Future is Quantum

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Abstract: New, emerging quantum resources, such as quantum computing, have a potential to provide benefits well beyond the capabilities of today's technology, and they are around the corner. Consequently, the current quantum progress brings up several open legal and ethical questions that herald awareness, analysis, and action! Foreshadowing this quantum wake-up, this paper presents a general overview of the quantum future within the framework of law, economics, and society.

Keywords: Quantum Awareness; Quantum Landscape; Action Strategy

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INTRODUCTION

The brave new world of new quantum technologies is upon us. In the past century, the quantum way of thinking has reshaped our worldview about the Universe but has also led to significant practical applications our modern society relies on. A current trend is to innovate more efficient and greener materials or components for future nanoelectronics by taking a better advantage of quantum resources[1], as it is getting harder to push the boundaries of Moore's law[2]. In addition to this evolutionary development, we are now experiencing a new wave of novel quantum technologies[3] that are promising in terms of social impact and commercial applications: *quantum sensing*[4], *imaging*[5], *metrology*[6], *communication*[7] *and computing*[8].

Although the emerging quantum technologies, such quantum computing, are still at the initial stage of utilization – transiting from the pilot phase to the commercial sphere, they have already begun to influence the structures and functions of international society in a spectrum of ways. Sovereign states, institutions, organizations, and corporations should be prepared for the emergence of these new technologies, with the constant goal of improving the current legislative framework and initiating new ones. The upcoming technological shift will take place gradually, thus continuing efforts to stay updated on this development is crucial in order to provide for meaningful legislation initiatives.

As we are entering into the new era of the quantum world, the sovereign states, institutional and organizational operators, as well as businesses should reflect upon the social and legal relevance of this technological progress. Towards this goal, we propose

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[1] See, for instance, P. Ball, 'Materials innovation from quantum to global*'* (2022) Nat. Mater.ls, *21*(9), 962-967.; F.P. García de Arquer and others' Semiconductor quantum dots: Technological progress and future challenges. Science' (2021) *373*(6555), eaaz8541.

[2] E. Moore, 'Cramming more components onto integrated circuits' (1965) Electronics 38, 114.

[3] See, for instance, Antonio Acín and others, 'The quantum technologies roadmap: a European community view' (2018) 20 New J. Phys. 20, 080201.

[4] See, e.g., C. L. Degen, F. Reinhard and P. Cappellaro, 'Quantum sensing*'* (2017) Rev. Mod. Phys., *89*(3), 035002.

[5] See, e.g., P. GA., Moreau, E. Toninelli, T. Gregory and M.J. Padgett, 'Imaging with quantum states of light' (2019) Nat. Rev. Phys., *1*(6), 367-380.; O.S. Magaña-Loaiza and R.W. Boyd, 'Quantum imaging and information*'* (2019) Rep. Prog. Phys., *82*(12), 124401.

[6] See, e.g., V. Giovannetti, S. Lloyd and L. Maccone, 'Advances in quantum metrology'(2011) Nat. phot.*, 5*(4), 222-229.
G. Tóth and I. Apellaniz, 'Quantum metrology from a quantum information science perspective' (2014) J. Phys. A Math., *47*(42), 424006; M. A. Taylor, M. A., and W.P. Bowen,' Quantum metrology and its application in biology' (2016) Phys. Rep., *615*, 1-59; L. Pezze and others,'Quantum metrology with nonclassical states of atomic ensembles'(2018). Rev. Mod. Phys., *90*(3), 035005.

[7] N. Gisin and R. Thew, 'Quantum communication*'* (2007) Nat. phot., *1*(3), 165-171; N. Gisin and others, 'Quantum cryptography*'* (2002) Rev. Mod. Phys.,*74*(1), 145; S. Wehner, D. Elkouss and R. Hanson, 'Quantum internet: A vision for the road ahead' (2018) Science, *362*(6412), eaam9288; H.J. Kimble, 'The quantum internet*'* (2008) Nature, *453*(7198), 1023-1030.

