a long-term impact."
Consensus report	Schmidt	**Structure and Operation** I would rename "Enabling science" to "Enabling (quantum) technologies". From my point of you this should relate to the development of e.g. lasers, detectors, integrated optics/electronics, experimental control systems, dedicated chip fabs, etc. Many of these points are currently being developed in parallel in many groups, diverting resources from "quantum" to rather "classical" technologies. We need these classical technologies to be readily available and sufficiently reliable to advance quantum technologies. The term "technology" also provides a direct link to industry R&D.
Consensus report	Morsch	**Values** The wording "...while paying attention to open scientific and technology issues" seems a little weak to me; although this is spelled out more clearly later in the document, one might make this statement a bit stronger, e.g.,

		"... while actively promoting research into open scientific and technology issues throughout the duration of the Flagship" **Governance** In the sentence "independent evaluation by peer review, based on excellence in science and/or innovation, with best practices (e.g. ERC-inspired) to deal with conflicts of interest", it is not clear to me why ERC is particularly suitable as a role model for best practice (some might argue it isn't); in fact, spelling out a little more clearly what issues are particularly important in this "best practice" might be helpful **Structure and operation** "1) Under ""Down selection and focus"", the fourth point regards the reduction of the calls to more focused consortia dealing with pillar development ""from demonstrators to products"". I find this rather limiting, as it suggests that in that phase there will be no more room for basic science, i.e., one step even before ""demonstrators"". Maybe this is not what was intended here, but it could be interpreted in this way. I think that a clear commitment to funding and supporting basics research throught the lifetime of the Flagship is important, both for the community and also strategically, in order to avoid the danger of neglecting promising approaches that may not have made it to the ""demonstrator"" stage by the end of the ramp-up-phase. 2) Under ""Funded industry participation..."" the fourth point reads: ""target at least 50% of the funding to be provided to support industry-led projects that will support joint research and development type activities"" If more than 50% of the total funding is earmarked for industry-led (and, therefore, heavily application-oriented) projects, that automtically means that the remaining less than 50% will have to fund non-industry led application-oriented projects as well as basic science and explorative projects, which realistically (depending on the evalutation criteria) will probably mean that less than 25%, probably more like 10%, will be available for non-application-oriented research. I'm not sure that quoting a minimum percentage of funding that should go into industry-led projects (and such a hight percentage at that) will ensure, especially in the ramp-up-phase, that the best projects receive funding; rather, it will force researchers to find industry partners willing to collaborate with or ""lead"" them, which will not be easy for many researchers in the community. In the steady-state-phase, it will probably make it impossible to fund non-applied projects, likely leaving that part of the research community without EU funding for several years. "
Consensus report	Kataoka	**Governance** Quite a few NMIs (National Measurement Institutes) in Europe have strong interests in the QT Flagship, however, they seem to be under-represented. (Only academic and industry stakeholders are listed, while NMIs sit

		somewhere in between.) NMIs need to be able to adapt to the metrological needs of the changing world. Also, NMIs possess certain expertise, such as device fabrication and measurement technologies, that they can offer to the community. It is worth mentioning that in the past, the field of metrology has been the first area of application of many new discoveries (plenty of examples such as the quantum Hall and Josephson effects) and is likely to be the first beneficiary of novel quantum enhanced technologies.
Consensus Report	Franz	**Additional aspects** "The quantum manifesto lists the creation of a new generation of quantum technology professionals as one of the key activities of the program and emphasises the importance of education as foundation of the flagship. We feel, however, that the role of education is not yet sufficiently addressed in the roadmap and the consensus report. To strengthen the role of education and education research in the program, we propose to include the following points in the flagship program: 1. Include a visible commitment to enhance quantum physics education and research into quantum physics education in order to support the development of a new generation of quantum technology professionals. 2. Exploit the momentum generated by the flagship program to engage young people throughout Europe in quantum science and quantum engineering, taking measures designed to respect the different structures and requirements of learning and teaching in the EU countries. 3. Support the communication between scientists, education researchers, educators, and stakeholders from politics and education industry. 4. Support measures to provide infrastructure to coordinate education efforts in order to maximize their impact. 5. Appoint a spokesperson for the duration of the programme for coordinating education and education research related actions. In order to gather support for this proposition, we have launched a call to colleagues in the education research community [1] and asked them to support these points by signing them online. The call went out 14 October and until today (25 October) a total of 133 education researchers and education professionals (73 professors) from 20 EU countries signed the proposition. Additionally we received endorsements from the chair of the physics

		education division of the European physical society Prof. David Sands and the president of the GIREP (Groupe International de Recherche sur l'Enseignement de la Physique) Prof. Marisa Michelini. We hope that the high level steering committee will discuss actions to include education and education research in the flagship program and consider our proposition on the Berlin meeting. With best regards, Torsten Franz, Oxana Mishina, Rainer Müller Quantum education research group, TU Braunschweig, Germany [1] see https://goo.gl/forms/bSTQw8J5vuC3z0uW2"
Consensus report	Boiko	**Governance** I find excellent that "Governance is formed by “wise people” (retired from the field) avoiding conflict of interest while retaining excellent knowledge of the area" **Structure and operation** I think this part need improvement: I find that only two first bullets define some concrete steps. Other seems to be too general statement reproduced from ERC or similar programs. This approach is not compatible with the targeted "Revolution."
Consensus report	Couteau	**Governance** People in boards and committies have to change/rotate regularly **Structure and operation** STREP-like projects are required and ERC-like process of selection too and mix of open calls and targeted projects. Need for medium-size call (up to 200k€) for 1 to 3 partners, quick and easy. **Additional aspects** "-We should have plans to obtain funding from venture capitalists, mecenas, private donations and so on as academia is not enough and industry is always targeted and thus tend to ""reduce"" the scope to very targeted applications. Even though these two are necessary (public money and industry money), a third one is necssary (private money) and we are not very good at it in Europe (as opposed to the USA or Canada for instance). This flagship is a good opportunity for it as it has all the components necessary for it: fundamental/ blue sky research but also day-to-day changes type of research that can change tomorrow's computation or security for instance -Awareness and outreach to the public and in particular working with middle and high-school science teachers so that they can transmit the dream of working in quantum stuff and they debunk the fear of science, physics and quantum (in increasing order of fearness)"

Consensus report	Rarity	**Structure and operation** This sounds a little like setting up a mini-EU refereeing organisation running a call for Quantum STREPS. I see a danger of spreading the funding very thinly across many groups. 1 postdoc 1student for 3years~£500K x 100 =£50M. Starting with many and thinning to only keep successful projects...on what timescale? What success criteria.... to be discussed I hope. Having a small number of focussed big vision projects that add what they need as they go along plus smaller feeder project calls might be a good compromise of bandwidth and focus.
Consensus Report	Omar	**Governance** Key decisions, including those on the topics and structure of the calls, should be sanctioned by a body where all EU member states are equally represented.
Consensus Report	Paternostro (on behalf of COST "Quantum Technologies in Space")	**Values** Adding an extra bullet point: "Encouraging large international entities not traditionally associated with quantum research, e.g., ESA, to prioritise quantum experiments that would otherwise not be possible. "
Consensus report	Cost Action	The comment is available on request at cost-nqo@uni-siegen.de
Consensus report	Ferrus	**Governance** It is not clear enough how 'inclusiveness' will be implemented in practice and the definition of 'wise' people is somehow arbitrary. These people have to be chosen from a pool of persons who have demonstrated, in the past, strong links between academia and industries without conflict of interest (present and past). Again, how to ensure an independent evaluation of the proposal knowing conflict of interest may arise from competitors or already ongoing or past collaboration ? One may for example ensure a reasonable repartition of funding over independent virtual centres. **Structure and operation** One possible concern is the prerequisite of academia-industry collaboration. External funding is generally required for such a collaboration to take place in practice as upfront investment from a company is risky and difficult to obtained. Could a 'proof of concept' call be devised so an initial funding (1 year) for example) could be used to start collaboration and develop an initial idea? There is mention of a 'start-up funding scheme' but with no clear indication this could be applied to industries. If there is, then this contradicts what is written in the section 'structure and operation'.

		Additional aspects The documents including the roadmap are pretty good and give an unique opportunity for Europe to gather industries and academia and build up an European supply chain for the first time, from research to chip and packaging
Control	Anonymous (upon request)	In the context of resource theories in the currently very active field of Quantum Thermodynamics a lot of results concerning the reachability of states given resources and allowed operations have been obtained. This could be mentioned here.
Control	Campbell	"As I remarked earlier, I found it odd that Quantum Control was assigned 1 of the 2 Virtual Facilities. Furthermore, the overall page count allotted to Quantum Control seemed disproportionate. I should clarify that I regard Quantum Control as an immensely important topic that is very relevant to the development of working quantum technologies. Currently, the field is supported by the EU funded QUAINT network. I am very glad that the QUAINT network exists and is working hard on solving quantum control problems, and I would be pleased if a similar entity continued to exist within the flagship. However, there are numerous strands of research that are equally fundamental to quantum technologies."
Control	Bertels	my main concern here is that the non quantum but classical computer engineering efforts are not enough present. I restrict myself to QC and therfore it should also involve operating system, routing, programming paradigms, application development etc
Control	Denschlag	"Section 2.6.2 C: Controlling chemical reactions on the quantum level is indeed a very important goal. It should be stressed, hwoever, that in order to do this, first chemical quantum processes have to be understood and explored on a quantum level. One has to build up this technology which is still in its infancy. Therefore, I think, in the short term goals (2.6.2 D) one should state: ""Gaining full quantum control and understanding of chemical reactions of several selected simple systems, where the educt states can be prepared in well defined intial quantum states."" It seems to me that the laser control of light harvesting molecules should be rather placed in the Mid-term or long term goals, since one has to build up to it. Likewise the ""full control of a chemical reaction"" belongs to Long term goals. A good mid-term goal rather would be controlling a chemical reaction with a polyatomic molecule."
Control	Sigg	As said, not very convincing a facility.
Control	Prati	Cryogenic circuits for controlling fault tolerant quantum information and quantum error correction schemes are cited in the quantum computation section, but they should probably be moved here. Indeed, electronic circuits