[8] See, e.g., Isaac L. Chuang and Michael A. Nielsen, *Quantum Computation and Quantum Information* (India, Cambridge University Press 2000).; D. Thaddeus D. and others, 'Quantum computers' (2010) Nature, 464(7285), 45-53.

the A-cubic approach - awareness, analysis, and action! - being employed in decision and policy making (visualized in Fig. 1).

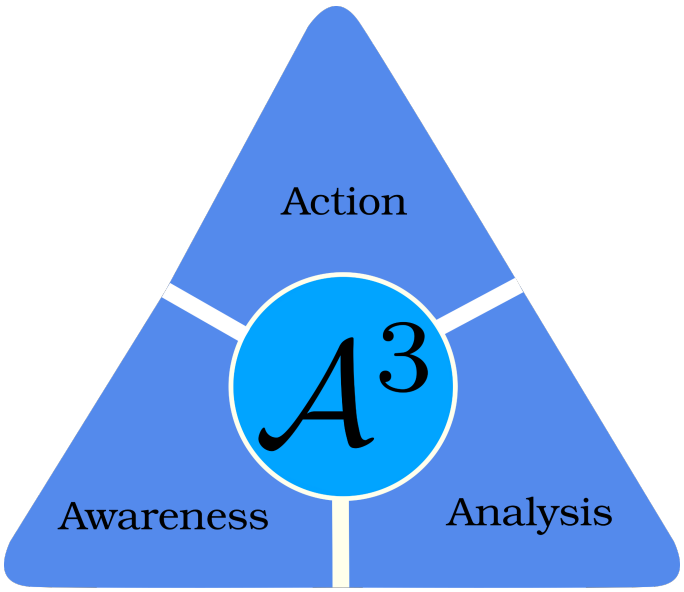

Figure 1. A-cubic approach to integrate new emerging quantum technologies into a part of future society: Raise awareness, analyze the environment, and take appropriate action.

First, it is of crucial importance that we are *aware* of these new technologies; secondly, their implications and ramifications must be carefully *analyzed* within their respective environments, and lastly appropriate *actions* should be taken to work for their development but also to safeguard for individual and social rights. In the international arena, the path dependency process plays a crucial role in finding balance with various rights and obligations. In the quantum-technological environment, we see that the legal design approach[9], which aims to empower within improving, supporting, and demonstrating, can pave the way towards a legal framework that is transparent, human-centric, efficient, and comprehensible as well as foster equality and nondiscrimination. We recognize that it is better to be proactive than reactive.

I. AWARENESS: ENTERING INTO A NEW AGE OF QUANTUM

To take full benefit of new emerging quantum technologies, we should first be aware of what they encompass. Based on the economic theories on path dependency, knowledge is prevalent in society and learning is considered as gradual.[10] We encounter the same dilemma with quantum technologies: we have the golden opportunity to embrace learnings from the past, to enhance, and build on the understanding that we have today. As a matter of exemplary incident, we may study the

[9] Katri Nousiainen, 'Legal Design in Commercial Contracting and Business Sustainability – New Quality Metrics Standards' (2022) Journal of Strategic Contracting and Negotiation.; Katri Nousiainen, 'General theory of legal design in law and economics framework of commercial contracting´ (2021) Journal of Strategic Contracting and Negotiation, 5(4): 247–256.

[10] S. Rizzello, 'Knowledge as a path-dependence process' (2004) Journal of Bioeconomics, 6 (3): 255–274.

policy frameworks of the 1990's for the internet.[11] A more modern reference point for the embodiment of quantum technologies is an envisaged social-legal-ethnic framework for nanotechnology.[12] Like with these technological steps, the introduction of quantum will raise ethical, legal, and distributive challenges. For instance, there might develop a quantum technological "gap" between haves and have-nots, as certain nations, corporations, or groups dominate access to the technology. Quantum technologies, like the rise of the internet or the birth of nanotechnology, might also have the unfortunate effects of exacerbating wealth and power differentials in a manner that attracts criticism and resistance. However, just reflecting the past is not enough, and a new point of view on quantum matters is a linchpin, even when the learning process comes with a cost. Today much of these aspects are ill-defined, but the technology is already arriving, and its consequences will be eventually felt by the whole society. At the end of the day, comprehensive understanding and knowledge are pivotal for successful innovation, development, and competition. Thus, we should raise quantum awareness.

Even though the zoo of quantum technologies share some common features, even with current technologies as pointed out above, they also have their own special characteristics we need to acknowledge in any prospective policy and legal actions. In addition, specific future measures depend on multiple unknown variables: technological progress and breakthroughs, the changes in the overall society including the status of international relations and how transparently operators reveal their level of development within these technologies, and other unforeseeable conditions. World politics, underlying power dynamics, and uncertain contingencies bring their challenge to predict what the future holds. As regards warfare and other sensitive fields, the underlying incentives of nation states and non-state actors play a key role.[13] This further affects how countries will engage in international collaboration and other incentive-based frameworks.

On the other hand, the different technologies, such as quantum sensing, imaging, metrology, communication, and computing, intertwine with each other in synergy. For instance, an advancement in sensing and metrology often speeds up the development of quantum computers and networks. Vice versa, the exigencies of the quantum information field stimulate the development of imaging and metrology. Another aspect is that various of these technologies can act in a cooperative manner. A prime example is a speculative scenario, where a military force takes advantage of quantum sensing and metrology for monitoring the enemy forces and planning the best timing for their military actions, while employing quantum communication to keep classified

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[11] Andrew Chadwick and Christopher May, 'Interaction between States and Citizens in the Age of the Internet: "e-Government in the United States, Britain, and the European Union' (2003) GOVERNANCE 16, no. 2: 271-300.; Jan Van Dijk AGM, 'The deepening divide: Inequality in the information society', (2005) SAGE PUBLICATIONS.

[12] See for instance, BL Shumpert and others, 'Specificity and Engagement: Increasing ELSI's Relevance to Nano-Scientists*'* (2014) Nanoethics,8(2):193-200.; Antonio G. Spagnolo and Viviana Daloiso, 'Outlining Ethical Issues in Nanotechnologies' (2009) Bioethics. 23. 394-402.; Tsjalling Swierstra and others, 'Converging Technologies, Shifting Boundaries*'* (2009) Nanoethics. 3. 213-216.

[13] More on national security applications and implications, see for instance, Hoofnagle, C., & Garfinkel, S. (2022). Law and Policy for the Quantum Age. Cambridge: Cambridge University Press. doi:10.1017/9781108883719.

information and quantum computing to spy on quantum-vulnerable messages.[14] Besides interacting in a complicated manner, individual technological fields usually evolve at an asynchronized tempo. Furthermore, distinct operators, like governmental institutes, commercial companies, and academy, drive the development of the technologies from different points of view. Due to all these aspects, it is arduous to grasp the full picture, not to mention prognosticating the future of the whole multi-faced field. Nonetheless, general awareness is a necessary precursor towards deeper analysis of the technologies paving the way to desirable actions.

Ideally, there should not be any great knowledge and information asymmetry between all the relevant operators. Furthermore, knowledge on quantum technologies should also be disseminated in understandable terms to the general audience to achieve a wide social comprehension. In particular, the academy and education system have a central role to play in raising public quantum awareness, and to generate" quantum-skillable work force" which is a prerequisite to sustain a quantum ecosystem in general.

In order to learn from best interdisciplinary practices and to create awareness and the most value, it is crucial to bridge more between business, academia and society. We see it is worthy of increasing knowledge and information between different operators regarding interests, incentives, and objectives supporting the creation of standardization and best practices within quantum technologies. Thus, the goal is to thrive the technological development and its social embodiment, and to create a flourishing quantum ecosystem in the future.