		implementing quantum control provide the primitives from creating complex operations on virtual qubits and virtual logic ports, to upper architecture layers.
Control	Remacle	Following the points discussed above, I propose to add a new goal in this section on p 16 : Using sequences ultra short laser pulses to implement quantum control in molecules, both for encoding inputs and reading outputs. Exploit ensemble phase matching conditions to get a macroscopic reading of the observables in parallel.
Control	Levine	molecules with their high density of connected states are a medium of choice for implementing quantum control.
Control	Mihailovic	"The Challenge: classical/quantum interface. Currently there is no method of entering a large amount of data into the quantum computer (e.g. based on JJs) - particularly the one with a significant number of qubits. What is needed are parallel, addressable architectures for interfacing with quantum memory. This requires new approaches and demands new ideas and solutions (materials) in ultrafast nonequilibrium physics and nonoequilibrium quantum data transfer, which are not yet invented, or are only in their infancy. This bottleneck has not been identified in the current Quantum reoadmap, but would be crucial for the construction of a viable universal quantum computer for handling big data. Let us illustrate the point. To use a universal QC for superpositional search algorithm, all the data in classical form needs to be input somehow. If this is slow, the advantages of the QC are lost. Data needs to be input and output using non-equilibrium quantum methods which include ultrafast memory and interface systems, probably optical or electronic."
Control	Cost Action	The comment is available on request at cost-nqo@uni-siegen.de
Control	Ferrus	The section may be completed by a more general introduction to electronic circuits controlling a large number of qubits, either at room or low temperatures. Such architecture is quite complex and an efficient study is necessary, in particular, how to control the feedbacks loops, how to deal with crosstalks and fast line circuitry?
Information Theory	Benenti	"Section 2.4.4, page 114-115 on Quantum thermodynamics. I suggest that this part focuses more on quantum heat engines of potential interest for applications (coherent manipulation of heat, nanoscale heat management, on-chip refrigeration, quantum thermal machines, development of nanodevices for efficient energy conversion). A recent review paper that could be considered as a key reference in the field is G. Benenti, G. Casati, K. Saito and R.S. Whitney, Fundamental aspects of steady state conversion of heat to work at the nanoscale, preprint arXiv:1608.05595 [cond-mat.mes-hall]."

Information Theory	Campbell	This section covered a lot of the interesting theory work in the EU. Much of it has clear overlap with specific applications and I would highlight the importance of the following bullet points (selected from page 89): 1. Novel quantum algorithms; 2. Quantum communication protocols; 3. Novel quantum cryptographic protocols; 7. Optimisation of protocols for quantum cryptography; 8. New quantum computer models and architectures; 11. Quantum simulation methods to simulate quantum systems.
Information Theory	Glattli	Electron Quantum Optics viewed as a resource for quantum information has been intensely discussed recently by several European theory group. This was initiated by the Geneve theory group (formerly lead by the late M. Büttiker) and by the Leiden theory group lead by C. Beenakker and there have been important contribution from the ETHZ theory group lead by G. Blatter. Other contributors are P. Degiovanni group in ENS Lyon, Basel teory group, and in Sweden J. Splettstoesser (Chalmers) and P. Samuelsson (Lund) to cite a few.
Information theory	Remacle	We propose to go beyond the 'qubit paradigm' based on the concept of 'computing by observables' discussed in the comment on the 'quantum computing' section. This approach encodes information in observables and the information processing is realized by the quantum dynamics of these observables. One key advantage is that these observables can be read optically simultaneously in parallel at the macroscopic level.
Information theory	Levine	both amplitude and phase can be processes in a molecular process. This allows gates with built in memory.
Information Theory	Mihailovic	The solution to the interface and control problem necessarily involves the implementation of non-equilibrium quantum systems, typically discussed in terms of Markovian processes (quantum channels). Understanding and manipulating time-dependent relaxation phenomena of strongly interacting many-qubit quantum channels is still at its infancy but currently intensively studied, and here a lot of theoretical work is needed. Extension of the non-equilibrium quantum physics to realizable practical systems (materials) is essential for progress in QC data interfaces.
Information Theory	Pekola	I find it a very limited approach on Quantum Thermodynamics to discuss it only within quantum information theory. (See for example the opening of section C on challenges on p. 114: "The challenge for Quantum Thermodynamics is to identify simple but physically suitable coarse-grained descriptions in order to connect the microscopic formalism with macroscopic phenomena.") Instead, it is definitely an experimental challenge to control heat and work and other observable quantities in quantum circuits, and to draw concrete conclusions about thermodynamics in quantum regime.

Metrology sensing and imaging	Il'ichev	Different Realisation of the single spin and the single photon superconducting detectors. Current standard based on novel type of superconducting weak links (conjugate to Josephson junctions) phase-slip junction
Metrology, Sensing and Imaging	Buchmann	I miss the inclusion of recently developed exploitation of complex squeezing and the generalized implementation of Synodyne measurement techniques. In particular, since squeezing from optomechanical sources is mentioned in the document, the recent proposal to exploit the full complex squeezing spectrum to reach back-action free force measurements should be included.
Metrology, Sensing and imaging	Bresson	"In chapter 2.5.1. Quantum metrology (B / Atomic gravity sensors). In this state of the art, to reinforce and shows the rapid evolution of the atom interferometry techno. (start-up, spin off, space projects, drop tower results, ...), the doc could mention operational gravimetric survey done in 2016 with a atom gravimeter on a marine ship. http://www.onera.fr/fr/actualites/cartographie-marine-haute-precision-pesanteur-atomes-froids"
Metrology, sensing and imaging	Poli	A detailed section on atom interferometry with specific short, mid and long term goals is missing. Also detailed goals for clock development is still missing in sec 2.5.4
Metrology, sensing and imaging	Von Klitzing	"SENSING: Atom based devices such as matter-wave interferometers are amongst the most advanced quantum sensors available today. They are also the only ones that can be purchased commercially (muquans / aosense etc). Atoms have generated far higher squeezing than photons and are more sensitive to inertial effects. It would be highly unwise for the flagship not to pay more attention to the potential and application of matter waves. The Roadmap should mention the coherent manipulation of atoms as one of its aims. The emerging field of *Atomtronics*, which is not even mentioned, has an enormous potential in the field of quantum sensing and even quantum metrology. The trapping and coherent manipulation of atoms for longer times and over larger distances offers the hope of an extreme increase in sensitivity and precision -- as well as miniaturisation. Portable precision measurement of gravitational gradients for example would have an immediate effect on geology and the exploration of minerals and oil. I believe that *Atomtronics* should be mentioned explicitly. METROLOGY: - Atom/ion clocks are most profound quantum devices with a considerable potential for new physics to be discovered. Reducing the attention of the flagship to entanglement in clocks is to close ones eyes to the potential

		of clocks. There is a great need for new detection techniques beyond squeezing as well as the usage of the quantum-sensor clock in geodesy and even gravitational wave detection. - Atomic interferometers also have considerable potential in metrology. For example the metrology of gravitation will be hard to achieve with any other means."
Metrology, sensing and imaging	Grillo	"I'd like to introduce suggestions about a quantum sensing technology that might have been overseen by your list of quantum systems: free-electron quantum experiments. In particular pag. 14 par 1.4 1) After the sentence "Enormous progress has been made on single photon sources, both deterministic and heralded, that can be used for optical calibration as well as a building block for photonic quantum communication and computing." I propose to add "single electron sources and detection, quantum-logical readout of the single electronic state after interaction can be used for highly dose-efficient investigation of soft matter, material science and applications." 2) The sentence reads: "Because of the wide range of prospective applications and their specificity, a broad range of physical platforms needs to be considered, including (but not limited to) […] ". I propose to add in the list of technologies "Structured free-electron waves" 3) Pag 123 A. Physical approach and perspective There is a reference to "imaging in life science". Something like "on the other hand free electron can already be used in microscopy in life science but at the cost of sample damage. The use of quantum based technology may introduce new concepts in microscopies where new efficient measurements use single electron and quantum state readout" 4) Pag 125 some of the "atom-based sensor" ideas can be applied also to free electrons. It would be nice if the title could make a generic reference to "matter waves" and maybe mention free structured electrons in text. Beyond these points some more would be necessary. NOTE: What is going on in the electron community? How is this connected to quantum manifesto? here are a few examples of recent quantum-electron microscopy connections