II. ANALYSIS: CHARTING THE QUANTUM LANDSCAPE

A key concept in quantum awareness is to acknowledge that the employment and possession of new technologies create possibilities but also bring responsibilities. To navigate through a widely uncharted legal landscape towards a bright quantum future, we have launched an idea of *Quantum Roadmap*[15] that is also motivated by the desire to raise quantum awareness and to encourage further debate on the topic. Our suggested Roadmap of five principles for the social embodiment of quantum technologies are: *ethics*, *inclusion*, *balancing regulatory activities*, *safeguarding individual rights*, and *innovating by design* (collectively shown Fig. 2).

[14] More on national security applications and implications, see for instance, Hoofnagle, C., & Garfinkel, S. (2022). Law and Policy for the Quantum Age. Cambridge: Cambridge University Press. doi:10.1017/9781108883719.

[15] Katri Nousiainen and Joonas Keski-Rahkonen, *Quantum Computing Era – New Legal Order, Berkeley Global Society: The Tech Book* (1st edition Europa Institut EIZ, 2022).; Katri Nousiainen and Joonas Keski-Rahkonen, 'Law and Order at the Quantum Computing Era´ (May 2022) Berkeley Technology Law Journal, Podcast.

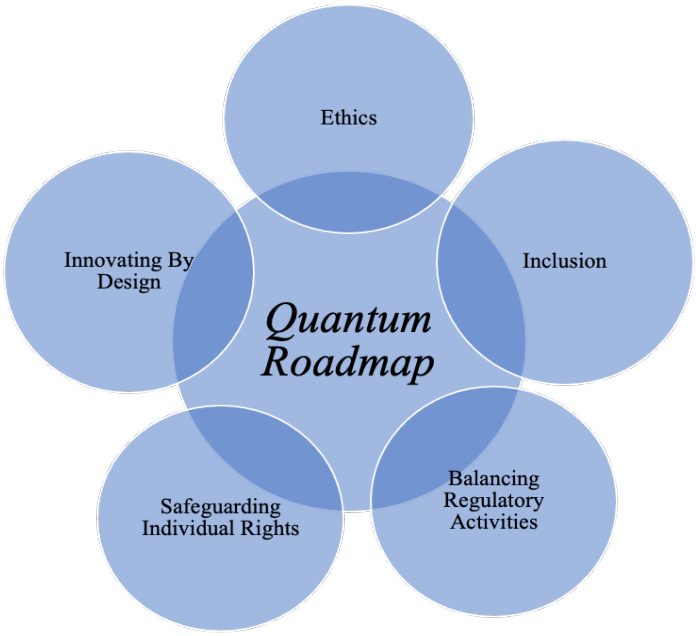

Figure 2. Quantum Roadmap – Law, Economics, Sustainability, and Society – comprises five basic guiding principles towards a bright quantum future.

Even though legislation and ethics frequently interrelate and align, ethical standards are never a supplementation or replacement to legal measures. In particular, ethics alone is not adequate when regulating high-risk dual-good technologies. Nevertheless, ethical aspects *do* provide a valuable direction to construct a legal framework for society. A near-future example of arising ethical issues is the dual-usage of quantum technologies referring to the aspect that the given technology can be employed in both military and in the commercial sphere.[16] Like all technologies, quantum technologies can be applied within contrasting ethical points of view. For example, the benefits of quantum metrology and sensing can improve the sensitivity of scientific apparatus, paving the way to unravel the mysteries of the Universe, but also have real-life applications in satellite systems, such as improving the current global position system. On the other hand, these benefits can be easily geared for military purposes. For instance, improvements in telescopy for astronomy with long-baseline interferometry would be a similar use "for good" as improvements to X-ray astronomy aided by a quantum-boost, but each would have very different applications when harnessed for military purposes, which might be damned as “evil” in some contexts.

Another ethical risk is increased inequality via winner-takes-all effects, yielding a “quantum divide” during the introductory phase. Subsequently, we may result in an ethical quandary, where we need to ponder the general benefit in respect to the social-ethical justification of immaterial rights, like the sharing of the quantum fruits stemming from better medical diagnostic tools such quantum-enhanced tissue imaging. In general, all broad application areas of quantum technologies should be realized in a social, sustainable manner, and in a fashion of preventing harmful impact on the environment, society, and humanity. Following this path, new technologies can assist us to resolve some of the current key problems, such as tackling climate change by

[16] See, for instance, Michal Krelina, ‘Quantum Technology for Military Applications’ (2021) EPJ QUANTUM TECHNOL. 8, 24).

designing greener materials and energy solutions thanks to the simulational power of a quantum computer.

When it comes to the ethical issues regarding the uprising of new technologies in a society, we do not start out of nothing. There has been a lot of discussion on ethical rules for different technologies, which has paved the way to modern generic ethical guidelines. Every field and industry nevertheless has its own special traits and characters; surprisingly the society has relatively recently woken-up to consider the ethical aspects of quantum circumstances.[17] However, since society is in a constant flux, the ethical norms are thus expected to be dynamic and contextual: the exact quantum-tech regulations will always be a product of their time following the current trend of the applications and implications of the given technology and contemporary understanding of ethics. We thus see that the legal-ethical framework has to be agile and updated with regular intervals.

The ambition of the inclusiveness is to prevent various risks of increased inequality, e.g., stemming from the monopolization through immaterial property rights, and a quantum division during the commercialization phase, which holds both companies as well as countries. Furthermore, it aims to integrate our democratic values into the social-ontogenesis of new quantum technologies, which, for example, requires educating the general public on quantum-related technologies. For commercial players, a further motivation to this direction is that technology which has gained the trust of the people has a significant market advantage. In general, it raises a question what role the public and the private sector involvement and funding should play, and at which stages. For instance, there might be a reason for public authorities to prohibit or to restrict access to some part of the technology, e.g., because of dual-usage and mitigating security risks, or of moral and public grounds. On the other hand, social-ethical reasons may lead to prioritizing the greater good over the benefits of the rights of individual private actors.

It is of the utmost importance to find the regulatory balance, ensuring the functionality of society while not smothering the evolution and integration of quantum technologies. Some people see the quantum possibilities as miraculous to be shared openly, others are demanding strict control on the usage. For most part, neither of these extremes is desirable; only by finding a regulatory balance between freedom and control can we take advantage of the new emerging quantum technologies in the most beneficial ways to the whole society. In other words, the regulatory actions should be guided by the Aristotelian-like philosophy on the excess and deficiency: balancing legal development, legal rights and obligations, public good, and incentives to innovate as well as to safeguard the progress of technological development.

To initiate this process for emerging quantum technologies, we herald conceptual and legal assessments of what level of regulation is in order and, if needed, provide a public, transparent cornerstone for any new regulatory framework. The possible tools vary from self-regulation to primary regulation by their financial regulators. However, due to the extraordinary potentials and possibilities of the quantum imperative, it is likely that there will be a quantum-specific framework regulatory environment. Furthermore, we see that there will be restrictions on export

[17] See for instance, M. Kop,' Establishing a legal-ethical framework for quantum technology' (2021) Yale Law School, Yale Journal of Law & Technology (YJoLT), The Record.

and import on quantum technologies and knowledge, such as quantum computing and metrology, motivated by the dual-good nature and national interest. In contrast, an establishment of quantum internet will most likely entail an international collaboration and agreement on the common playbook.