		- We are a group (http://tem-s3.nano.cnr.it) working on electron optics and electron microscopy. We have a strong collaboration with groups of light quantum optics (e.g. University of Ottawa, University of Glasgow) and centers of microscopy (ER-C center forschungcentrum Jülich) aimed to bring techniques and ideas of optics and quantum optics in the field of high energy free electrons. In particular we work on the possibility of new electro-optical elements transforming the electron wavefunction. The aim is to introduce a quantum revolution in the electron microcopy where a single or few electrons are used for the measurement of important sample properties. The amount of information per electron is optimized by an appropriate base change operated by the innovative optical elements[1]. The paradigmatic example is the Orbital Angular Momentum well known in optics and recently brought to electrons [1-4]: it permits to explore magnetic properties, dichroism, chirality and symmetry of a sample potentially down to atomic scale. This would open the scale also to the observation of dose sensitive materials like molecules, on a very long term we can envision even medical/biological applications. - Beyond our group activity other groups are studying the possibility of quantum "Zeno" effects and/or Elitzur-Weidman effects in electron microscopy. These approaches have the specific aim to obtain interaction-free measurements using advanced quantum mechanical concepts. In particular a big international (European and US) collaboration has been funded (http://www.rle.mit.edu/qem/) by the Moore foundation to investigate innovative concept and instrument in this direction. This project also involves a collaboration of microscopist and expert of quantum foundations [5][6]. - It is finally worth mentioning a few of groups working on fast electron microscopy and light-electron interaction. This is yet another approach to bring together photons and electrons experiments, and potentially to go in the single electron source/detection regime. Thanks to the temporal coincidence of laser and electron beams and near field interaction of nanoparticle these groups are able to produce unprecedented quantum experiments potentially on the level of single electron. Recent experiments include coherent Rabi and Ramsey oscillation in electron and light interaction [7][8]. But I foresee the possibility of electron-photon entanglement. This example are meant to introduce the concept that there we are at the down of a quantum revolution in the electron beam science. Incidentally these ideas potentially could be even brought to higher energy and to different charged particles. Moreover the recent technologies in laser based electron acceleration could bring in future electron technology on a much lower scale, potentially amenable in a small device outside a lab activity. We think that this emerging technology that leverages quantum properties should find a space in the "sensing" part of "quantum manifesto" at the side of single photon measurement. Whereas electrons are at the moment

		less flexible than photons, they are a more powerful probe of matter because of the small wavelength (the atomic resolution can be easily obtained nowadays) and the electric charge that makes electron the ideal magnetic probe. [1] V. Grillo et al. Measuring an electron beam's orbital angular momentum spectrum https://arxiv.org/abs/1609.09129 [2] Verbeeck, J., Tian, H. & Schattschneider, P. Production and application of electron vortex beams. Nature 467, 301–304 (2010). [3] McMorran, B. J. et al. Electron vortex beams with high quanta of orbital angular momentum. Science 331, 192–195 (2011). [4] V. Grillo et al. Phys Rev. X 4, 011013 (2014) [5] P. Kwiat Phys Rev Lett 74 (1994) 4763 [6] W.P. Putnam M.F.Yanik Physical Review A 80, 040902 (2009) [7] A.Feist et al. Nature 521 (2015) 200 [8] K. E. Echternkamp et al. Nature Physics (2016) doi:10.1038/nphys3844"
Metrology, sensing and imaging	Kashcheyvs	Electrical quantum metrology should be part of the "Quantum metrology, sensing and imaging" component. Detailed scientific and technological arguments will have been submitted of representatives of European national metrology labs (EURAMET Technical Committee for Electricity and Magnetism).
Metrology, sensing and imaging	Bongs	This section highlights in a good way all the fundamental research steps to be taken to use entanglement or other advanced quantum features to enhance sensors and metrology devices. It also names appropriate application areas to motivate the work. However, I am missing suggestions on the pathway to exploitation. the fundamental work suggested will need a lot of technology work, in order to become exploitable. If the Quantum Flagship is to have an exonomic impact to demonstrate to politics that this investment is a good one, then I think there needs to be some explanation on how this economic benefit is going to be achieved in practise. This might be done by pointing to the industry part of the flagship, if there i a separate one. If there is no separate industry part of the roadmap, then one solution could be to add some respective statements here. Other pathways to exploitation outside of the Flagship could be linking up to the application driven research centres, such as the Fraunhofers, ONERA, the UK quantum hubs,...
Metrology, Sensing and imaging	Lodewyck	"Paragraph on atomic clocks

		The frequency stability of laboratory scale microwave fountains clocks and optical ions clocks have now reached the quantum noise limit. Otical lattice clocks, for which this limit is exceptionally low due to a high quality factor and a large number of simultaneously interrogated atoms are expected to reach this limit soon, thanks to recent advents in laser stabilization. Furthermore, these high performances atomic clocks, developed in several metrology institutes in Europe, are now being connected by optical fiber links whose noise is enables the comparison of remote clocks with instabilities much below the quantum noise. Pursuing the quest for ultimate accuracy in time keeping, and along with it the numerous fundamental and applied utilizations of these clocks, will thus require to overcome the quantum noise limit. As of yet, no metrological grade atomic clocks uses quantum correlations to reach a better stability, and proofs of principle have yet to be applied to the higher performing optical clocks. A significant challenge in reaching the quantum regime with atomic clock is to make quantum experiments compatible with the high degree of reliability required for metrology experiments which can run for extend period of time, for instance when used to calibrate international atomic timescales. In addition, the quantum protocols designed to improve the clock stability beyond the quantum limit should not negatively impact the clock accuracy."
Metrology, sensing and imaging	Treutlein	"The current version of the quantum metrology part of the roadmap contains dedicated sections on spin qubit based sensing (section 2.5.2), optomechanics (2.5.3), and quantum clocks (2.5.4). On the other hand, a dedicated section on quantum-enhanced atom interferometers is currently missing and should be added to the document. Interferometers operating with entangled atoms are one of the most active research areas in quantum technology, with a number of important applications in gravitational sensing, acceleration sensing and electromagnetic field measurements. Research in this field involves both ultracold and room-temperature atomic ensembles and has shown very fast progress in recent years, from first proof-of-principle experiments on spin-squeezing to factors of 100 improvements of precision in the most recent work (see e.g. the recent review article http://arxiv.org/abs/1609.01609). It is crucial to further support fundamental research in this direction as well as to support ongoing efforts to commercialize atomic sensing technology. I strongly support the recent initiative of the precision sensing community to include this as well as other missing topics such as the interferometry with squeezed light in the Roadmap document, and more importantly, in the subsequent documents that define the aims and functioning of the QUTE Flagship programme. "

Metrology, Sensing and imaging	Schnabel	"The precision sensing community recently developed a list of concrete suggestions for additions to the Roadmap, to address missing topics and to provide concrete goals for technologies that have already passed proof-of-principle. The Director of the Metrology/Sensing VI indicated willingness to consider such changes, but no action has yet been taken. I strongly support the inclusion of these topics in the Roadmap, and more importantly, in the subsequent documents that define the aims and functioning of the QUTE Flagship programme. The following statements (or similar) need to be added to the roadmap. 1) “In the field of gravitational-wave detection indeed the routine quantum-enhanced sensitivity has been realized already. Since 2010, the gravitational-wave detector GEO600 is equipped with squeezed light, which provides sensitivities beyond the photon shot-noise limit.” 2) The Roadmap needs to make clearer that there exist already high-performance nonclassical light sources, for example by stating: “Development of better performing and of novel sources of non-classical radiation and methods to engineer quantum states of matter to attain comprehensive quantum-enhanced metrology, sensing and imaging.” 3) “Development of quantum back-action evading and quantum-non-demolition (QND) measurement techniques for gravitational-wave detectors.” 4) The existing paragraph about gravitational-wave detection contains mistakes and needs to be changed as follows: “Large-scale laser interferometers with kilometre arm lengths are being operated or constructed in Europe, the USA and Japan with the goal to open the new field of gravitational-wave astronomy. The first detection of a gravitational wave recently occurred at the advanced LIGO interferometer [1]. It currently operates at the quantum shot-noise level for signal frequencies above 150 Hz, and a significantly higher rate of events can be expected by injecting the interferometer with squeezed light. In 2011, a collaboration of scientists from Europe, USA and Australia (LIGO Scientific Collaboration, LSC) reported 3.5 dB quantum noise reduction in the sensitivity of the gravitational wave detector in Germany (GEO600) [2] through the implementation of a squeezed light source. Since then GEO600 has continuously used squeezed states of light during its observational runs [29, see

		below]. In 2013, the injection of squeezed states of light was also successfully tested in one of the initial LIGO detectors in the USA [3]. A noise reduction of 10dB corresponds to an increased sensitivity of $(\sqrt{10})^3 \approx 30$ in the event rate at quantum noise limited frequencies.” 5) The sentence „For instance, in the latter case, picosecond resolution at 3 km distance has been attained“ is unclear. What was nonclassical here? 6) The corresponding existing paragraph is not entirely correct and needs to be changed to: “In addition to quantum correlated multi-photon states, squeezed states of light play an important role for quantum-enhanced sensing. The technology of squeezed light sources has been significantly advanced in recent years with demonstrated noise suppression of 15 dB, which corresponds to just about 3% of the shot noise level [30, see below]. This technology has now matured to a point where real-life applications can be explored. Besides the demonstrations of quantum-enhanced gravitational wave interferometry, squeezed light has been exploited to resolve a small beam displacement [5], which in turn has been used to perform quantum-enhanced microrheology on a living cell [6]. Recently, it was shown that bright squeezed light can be used to calibrate the quantum efficiency of photo diodes without the need for a standard nor the knowledge of the incident light power [30, see below].” 7) A short-term goal should be: “Experimental demonstration that not only the shot noise but also the quantum back-action in laser interferometers can be reduced by squeezed and entangled states. This will give access to the quantum non-demolition regime of force measurements.” 8) The currently stated mid-term goal „Demonstration of quantum enhancements in sensors where there are intrinsic constraints on in-sensor power (i.e. where there is a maximum input optical power due to e.g. sample damage)“ needs to be rephrased since it is already achieved in GEO600. GEO600 cannot be operated at higher laser power due to absorption of light and thermal lensing in the beam splitter.” 9) The following mid-term goal should be added:

		„Demonstrate the transition from the classical world to the quantum-entangled world by entangling the motions of two vibrating mechanical oscillators.“ 10) The following result was overlooked and not included: [28, see below]. This proof-of-principle experiment shows how entanglement can be used to improve interferometric measurement in the presence of noise. 11) The following references need to be added “[28] S. Steinlechner, J. Bauchrowitz, M. Meinders, H. Müller-Ebhardt, K. Danzmann, R. Schnabel, Quantum-dense metrology, Nat. Photonics 7, 626 (2013). [29] H. Grote, K. Danzmann, K. L. Dooley, R. Schnabel, J. Slutsky, H. Vahlbruch, First Long-Term Application of Squeezed States of Light in a Gravitational-Wave Observatory, Phys. Rev. Lett. 110, 181101 (2013). [30] H. Vahlbruch, M. Mehmet, K. Danzmann, R. Schnabel, Detection of 15 dB squeezed states of light and their application for the absolute calibration of photo-electric quantum efficiency, Phys. Rev. Lett. 117, 110801 (2016).” Generell comments to increase the readability of the text: The term “standard quantum limit, SQL” (below) is used with different meanings by different communities in the field of metrology, sensing and imaging. I suggest to avoid this term and use either “shot-noise”/”counting noise”/”quantum measurement noise” or “radiation pressure noise”/”back-action noise”. The term „quantum coherence“ is not suitable for describing the special property of nonclassical light such as squeezed light. "
Metrology, Sensing and imaging	Siegner	Electrical quantum metrology based on the manipulation of single electrons, Cooper pairs, and flux quanta has made tremendous progress in recent years. In particular, different types of single-electron current sources have been developed using semiconductor as well as normal metal and superconductor technology. These sources can be integrated with single-charge detectors [L. Fricke et al., “Self-Referenced Single-Electron Quantized Current Source”, Phys. Rev. Lett. 112, 226803 (2014)] and quantum Hall conductors [F. Hohls et al., “Semiconductor

		Quantized Voltage Source", Phys. Rev. Lett. 109, 056802 (2012)]. There is large potential to adapt these technologies to the field of electron quantum optics and to establish quantum-enhanced measuring techniques for electromagnetic quantities. This aspect should be mentioned in the Section "Quantum Metrology, Sensing and Imaging".
Metrology, sensing and imaging	Schumacher	Unfortunately the aspect of electrical quantum metrology has been completely omitted in the present document. Electrical quantum metrology is the application of solid state quantum effects for of ultra precise electrical measurements and sensing. Such presision electrical metrology can for example be based on macroscopic quantum effects (such as the Josephson Effect or the quantum Hall effect) or on the controlled capture and emission of single electrons in nanopatterned devices. Such electrical quantum metrology allows the ultra precise measurements of voltage, current, resistance, and magnetic field traced back directly to the quantum units of e and h. This electrical quantum metrology is the foundation of all electrical measurements we are carrying out, today. Several european research groups are world leading players in this field (e.g. NPL (UK), LNE (France), PTB (Germany), MPI Stuttgart (Germany), CEA (France)). Already today, electrical quantum metrology, is one of the few quantum technologies with direct industrial application. Furthermore basic research in this field will lead to more advanced applications both on the short and longer time scale (beyond 5-10 years). For example AC Josephson systems that will allow traceable calibrations of AC voltages with quantum precision are presently under development and will find industrial applications within a few years time. On the other hand on-demand single electron sources are presently developed and investigated with respect to the planned redefinition of the electrical SI base unit ampere. These single electron pumps generate a single electron current which has the unique feature of full suppression of shot noise. Therefore these sources offer similar perspectives for electrical measurements as on-demand single photon sources or squeezed light sources for optical measurements. In addition in the future they also might allow the control of the quantum state of the emitted electron (e.g. the spin orientation) with many interesting prospects that are addressed in the emerging field of electron quantum optics. Therefore the field of electrical quantum metrology needs to be represented in the road map.
Metrology, sensing and imaging	Auzinsh	I would like to emphasize the promise of nitrogen-vacancy (NV) centres in diamonds for scaleable sensing and imaging platforms with a high potential for interdisciplinary applications. Also, it is important to remember that deeper understanding of the basic physics involved is essential for continued innovation at the practical and technology level.

Metrology, sensing and imaging	Poirier	The solid-state quantum electrical standards (quantum Hall resistance standards, Josephson voltage standards, single electron current source) are under-represented in the roadmap. However, they are real outcomes from quantum technology, which are revolutionizing the International System of units (SI). Moreover, they are the building blocks for more advanced applications such a quantum multimeter. More generally, while noise reduction is a clear objective of the roadmap, the issue of measurement accuracy and traceability to the SI is not considered. Nonetheless, worldwide consistency of measurements is at the heart of scientific and economic exchanges.
Metrology, sensing and imaging	Levine	Observables map the connections of a system on ever deeper scale up to a complete characterization of individual quantum states. But the hierarchical structure of the density of states of molecules means that one need not go all the way.
Metrology, Sensing and imaging	Vitali	The role and potentialities of nano-opto-mechanical systems is very well described and underlined.
Metrology, sensing and imaging	Schmidt	"We have rewritten section 2.5.4 Quantum clocks to match the structure of the other sections. The updated section was harmonized with representatives from the major metrology institutes within Europe (SYRTE, INRIM, PTB) and is available here: https://www.dropbox.com/s/zz29shme8f5v8mp/QT%20Roadmap-2.5.4%20Quantum%20clocks-20161025.docx?dl=0 Further comments: * In ""2.5 Quantum Metrology, Sensing and Imaging"" the definition of quantum-enhanced metrology ""Quantum-enhanced metrology is concerned with a single task: preparing a quantum state that is sensitive to a parameter, \phi, and implementing a measurement on that state so that the uncertainty in the measurement of the parameter, \Delta\phi, is lower than the uncertainty that would be obtained by using the same number of classical resources."" is unnecessarily narrow. There are a large number of quantum-enhanced protocols that improve metrology beyond classical limits, such as quantum logic spectroscopy, probing/eliminating systematic shifts using nonclassical states or decoherence-free subspaces, composite pulses, ... Furthermore, this definition is not consistent with the first sentence of the section, that ""Specific quantum phenomena such as coherence and entanglement can be exploited to develop new modes of measurements..."". Therefore, I suggest to use the term ""quantum-enhanced (sensor)"" for all sensors that employ fancy protocols, even if no entanglement is involved

		and use the term ""entanglement-enhanced"" for the specific case referred to above. Some of this inconsistency is also found in section ""2.5.1 Quantum metrology"". * In ""2.5.1 Quantum metrology"", ""Atomic Clocks"": The statement ""... a new generation of clocks may be realized when using the recent advances of chip-scale microresonators based optical frequency combs..."" is wrong. Miniaturization of the oscillator in a frequency comb is just one out of many more examples where R&D is required for higher integration; it is certainly not the most pressing one. I therefore suggest replacing the sentence by a more general one: ""While chip-scale atomic clocks (CSAC) based on miniature packaged vapor cells are ubiquitous in navigation and telecommunications, a new generation of clocks may be realized through microfabrication techniques and optical integration that enable dramatic reduction of size, weight and power of the necessary components to create optical atomic clocks."" Furthermore, this section could be extended upon request to account for important applications and perspectives as can be found in section 2.5.4. * ""2.5.4 Virtual facility needs - Quantum engineering"": Addition to bullet point ""Improved infrastructure for high accuracy clock comparisons ... sustainably over the long-term"":, complemented by free-space optical links. Addition to bullet point ""Progressive development in clock stability and accuracy, combined with reductions in size, weight, power consumption and cost"":, through microfabrication and optical integration techniques."
Metrology, sensing and imaging	Boiko	I think that goals need to be defined differently. On one side the present goals are very specific for a few particular research groups/ research projects. They have to be much broader in terms of the subject in order to involve many more research groups in the "Revolution". On the other side, the present goals do not define any criteria on the basis of which one can check if the goal is reached or not in 5 years. Some numbers shall be put in the definition of goals, especially in the Short-term goals.
Metrology, sensing and imaging	Couteau	-Missing keywords: quantum nanodevices, nanomaterials
Metrology, sensing and imaging	Dolata	"Many of the envisaged goals (e.g. 2.5.3. Optomechanical sensors) may be addressed with microwave photonics. Over the last years the field of so called Circuit Quantum Electrodynamics (circuit QED) has grow rapidly and offers promising prospects for the control of quantum systems in the area of Quantum Metrology and Sensing. These systems are based on the interaction of microwave photons with superconducting high quality resonators, nonlinear elements like Josephson-junctions, artificial atoms (Qubits), superconducting quantum metamaterials, quantum-limited parametric amplifiers, SET-based and Josephson single photon detectors, micro- and nano-

		mechanical resonators, etc. Modern technology allows generation of single microwave photons on-demand, tunable and entangled microwave photon pairs bringing less utilized yet advantages for various quantum technological applications. Such solid state realizations of quantum circuits, especially those based on superconducting technology enabling their operation with minimal dissipation, have the charm of being easily scalable and relatively cheap since they are fabricated similar to standard semiconductor circuits, and moreover, they are working with or close to rf telecommunication frequencies. So I suggest adding research and development of "Microwave Photonics" to the agenda. In general I think that "Quantum Metrology, Sensing and Imaging" should not be limited to pure optical systems, other topics to be considered are "Electrical Quantum Standards" and "Electron Quantum Optics"."
Metrology, sensing and imaging	Stefanov	"There is no mention in the document on the promising new spectroscopy techniques based on quantum state of light as reviewed in [""Nonlinear optical signals and spectroscopy with quantum light"" Konstantin E. Dorfman, Frank Schlawin, and Shaul Mukamel. Reviews of Modern Physics (In Press, 2016) arXiv:1605.06746v1.]"
Metrology, sensing and imaging	Hensinger	"There is an alternative approach to build magnetometers which may have a number of distinct advantages. It would therefore make sense to mention it in the roadmap. Please add on p. 122, following the paragraph: 'Magnetometers based on thermal atom ensembles already show spin squeezing, allowing them to surpass the sensitivity of SQUID magnetometers, but without the need of cooling. The potential of brain monitoring relating to dementia, epilepsy and trauma research, has triggered extensive activities in the development of these sensors in the US and in Europe.' the following sentence: 'An alternative approach to construct room temperature magnetometers exists utilizing trapped ions [ref] with applications in chemistry, medicine and national security. Such devices could also be used as portable atomic clocks.' [ref]: I. Baumgart, et al., "Ultrasensitive Magnetometer using a Single Atom", Phys. Rev. Lett. 116, 240801 (2016)"
Metrology, Sensing and imaging	Flury	"I found a lot about metrological concepts and principles but very little on how quantum sensors have the potential to transform everyday life applications in the near future. At least for the field of quantum inertial sensors and optical clocks – the field I am familiar with – this potential seems evident. I expect these sensors to become workhorses for a vast range of applications in engineering, geodesy, and navigation, comparable to the ubiquitous GPS positioning or acceleration sensors of today. I add some more formulations on this in the paragraphs below in case they may be useful in the process.