Of course, there is always the option of not regulating, particularly in the absence of a demonstrated, compelling public need. As demonstrated by highly concentrated social media platforms, the social harms easily arise from an unregulated operation of ubiquitous technologies such as quantum computing and communication. Therefore, international consent is required to establish framework rules governing aspects such as, dual usage, immaterial property rights, export restrictions as well as international safety and security. Although some initial steps have been taken,[18] contemporary legal frameworks are inadequate to cover quantum technologies. The current non-legally binding agreements, such as Wassenaar Arrangement[19], are not sufficient for securing international peace and security, thus we propose to initiate international conversations towards legislative actions. We want to emphasize that there is particularly a pressing demand for an international regulatory framework for the employment of quantum technologies in the society-wide global context. This urgently calls for deepening transatlantic collaboration, engaging in dialogue, and initiating an international legal framework.

At the current age of information, a central question has been who is allowed to utilize data and what kind of, i.e., where lies the boundary of the privacy of personal data, but this issue is also relevant for the future quantum technologies. For example, in the coming decades, a fusion of quantum technology and artificial intelligence may open a new chapter in data science.[20] As regards, for instance, quantum-boosted artificial intelligence and machine vision can be employed to categorize data, to track patterns, to benefit process development, and to make more accurate forecasts.

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[18]See for instance some examples of intergovernmental friendly agreements and research partnerships on quantum technologies, (FI-USA), Press Release, U.S. Dep't. State, Joint Statement of the United States and Finland on Cooperation in Quantum Information Science and Technology (Apr. 6, 2022), U.S. DEP'T. STATE https://www.state.gov/joint-statement-of-the-united-states-and-finland-on-cooperation-in-quantum-information-science-and-technology/ (Apr. 6, 2022); ;(AU-USA), Press Release, U.S. Dep't. State, Cooperation in Quantum Science and Technology Joint Statement (Nov.17, 2021), U.S. DEP'T. STATE, https://www.state.gov/cooperation-in-quantum-science-and-technology-aus;(SWE-USA) https://www.quantum.gov/the-united-states-and-sweden-sign-quantum-cooperation-statement/ (Nov. 17, 2021).; (UK -USA) Press Release, White House, The United States and United Kingdom Issue Joint Statement to Enhance Cooperation on Quantum Information Science and Technology (Nov. 4, 2021), WHITE HOUSE https://www.whitehouse.gov/ostp/news-updates/2021/11/04/the-united-states-and-united-kingdom-issue-joint-statement-to-enhance-cooperation-on-quantum-information-science-and-technology/. (UK-SWE) Press Release, Dep't Bus, Energy & Indus. Strategy George Freeman MP, New joint statement between UK and US to strengthen quantum collaboration (Nov. 4, 2021), GOV.UK https://www.gov.uk/government/news/new-joint-statement-between-uk-and-us-to-strengthen-quantum-collaboration. See also, for instance, the National Quantum Initiative Act in the USA, 115th Congress Public Law 368, *https://www.congress.gov/bill/115th-congress/house-bill/6227/text* (December 21, 2018).

[19] Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, https://1997-2001.state.gov/global/arms/np/mtcr/000322_wassenaar.html.

[20] Xing-Dong Cai et al., *Entanglement-based Machine Learning on a Quantum Computer,* 114 Phys. Rev. Lett. 110504, 110504-110507 (2015); Maria Schuld, Ilya Sinayskiy & Francesco Petruccione, *An Introduction to Quantum Machine Learning*, 56 Contemp. Phys. 172, 172-185 (2015); Maria Schuld, Ilya Sinayskiy & Franceco Petruccione, *Prediction by Linear Regression on a Quantum Computer,* 94 Phys. Rev. A 022342, 022342-022348 (2016); Jacob Biamonte et al., *Quantum Machine Learning*, 549 Nature 195, 195-202 (2017).

Moreover, it is speculated that quantum-enhanced artificial intelligence can play a major role in the rise of autonomous decision making. Nevertheless, quantum data utilization should not violate human rights, oversight with the right to an explanation, and the rights of humans with respect to artificial intelligence. The principle of safeguarding individual rights should be methodically embedded in the existing and future regulatory structures. For example, we want to ensure that the design and establishment of different data sets will follow this underlying value.

The future quantum applications and innovations can be expected to comply with the legislation on data protection, governance, and privacy. However, it is currently unknown to what extent we can rely on current and emerging regulatory frameworks. This privacy issue culminates in the matter of cybersecurity where one must switch eventually to new quantum-proof encryption standards as quantum computers scale up. As quantum technologies mature, we should ensure that the legislation fosters open-datasets transparency, comprehensibility, and also improves privacy as well as safeguards recognized individual rights by providing an equal access to technologies, impeding discriminatory practices and supporting democratic principles, such as the European three pillars consisted of freedom, democracy, equality and the rule of law promoting peace and stability. Like with balancing the regulatory actions, it remains to be seen whether the current incentives are enough for the field itself to take the precautionary step, or if a governmental nudge is required to motivate its reformation.

A pivotal question is what type of innovations we want in the future. First, when we investigate, develop and design quantum technology, academia plays a central role and is a good medium to initiate the quantum debate. Researchers do have the duty to steer research and innovation; various risks, legal gaps, ethical questions, societal implications, and other unknown ramifications associated with quantum technologies should be factored in. Prospective practices should be designed and tested. Subsequently, insights should be shared and disseminated openly within and outside of the academic community. On the other hand, quantum technologies that have gained the trust of the general public can have significant marketing advantages, boosting further the development and commercialization.

Side by side with academia, a public sector needs to step in. For example, governments and governmental institutions can bring the quantum community together, which instead can forecast future trends of quantum technology evolution for the service of the public. With this information, the public sector can become more aware of risks and engage in potential benefits related to quantum technologies. Moreover, it enables the public sector to set up quantum-targeted strategies and policies to steer the progress into the right direction, to maximize the social benefit of the technology. This also enables governments to found new specialized public institutes to offer legal-ethical guidance on the current possibilities associated with the development and usage of quantum technologies from the public point of view. The public sector should also have healthy dialogue with the private sector to establish a pathway for commercial innovations.

In consequence, we can ask what type of intergovernmental governmental and public ties the emerging technology requires to achieve a bright quantum future. For example, if the development of such basic research is carried out or supported by public funding, the fruits could be then shared accordingly. This could mean that the

fundamental research results should be announced as open access to be utilized, and the commercialization from academia could take place via licensing to prevent the centralization of the crucial quantum innovations on one player, like on an individual university. This kind of proactive involvement of the public sector could be also a first step towards establishing industry-wide hardware standards which further stimulate technological evolution on a broader front, e.g. to lure smaller, new players into the quantum play. Therefore, along with the legislational route, an effective regulatory tool is to control the flows of (public) funding to design socially and ethically equitable quantum infrastructure without sacrificing the evolution and integration of the technology. Furthermore, it is important to see synergy formed by the symbiosis of academia and the commercial sphere, where money and other resources can be fed back into basic research and further development of quantum technologies for commercial applications. This will ensure a technological pre-eminence in the longer term and boost morale and dedication in the fields of fundamental science.

As elucidated above, the necessity of updating the legislation is a multifaceted and complex challenge. Though, the presented classification of our Quantum Roadmap can assist to operate and acknowledge different standings in the post-quantum legal landscape where different actors, such as sovereign states or multinational companies, have varying incentives. The five principles are intended to support the relevant governmental agencies and institutions, the elected representatives as well as the quantum industry members alike to orient in the post-quantum era. In an ideal case, the principles will guide them to establish a solid foundation for taking actions towards the future society of quantum. The most salient conundrum is to obtain regulatory equilibrium within quantum technologies, namely, to safeguard the functionality of society while not impeding or hindering the development, integration, and evolution of it. At the end of the day, the foundations of a functional and respectful society are enforceability, effectiveness, stability, predictability, and transparency. Nevertheless, the time to act is now as we are already entering into a new age of quantum!