		I guess many will agree that quantum inertial sensors are at a stage where a large variety of innovative options and sensor configurations can be explored, and if this is done, that one can expect sensors with extreme accuracy and versatility that may be very compact and very robust with respect to environmental disturbances, and that dedicated research on this field is the basis for sensors that are ready, e.g., for field applications, potentially for mass production, and for space applications, and probably for spin-offs of many kinds. I think that while the quantum computing and quantum information sections of the roadmap provide a clear case, the sensing section provides much less clear answers about why to invest into this field. I also miss a compelling rationale explaining the subsections of the sensing chapter: which types of quantum sensors are being considered and why? Of course, sound metrology concepts are important but one should never forget about the applications! And this is something that could really be showcased very nicely. Here I add two more paragraphs as an attempt to showcase applications of quantum sensors: On a horizon of 10-20 years, quantum sensors have the potential to become workhorses for a vast range of applications in engineering, geodesy, and navigation. Their role and their markets will be comparable to the ubiquitous use of GPS position sensors or electronic acceleration sensors today. Quantum inertial sensors for sensing acceleration, rotation or tilt will facilitate the accurate positioning and tracking of vehicles and moving objects, e.g., for construction, transportation and infrastructure engineering. Quantum gravimeters will allow locating subsurface structures such as groundwater or mineral resources based on gravity signatures. Quantum sensors will enhance the capabilities of Earth observation satellite missions, e.g., for quantifying and monitoring climate change processes and the global water cycle. Similar to GPS, measurements with quantum sensors will allow transforming the fundamental geodetic reference networks, providing atomic standards for geo-metrology to monitor the restless planet Earth with all its continuous deformation and change processes to the mm accuracy. This is very beneficial for geodesy because there is a strong need for better knowledge of the variations of the geometry and the gravity field of the Earth on global and regional scales. Particularly fascinating is the very practical perspective to use optical quantum clocks

		and continental-scale optical frequency transfer networks to define a world height system based on atomic transition frequencies and the principles of Einstein’s General Relativity. Such a well-defined and stable height reference does not exist today but would be very beneficial for many applications such as monitoring sea level rise, tectonic uplift or subsidence, and volcanic activity."
Metrology, sensing and imaging	Manninen	"Quantum Sensors and Metrology is an excellent key pillar of activity that can be used to illustrate end user applications of quantum technologies. However, in the present version of the Quantum Technologies Roadmap, Sections 1.5 and 2.5 on Quantum Metrology, Sensing and Imaging are focused on rather special and narrow subfields of optical quantum measurements. Especially, a very important field of electrical quantum metrology and electrical quantum sensors is missing from the roadmap altogether in spite of its present and potential importance. Quantum standards based on Josephson effect and quantum Hall effect are the backbone of electrical metrology. New research topics that should be added into Section 2.5 of the Quantum Technologies Roadmap (and into the research agenda of quantum metrology and sensing in the Quantum Technologies Flagship) include: - Superconducting quantum sensors and actuators. - Solid-state quantum radiation sensors with single-photon sensitivity for microwaves, applications include detection of qubit states in circuit QED systems. - Development and studies of single-electron pumps as a quantum current standard for electrical metrology. In analogy with the ""squeezed state"" lasers of precision optical metrology, current generated by a single electron pump it is characterized by suppression of shot noise. Single-electron pumps can also be applied to study “quantum optics with electrons”."
Metrology, sensing and imaging	Paraoanu	magnetic field sensors based on superconducting qubits could be as well mentioned in the document (e.g. using a flux qubit to detect magnetic fields, as done by A. Lupascu in Canada)
Metrology, sensing and imaging	Paternostro (on behalf of COST “Quantum Technologies in Space”)	"page 15: add the bullet points ""The development of space-borne quantum-limited sensors for measuring changes in distances, as well as investigating the boundaries of quantum mechanics"" & ""Development of reliable space-based cold-atom experiments for high-precision tests of general relativity and Planck-length physics, as well as space-based optical atomic clocks for improved precision in geo-positioning, Earth observation.""

		page 122, end of the first paragraph: add ""Further improvements in sensitivity are expected by operating gravitational-wave detectors in space, where baselines as large as 1-to-5 million km are planned for the LISA mission."" page 122, end of the second paragraph: add ""Matter-wave interferometry in microgravity environments, or in space, will allow novel high-precision tests of general relativity, Planck-length physics, and will provide benchmarks for possible deviations from the standard model of physics."" page 123, end of third paragraph: add ""The limits of quantum mechanics will also be open to investigation. Levitated particles, in particular, provide the means to test hypothetical modifications to quantum mechanics that are only relevant at large mass scales. Such systems also stand to gain significantly by operating in space; this is the subject of the MAQRO proposal [R. Kaltenbaek, et al., EPJ Quantum Technology 3, 5 (2016)]."" page 126, end of first paragraph: add ""Substantial progress has been made towards cold-atom interferometry in microgravity, demonstrating atom interference on parabolic ""zero-g"" flights (ICE). This is particularly significant in experiments in the Bremen drop tower (QUANTUS), which will soon lead to the first atom-interferometry experiments on a sounding rocket (MAIUS)."" page 127, end of ""Atomic clocks"", add ""In 2016, a cesium clock (PHARAO) will be launched to the International Space Station, and the mission proposal STE-QUEST suggested to use an improved version of the PHARAO clock or even an optical atomic clock to test the gravitational redshift in a highly elliptical orbit, and to synchronise atomic clocks on the ground."" page 129, end of Sec. C: add ""Current experiments do not permit to falsify all conceived extensions to quantum mechanics, nor quantum mechanics itself, at mass scales of interest. It remains a challenge to produce systems that are resilient to ordinary sources of decoherence to the required levels."" &, at end of Sec. E: add bullet point ""Falsification of quantum mechanics on certain size or mass scales, or of widely-studied hypothetical theories.""""
Metrology, sensing and imaging	Cost Action	The comment is available on request at cost-nqo@uni-siegen.de
Metrology, sensing and imaging	Schiller	"General impression: =============== The section on quantum metrology needs significant improvements.

		Right now, there are too many goals. The goals should be quantified and should be verifiable. The utility of the goals must be clearly spelled out. A reasonable balance between QT for fundamental science and QT for real-world applications should be developed. Overall, the roadmap must be a realistic one, otherwise it will not be taken seriously and would do a disservice to the community. One should also be careful with goals such as “All integrated chip scale XY sensor”. Such developments are so expensive that only a dozen would fit the flagship funding envelope. More specific comments on the topic of atomic clocks: == In the introductory text on atomic clocks, p. 127 of ""QT Roadmap"" I do not agree with the statement ""...a new generation of clocks may be realized when using the recent advances of chip-scale microresonators based optical frequency combs..."". In fact, a new generation, and possibly more than one generation, may be realized without chip-scale microresonators. Even many applications will not require such microresonators, because they can be implemented with the more traditional fiber-laser-based combs. While microresonators are an interesting approach, they are not all-important. In addition, this introductory text does not give a good overview of the state-of-the-art, which is the intended purpose. Together with colleagues P. Schmidt, C. Salomon, and others, an improved text for replacement of the text on p. 127 and the section ""2.5.4. quantum clocks"" on p. 138 - 140 has been drafted. It has been uploaded by P. Schmidt as a file ""QT Roadmap-2.5.4 Quantum clocks....."" The above text contains a set of goals that are concrete, application-oriented and quantified. They replace the goals on clocks on p. 129 of the original file ""QT Roadmap 2016"", which should be removed."
Metrology, sensing and imaging	Macucci	"On Page 68, in the Medium-term goals there is text reading ""and low noise (< 1 Hz)"", however the Hz is not a unit of measurement of noise, which can be expressed in terms of power spectral density [V^2/Hz] or [A^2/Hz], of r.m.s. value over a given bandwidth [V]. Overall, the discussion on noise should be made more pertinent, also presenting the different possible approaches for mitigating it."

Metrology, sensing, imaging	Mitchell	"As part of the Metrology and Sensing community, I am concerned that the Metrology/Sensing section of the Quantum Technologies (QUTE) Roadmap favours technologies that are hypothetical or barely proven in the laboratory, while minimizing technologies already demonstrated at the proof-of-principle, applied science, industrial, and commercial levels. If also the Flagship minimizes these advanced sensing methods, it will discard decades of excellent technological development, and diminish the research communities with most experience turning fundamental results into working solutions. Moving technologies from the research laboratory into practical application is central to the goals of the Flagship. This famously difficult transition, crossing the ""valley of death,"" should not be underestimated. Technologies that are already far advanced in this transition should not be discarded in favour of technologies that have yet to begin it. In the current Roadmap, there are detailed goals for several sensing technologies that to date only exist in research laboratories, including interferometry with entangled single photons, field sensing with NV centres in diamond, and quantum optomechanics. In contrast, technologies that have already passed the proof-of-principle stage are for the most part not included in the goals. Examples include interferometry with squeezed light, field sensing with atoms, and gravitation/acceleration measurements with atoms. These more advanced technologies have proven practical in the real world: squeezed light has improved the GEO600 and LIGO gravitational wave detectors, atomic sensors are sold commercially for use in medical diagnostics and geophysical industries. They are mentioned in the Roadmap as background (state of the art) but not as goals to be pursued. The precision sensing community recently developed a list of concrete suggestions for additions to the Roadmap, to address missing topics and to provide concrete goals for technologies that have already passed proof-of-principle. The Director of the Metrology/Sensing VI indicated willingness to consider such changes, but no action has yet been taken. I strongly support the inclusion of these topics in the Roadmap, and more importantly, in the subsequent documents that define the aims and functioning of the QUTE Flagship programme."
Scientific roadmap	Anonymous (upon request)	I wasn't able to understand the role of the Virtual Facilities from the document.

Scientific Roadmap	Montangero	(see document “flagship and tensornetwork”)
Scientific Roadmap	Joachim	Scientific Roadmap: One issue is missing in the scientific roadmap: surface science at the atomic scale which is offering a lot about quantum enginnering, quantum control of atomic scale surface states (like dangling bond) and atomic scale contacts
Scientific Roadmap	McGettrick	I would have the same comment as before: I would only comment in general terms. I think the whole research area is / should be as important for "computer science" as it is for physics. I think, at many points, a little more emphasis should be made on the fact that ultimately we are designing quantum algorithms, i.e. software. More of this research should sit inside the computer science community. Indeed - though it is arguable - I think a better title for the whole project is "Quantum Computing Technologies", or "Quantum Information Technologies"
Scientific Roadmap	Galofaro	I'm interested in an application of QT to Information Retrieval, a filed which grew up in the last ten years. This is why, from my point of view the proposed document does not include many new fields in which QT is a promising framework. I think, for example, to Quantum Machine Learning, which is currently developed at the MIT and by many international stakeholders in ICT.
Scientific Roadmap	Campbell	"I found the 5 Virtual Institutes and the scientific content within to be an excellent overview of the R&D problems relevant to quantum technologies. I also believe there must be some element of ""cross-cutting"" structure that intersects across the institutes. However, I found the two Virtual Facilities were a poor way to capture cross-cutting research themes. In particular, there were only two Virtual Facilities: engineering and control. With only two examples it was hard to discern the pattern that defines a Virtual Facility. The engineering virtual facility was vast and seemed to encompass the majority of the experimental challenges. Whereas, quantum control is much smaller topic. I note that in the consensus working group document the proposed structure appears to be slightly different. The document proposes 4 pillars corresponding to the 5 Virtual Institutes, but with the theory VF removed. In place we have ""theory: applications and protocols"" as 1 of 3 areas of cross-cutting activity. This seems reasonable. I would be surprised if ""theory"" was assigned its own pillar in a flagship geared towards delivering technology. At the same time, many theory results apply across hardware platforms. It would be of great benefit if the flagship supported interaction (e.g. between theorists) working within distinct pillars, with specific funding

		earmarked to facilitate this interaction. Lastly, I remark that I was unsure what was meant by ""Enabling Science"" as a cross-cutting activity."
Scientific roadmap	Von Klitzing	The main problem of the document is that it is somewhat unbalanced. It tries to include all subjects, but in doing so reduces the weight of some of the most important ones. For example opto-mechanics is mentioned 50 times on 11 pages, whereas the more traditional (and arguably advanced) atom based devices are largely ignored.
Scientific roadmap	Kominis	My general concern with the roadmap document is that it seems a bit restrictive on its outlook on the future development of quantum science. In particular, the stated goals are "linear" extensions of what is currently researched. The problem with that is the following: (a) What is currently researched in quantum science may not necessarily form an active field of research 5 or 10 years from now, because e.g. a particular technique might hit a dead end. (b) New and as yet unpredictable discoveries may radically alter what one currently thinks will be the natural continuation of current research. To give an example, the study of quantum effects in biological systems forms a current niche in quantum science, and is rightly included in the roadmap, but ten years ago, if there was a similar roadmap designed back then, such studies would not be part of it, as they had not yet appeared, nor predicted. Thus, the current roadmap might be restrictive of such novel outbursts of quantum science research that we are not yet aware of. In terms of funding, it would be unfortunate that what makes research most exciting, i.e. the unpredictable discoveries, are not given proper support because they are not outlined in the roadmap. Thus, at the practical level, the roadmap text should explicitly elaborate on and support the possibility of blue-sky research related to quantum science in general. Along the same lines, it would be unfortunate to push too much for the link between basic quantum science research with innovative and marketable technology. The history of science is full with examples were diruptive innovations just appeared randomly out of the blue. There are few researchers that wouldn't like their research output to trigger the development of novel products, however, putting too many restrictions on the style of research regarding this aspect will have negative repercussions both for fundamental research and for applied market-related research. The example I use with my students is, imagine if Townes wasn't left alone to study e/m cavities and stimulated emission, but instead was instructed by the dean to come up with a new cosmetic or metal cutting technique. Would he discover the laser ?
Scientific roadmap	Bertels	I think the document tries to cover all and thus too many fields which will lead to effort dilution
Scientific Roadmap	Kashcheyevs	I'd like to bring the attention to a recent promising cross-field development directly relevant to the challenges of electronic semiconductor qubits and quantum metrology of charge and current.
Scientific roadmap	Charbon	I would add a section dedicated to classical circuits and systems for the control of quantum processors. This section could be part of the Quantum Control segment of the document (p. 16 and following) and focus on

		cryogenic circuits for the control of quantum processors. This section should be much more specific than it is now ans reference circuits and systems implemented preferably in CMOS technology operating a cryogenic temperatures. See addendum.
Scientific Roadmap	Schnabel	"As part of the Metrology and Sensing community, which includes the gravitational-wave community, I am concerned that the Metrology/Sensing section of the Quantum Technologies (QUTE) Roadmap favours technologies that are hypothetical or barely proven in the laboratory, while minimizing technologies already demonstrated at the proof-of-principle, applied science, industrial, and commercial levels. If also the Flagship minimizes these advanced sensing methods, it will discard decades of excellent technological development, and diminish the research communities with most experience transforming fundamental results into working solutions. Moving technologies from the research laboratory into practical application is central to the goals of the Flagship. This famously difficult transition, crossing the ""valley of death,"" should not be underestimated. Technologies that are already far advanced in this transition should not be discarded in favour of technologies that have yet to begin it. In the current Roadmap, there are detailed goals for several sensing technologies that to date only exist in research laboratories, including interferometry with entangled single photons, field sensing with NV centres in diamond, and quantum optomechanics. In contrast, technologies that have already passed the proof-of-principle stage are for the most part not included in the goals. Examples include interferometry with squeezed light, field sensing with atoms, and gravitation/acceleration measurements with atoms. These more advanced technologies have proven practical in the real world: squeezed light has improved the GEO600 and LIGO gravitational wave detectors, atomic sensors are sold commercially for use in medical diagnostics and geophysical industries. They are mentioned in the Roadmap as background (state of the art) but not as goals to be pursued."
Scientific roadmap	Haug	"Not all the research fields investigated in Europe are treated in an equivalent depth.There is a community in Europe interested in single-electron control and studying quantum physics quite in analogy to quantum optics in electronic semiconducting devices. Such investigations are not mentioned in the roadmap. There are papers as e.g. Nature Nano 10, 46 (2015) and Nature Nano (in print). There is also a special issue of PSS under the way with more than contributions from more than 20 different groups and the title 'Single-electron control in solid state devices'"

Scientific roadmap	Sigg	Overall, this is a strong and comprehensive document. Many citations with a detailed analyzes from state of the art to challenges in long term. The document gives a sense of completness which however, is not given in all aspects. To give an example, the Quantum Molecular pathway is mostly absent, while the virtual facilities are just mentioned but much details. For the Quantum Control, the facility character is not at all evident, from that only devoted subparagraph 1.6. The second Quantum engeneering facility does not even appear in a paragraph, but only is detailed in the wish-list of the Q-Computing community.
Scientific roadmap	Prati	The document systematically covers a very large number of topics and it represents a very good starting point for the discussion of the community. As a result of the discussion with industries of the consortium QuEST, we stress that in its current version the topics are mapped in some cases by application, while in some cases by technology. For example main headings correspond to Virtual Institutes of Qurope, therefore on one hand there are "Quantum computation" and "Quantum communication" (similarly to the two applications targeted by the respective US roadmaps) which are classes of applications (performing quantum information processing and granting secure communications respectively), while on the other hand "Quantum information theory" and "Quantum control" are not applications as they are means including methods and technologies devoted mainly to quantum communications and computation etc. The same occurs throughout the whole document, as also sub headings mix applications (Quantum Random Number Generators, Quantum Key Distribution systems...) with technologies (Sources, Detectors...). Quantum Metrology, Quantum Sensing and Quantum Imaging are three different applications, currently under the same section. In order to rationalize the perspectives offered by the Quantum Technologies and consequently to raise the interest of the industry, the Roadmap should be re-arranged in terms of applications. It is of importance to prioritize those applications identified by the roadmap matching the industrial supply chains existing in EU. Another possible concern arises from the fact that the separation between Quantum Simulation and Quantum Computation looks artificial. As clarified by the document itself, the experimental approaches used in both are almost the same, while their difference consists in the exploitation of the hardware, as one is aimed to small simulations requiring even small number of quantum subsystems, and the other to achieve a universal machine where complex algorithms can be treated. A quantum computer will be hopefully able to perform quantum simulations, so such a classification relies only on the algorithms to be currently implemented respectively.

		It looks that some subsections are more plans of individual groups, as revealed by sentences such as "Firstly, we wish to characterise and verify entangled resources..." than general perspectives, so the scope should be generalized. About both the Short-term goals and the Long-term goals, the document provides a good starting list but we noticed that several goals lack of quantitative targets and detailed benchmarks, including TRLs references.
Scientific roadmap	Remacle	I agree with the overall structure of the document but I have comments to make about directions of research that should be pursued.
Scientific roadmap	Levine	I have additional points that I consider to be essential for the introductory part as are detailed below. In essence I suggest that molecules offer novel advantages for quantum technologies and quantum computing.
Scientific roadmap	Michielsen	"Contribution of Forschungszentrum Jülich to the online consultation of the Quantum Flagship Initiative The Quantum Technologies Roadmap is a highly welcomed step towards the development of computing and other information processing devices based on quantum physics. In essence, there are two fundamentally different approaches to use quantum physics for computations, (i) the quantum circuit model, and (ii) adiabatic quantum computations, or quantum annealing. The Roadmap of the QT flagship community makes short mention of quantum annealing as a means of quantum computing (quantum annealing is shortly mentioned on pages 19, 20, 29 and 73). Quantum annealing appears to be not included as a future direction of research as it is not listed under section 1.1. Indeed, D-Wave quantum machines are mentioned as devices implementing quantum annealing (pages 19 and 29) and solving non-trivial problems beyond the reach of existing gate-based quantum processors (page 20), but with a computational speedup that remains a source of heated debate (page 29). In the roadmap some research on quantum annealing is mentioned under “Quantum Simulation” (section 2.3) with the belief that photonic, cold-atom, and ion systems are highly promising platforms in this respect. In this section current D-Wave quantum annealers unfortunately are not mentioned as quantum systems worthwhile to study, while they are far from being understood from a scientific point of view. What is more, industries with high demand on computing for optimization as well as machine learning problems, e.g. mechanical engineering, process technology, automated driving, flight route optimization, internet services or gene-gene interactions have become very interested in the potential D-Wave capabilities.

		We are of the strong opinion that D-Waves Systems offers a quantum computing technology (their newest machine D-Wave 2000Q with more than 2000 qubits and an enhanced quantum control of the qubits will be released in 2017) that allows exploring the benefits of directly using quantum processes in computations. We consider it very important to test the quantum annealer in a research and development environment with the goal to build up competence in Europe in using these technologies for scientific and industrial applications. While the vision of exponential quantum speedup cannot be obtained with the current quantum annealer architectures, in near future, the technology will be massively enhanced, and speedups obtained in a hybrid quantum-classical compute mode might become very important. Moreover, although simulated quantum annealing based on quantum Monte Carlo simulations, is believed to efficiently mimic the computation performed by the D-Wave machine on a classical digital computer, the real-time dynamics of these quantum devices and their control is not yet understood and by matter of principle cannot be understood from this type of simulations. Hence, statements about obtained speedups based on comparisons with these simulations should be considered with some care. A lot more fundamental research in this respect is required before questions about a quantum speed up of quantum annealers can be answered. Moreover, although the concept of a quantum speedup is very important in (quantum) theoretical computer science, for real-world applications in a particular branch any speedup compared to classical algorithms run on classical digital computers is of highest importance. In order to assess such situations, fine-tuned benchmarks are required. Forschungszentrum Jülich, in a consortium of public and large industrial partners, plans to operate a D-Wave machine of the newest generation and to establish a Quantum Annealing Centre for Scientific and Industrial Applications in Germany and Europe. This should allow providing, within the next 5 years, European researchers with the required skills and competences in order to become leaders in the field of quantum annealing. An attractive provisioning-concept proposed by T-Systems SfR, one of our partners, is to take a public cloud infrastructure (The Open Telekom Cloud - OTC) hosted in Europe and operating under European law – specifically with respect to data-protection – as an access-infrastructure to quantum computing. For the users a forthcoming quantum computing system would look like a special “flavor” of a cloud-resource, specifically well suited for

		optimization tasks. Together with HPC-resources, FPGAs and GPUs, it would be part of a computational ecosystem in which any kind of business- or research-workflows can be mapped to optimal infrastructural resources. We are convinced that quantum annealers as a topic for research and development can very much strengthen the Quantum Technologies Roadmap, in particular as leading companies (in Germany and Europe) are highly interested and thus will also be brought into contact with all the broad aspects of development of quantum technologies. Forschungszentrum Jülich is highly interested that research in quantum annealing algorithms will become part of the European roadmap. With best regards, Prof. Dr. Kristel Michielsen Prof. Dr. Thomas Lippert Forschungszentrum Jülich GmbH Germany"
Scientific roadmap	Vitali	The document is highly detailed and comprehensive of the overall activity in QT in the world.
Scientific roadmap	Bajoni	"The document structure lacks, in my opinion, two very important sections.There are several devices that are transversal to most if not all areas (sources of quantum states of light, integrated detectors, quantum memories), and I believe that there should be a separate section on ""quantum components"" or ""quantum devices"" to help coordinate the development effort, with particular emphasis on integration. The lack of coordination could result in delays and wastes inside the project, and already results in contradictions inside the document (for instance efficient integrated detectors would be needed for many short and medium term goals stated for LOCQ (page 26), but their development is declared a long term goal in the quantum cryptography section (page 67)). In many parts the documents refers to the importance of cheap implementation and operation of the various protocols, but this is only possible through a consistent and coherent engineering effort to develop efficient integrated components. Also, there is almost no mention to intellectual property. There is a difficult balance between the advantages of openness and the need of patents. I believe the document should spend some paragraphs on possible strategies

		to both disseminate the results (in order to seed further research), but at the same time protect the achievements reached in the project."
Scientific roadmap	Peev	The structre is really good
Scientific roadmap	Schmidt	"I am missing a clear definition what is included in ""Quantum Technologies"" and what isn't. Are e.g. controlling a 2-level system on the Bloch sphere or single photons enough? If not, what are the criteria? Almost every system can claim to require or demonstrate quantum correlations in the future. As an example, quantum metrology devices based on e.g. single-electron systems are entirely missing from the roadmap. Why? One more detailed comment: Section 1.5, ""6. Implementation of entanglement assisted atom clocks"" seems unnecessarily restrictive. Replace by ""6. Implementation of advanced interrogation protocols in atomic clocks, e.g. using correlations and entanglement"""
Scientific roadmap	Kröll	The bottom up approach is strongly supported, however, it may be important to continuously update the roadmap, especially the listed goals.
Scientific Roadmap	Mihailovic	"While the QUTE working group consensus report highlights ""openness to involving emerging actors, attracting the best talent also from other fields"" The roadmap text does NOT envisage revolutionary new solutions beyond the ones currently offered. This needs to be corrected, otherwise new solutions will be blocked simply because they are not mentioned by the roadmap. Some specific comments: 1. Sometimes the same issues (topics) are repeated in different places. 2. Some important topics are missing (see below). 3. Some challenges are missing, particularly (i) nonequilibrium quantum systems, (ii) the classical/quantum interface for Big data input and (iii) the long standing challenge of low temperature memory."
Scientific Roadmap	Meijer	"Ion beam techniques for realizing solid-state quantum devices Ion beam techniques like ion implantation are CMOS fabrication processes in semiconductor technology and since decades constitute the standard tool to introduce impurity atoms into host materials. Using collimated or focused ion beams, ion implantation allows addressing single atoms inside a given solid with nanometer precision and is,

		therefore, ideally suited for the fabrication of future quantum devices. Indeed, ion implantation has, for example, been used to fabricate a quantum register with NV center or 31P spin qubits in Si. Furthermore, ion beams are powerful tools for materials characterization and modification, for example, for ultra-sensitive trace element analysis or diamond-to-carbon conversion. However, due to the statistical nature of ion beams, the highest probability to obtain exactly one ion in an "one-shot" implantation is only 37%. As a consequence, ordered arrays of hundreds or thousands of atoms, essential for the fabrication of a solid-state based quantum computer, are impossible to fabricate with this technology. Therefore, efforts have been made to develop a deterministic ion implantation, i.e. techniques to count each individual ion that is implanted. Deterministic single atom implantation relies on counting each ion before, or during, or in its implantation event. However, up to now, none of the approaches has gained sufficient maturity to allow fabrication of quantum devices beyond the few-atoms scale so that further technical development is required to exploit the potential of deterministic ion implantation in the field of quantum technologies. A second key requirement is a spatial precision of implantation sites of the order of a few nanometers. Implantation through nm-scaled holes or masks, but also steering laser-cooled ions from a Paul trap have been able to reach a spatial resolutions below 10 nm and further progress is expected. For either single ion implantation approach, it is necessary to have a good control of the depth to which the ion penetrates and the lattice location it reaches. These can be optimized with insights from quantum mechanics-based molecular dynamics simulations of the ion implantation process, that allow predicting implantation angle and crystal orientation conditions which minimize the beam spreading and damage of the host material. In summary, ion beam techniques are essential tools for the fabrication of quantum devices. In order to fully exploit their potential, further technical developments as well as theoretical work are required with excellent prospects to enable them to meet the demanding requirements of a scalable future quantum device fabrication.

		In order to achieve the prospective scientific progress mentioned above, it is necessary to develop these new engineering technologies with a dedicated and joint effort. Therefore, we propose to form a consortium of 22 institutes in 8 countries in Europe. Our main challenges and goals are written in an attachment. We would appreciate if the consortium would consider including this proposal into the given roadmap. Jan Meijer jan.meijer@uni-leipzig.de University Leipzig – Germany Daniel Spemann daniel.spemann@iom-leipzig.de IOM/University Leipzig – Germany Ettore Vittone ettore.vittone@unito.it University of Torino – Italy Marco Truccato marco.truccato@unito.it University of Torino – Italy Paolo Olivero paolo.olivero@unito.it University of Torino – Italy Kai Nordlund kai.nordlund@helsinki.fi University Helsinki – Finland Ferdinand Schmidt-Kaler fsk@uni-mainz.de Mainz University – Germany Bernd Rauschenbach bernd.rauschenbach@iom-leipzig.de IOM Leipzig – Germany Richard Curry r.j.curry@surrey.ac.uk University of Surrey – UK Gianluca Ghigo gianluca.ghigo@polito.it Politecnico of Torino – Italy Jean-Francois Roch jean-francois.roch@ens-cachan.fr CNRS/Cachan Paris – France Joerg Wrachtrup wrachtrup@physik.uni-stuttgart.de

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Scientific roadmap	Manninen	I think that the Quantum Technologies Roadmap is too much focused on optical quantum technologies, and solid-state quantum technologies seem to be compressed into only two subsections, 2.1.3 (Superconducting circuits) and 2.1.4 (Electronic semiconductor qubits), and partly into 2.3.2 (Experimental platforms for quantum simulators).
Scientific Roadmap	Cost Action	The comment is available on request at cost-nqo@uni-siegen.de
Scientific Roadmap	Macucci	"Overall the Roadmap is a valuable document. In the following I am listing a few issues that would deserve improvement, pointing out a few weak points. We also include a list of possible typos.

		On Page 5 it is stated that all possible implementations should be pursued. Is this wise? Maybe focusing on a number of more promising implementations could be a more practicable strategy. Referencing is very inhomogeneous. Some sections have no references, other have many references but the single sections have a very different number of references, not proportional to the existing literature. We also have a list of typos that we can supply if needed."
Scientific roadmap	Ferrus	This provides a pretty good document of the european activities and research subjects on quantum information
Simulation	Brantut	"One aspect that is missing in the bullet list page 72-73 is the understanding and use of driven system, e.g. open systems in cavities, impurities in a bath, mesoscopic systems connected to reservoirs. As a tool this may be way to dissipatively prepare new quantum states but also see emerging phenomena due to the open nature of the system. In the description of the physical approach in page 72, paragraph 3, it is written that « a first step […] is usually to identify the appropriate underlying Hamiltonian… » In my opinion the logic here is wrong: for many examples, like the issue of high-Tc superconductivity stated in the document, identifying the proper Hamiltonian would be the final step and the final goal of the simulation, in that it would indeed solve the problem. There is a conceptual difference between simulating a Hamiltonian and solving an open question. These two aspects could be covered by Quantum Simulation, but the presentation should also leave a room for simulations which goal would be precisely to identify the proper ingredients necessary to produce a certain class of macroscopic effects like superfluity or magnetism. In the working definition page 74, the second and third points specifically refer to « models » while the first one is more general. I would suggest to make more precise what it means to « simulate » a model and what the outcome of the simulation should be. The outcome has to be a certain macroscopic property that is of interest, such as ground state energy, correlation functions, transport coefficients etc.

		In the short or medium term goals, one could state explicitly that we want to « solve at least one open problem for which there is no answer to date using a quantum simulation ». We do not need to say now which problem exactly, but we would like to say in 5 years « There was this question, and we solved it using our quantum machine and no-one could have done it before ». That would make it more credible and concrete. At the moment one could criticize the fact that the stated goals seem to improve our simulators just for the sake of it, and may be in >10 years there will be some physics outcomes. On experimental approaches and perspectives in page 80: the first two points on cold atoms lead the reader to think that there are two ways to do quantum simulations with atoms, namely optical lattices and atom chips. I find this presentation a bit biased: (i) Bulk trapped atoms have been among the most successful quantum simulation, for example with the equation of state measurements that had enough precision to rule out some theoretical approaches. I suggest to formulate the first point in such a way that bulk gases, which also have tunable interactions etc also appear explicitly as a very prominent implementation. (ii) Concerning the second point, atom chips is one particular way to implement double well patterns and study non equilibrium physics. I suggest to put it in the more general context of engineered potentials, which also comprises all the work on digital mirror devices, box potentials and mesoscopic that are generated optically."
Simulation	Weitz	"Quantum simulation using gases of light (photons and polaritons) in periodic potentials could be emphazised more explicitely. Such systems are expected to allow (at least for the photon case) that if the ground state is an entangled manybody state this can be prepared by cooling alone in a thermal equilibrium process (see e.g: arXiv:1303.5772). For a recent conference on quantum simulation with photonic systems see: https://qlightcrete2016.org/ Several groups in Europe are working on this reserach"
Simulation	Arrighi	It is one thing to build quantum simulators, and another to feed them with something to simulate. Both are needed. But that second part, the "quantum simulation software", is not clearly stated in my opinion. There is for instance an ongoing, wide effort to reformulate Quantum Field Theory (Lattice Gauge theories, Dirac Eq., QED, Curved spacetime or not) in discrete terms (Local hamiltonians, Quantum Walks, Quantum Cellular Automata...) so that they can be simulated on quantum devices... which I think deserves to be represented. I am willing to write a paragraph on these if needed.

Simulation	Weimer	"I believe that Sec. 2.3.1 should be strengthened by including a statement on the prospects of quantum simulation of open quantum systems, especially as several examples are already being mentioned in Sec 2.3.2 as experimental platforms (trapped ions, excition-polaritons, circuit QED). As the classical simulation methods for open systems are still very limited, open quantum systems also provide a realistic route to reach quantum supremacy in the near future. Proposed text: Open quantum systems are promising candidates for quantum simulation, as many classical simulation techniques developed for closed systems cannot be applied. These systems also allow to dissipatively prepare highly entangled many-body states as the stationary states of the dynamics [1-3] and hence hold great potential to enable other quantum technologies. [1] S. Diehl, A. Micheli, A. Kantian, B. Kraus, H. P. Büchler, P. Zoller, Quantum States and Phases in Driven Open Quantum Systems with Cold Atoms, Nature Phys. 4, 878 (2008). [2] F. Verstraete, M. M. Wolf, J. Ignacio Cirac, Quantum computation and quantum-state engineering driven by dissipation, Nature Phys. 5, 633 (2009). [3] H. Weimer, M. Müller, I. Lesanovsky, P. Zoller, and H. P. Büchler, A Rydberg Quantum Simulator, Nature Phys. 6, 382 (2010)."
Simulation	Remacle	Since our approach allows for computing in parallel all the observables and to measure them, it provides a complete tomography of the quantum state of the system and allows to simulate the quantum dynamics of other quantum systems.
Simulation	Levine	Massive parallelism is possible using the internal connectivties of states of molecules. It is this that allows a range of different inputs to lead to readable outputs. Instead of N inputs leading at most to N outputs computing by observables allows an N(N-1) connections.
Simulation	Bajoni	I believe that an important avenue of research not mentioned in the text would be to find classical platforms that can simulate quantum computing protocols as efficiently as possible. These platforms could be used to test algorithms (for instance error correction) on a small scale (a few qubits) before running the same algorithms on actual quantum computers which will probably be very expensive to operate.

Simulation	Morsch	I was suprised to see that there was is mention of Rydberg atoms as a platform for quantum simulation (they are only mentioned as tools in conjunction with, e.g., trapped ions), although there are both a very active research community as well as a H2020 FET project on that topic.
Simulation	Couteau	Missing keywords: quantum nanodevices, plasmon-photon entanglement, quantum optics and metamaterials,
Simulation	Mihailovic	"The Challenge: quantum simulators scalable beyond 1000 qubits. The listed ones (NV centres, cold atoms, quantum dots, JJ devices etc.) have been known from some time and suffer from known drawbacks of scalability and addressability, particularly in systems with a larger number of qubits. A new, innovative solution: Self-organized topological defects (TDs) on a polaron lattice are potential quantum simulators controlled by an STM tip. The mesoscopic size of individual TDs allows individual setting up of initial state, control by transverse field using a tip and readout of the final state. The solution solves the problem of scaling: quantum relaxation of a 2-dimensional 100x100 polaron matrix on a hexagonal lattice has been demonstrated. The quantum behaviour of such topological defect systems is still in its infancy and requires significant research, but offers potential breakthrough in quantum simulator hardware. The main advantage of such mesoscopic systems is that they retain quantum properties, but solve the problem of addressing, control and readout inherent in microscopic quantum systems. The roadmap needs to be able to include such new, outside-the-box solutions to well defined challenges. Currently new breakthroughs don't fit the roadmap."
Simulation	COST Action	This comments is available on request at cost-nqo@uni-siegen.de
Simulation	Macucci	"On page 10 and elsewhere (starting from Page 71 and from Page 93) Quantum simulators are discussed. It would substantially be analog quantum computing, which is what Feynan envisioned, but an essential issue does not seem to be treated in reasonable detail: how well can we control decoherence in an analog quantum computer? Does some well structured idea exist? While in a digital quantum computer quantum error correction can be applied, this concept is not readily transferable to an analog quantum computer. I believe that it would be important to point out this issue and to mention possible solutions, if they

		are envisaged. In particular, in the section past Page 93 the problem of dephasing and errors is handled in a rather cavalier manner, stating that if one wants to know whether a material conducts or not, a precise knowledge of the conductance is not needed. This is not true, also because lack of precision will unavoidably lead, as the simulation is scaled up, to meaningless results. Furthermore, as stated above, there are multiple sections on Quantum Simulators that mostly repeat the same concepts and are therefore redundant. In particular Sec. 2.3.1 and the section starting on Page 93 are substantially on the same topic."