III. ACTION: NAVIGATING TOWARDS A BRIGHT QUANTUM FUTURE

By knowing the" bigger picture", we can take steps to ascertain the functionality and gain of society, while not smothering the evolution and integration of quantum technologies. In practice, success, most likely, requires a strategy plan with concrete steps for how to incorporate these technologies to fully capture the commercial opportunities, and to deliver maximum benefit to society at the same time. For example, one of these measures can be to launch a fleet of mission-driven flagships to solve industrial and societal challenges related to the embodiment of quantum technologies. Naturally, our legislational environment needs to be ready for the upcoming quantum change. For instance, the immaterial property right framework could encourage commercialization as well as accessibility. In the long run, there may be a necessity for an international framework to ensure the coherence and the optimal functionality of the global quantum community in respect to the values presented in Quantum Roadmap.

Quantum technologies present challenges in terms of both shared development and governance. Companies and nations are cooperating and in competition, or what has been described as "co-opetition," referring to when stakeholders can gain through working together, but are also in fierce competition and must balance the risks of over-

exposure, protecting security or trade secrets.[21] In contrast to the Cold War, when Western and Soviet-aligned nations had entirely different economic, political, and security institutions – such as the European Economic Community and NATO, or the Soviet-aligned Council for Mutual Economic Assistance (Comecon) and Warsaw Pact – nations today are closely linked, even when they have extensive divisions. The new competition between the United States, Europe, and China for example is fundamentally different, with integration. Economies have much more integration, there are more exchanges of citizens, and many shared interests.

Co-opetition is possible when both parties can gain without putting critical factors at risk, or the two parties together can gain an advantage over others. The key is in how partnerships are structured. The task is to manage these tensions and be proactive, to ensure benefits and manage risks. and we may need new institutions and processes. Naturally, our legislational environment needs to be ready for the upcoming quantum change. For instance, the immaterial property right framework could encourage commercialization as well as accessibility. An international framework will be required to ensure the coherence and the optimal functionality of the global quantum community in respect to the values presented in Quantum Roadmap.

This may be achieved by creating an architecture of the system.[22] Currently legal, economic, political, and security issues are negotiated through international bodies like the United Nations, World Trade Organization, regional bodies like the European Union, academic societies, and Non-Governmental Organizations such as ICANN. These are voluntary, and their formation is led often by a smaller group of powerful actors.

On the other hand, quantum-safe data transfers and storage are closely entangled with the security and defense field. Most likely, there will be a demand for a new intergovernmental legal rule framework and surveillance in certain research areas of quantum computing to ensure worldwide security. In particular, regulations need to cover data privacy, and access for government authorities such as law enforcement, shared governance of quantum internet, managing norms around cyber-attacks, developing solutions to shared challenges such as climate change, and establishing a common language and terms among all three sectors. These have been significant challenges for the United States and China, and quantum computing provides an opportunity to form new institutional arrangements for a fundamentally new technology. These could take the form of new voluntary bodies modeled after the World Trade Organization which have governed challenging economic issues, or the Internet Corporation for Assigned Names and Numbers which has facilitated cross-national governance of the internet.

A solution could be to establish a legal collaborative framework for “Mandatory Reporting and Supervision” to ensure international peace and security. For instance, this could be realized as a form of a Security Council or of a Union of Sovereign States - committing to the same goals on security and sustainability. The operations and accomplishment of the goals should be overseen equally by all the coalition members,

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[21] Brandenburger, Adam, Barry Nalebuff. “The Rules of Co-opetition.” (2021) *Harvard Business Review*.

[22] Mazarr, Michael J, and Tim McDonald. “Competing for the System: The Essence of Emerging Strategic Rivalries.” PE-A1404-2. (2022) *RAND Corporation*.

and the power should not be centered upon a few selected parties. Ideally, these member states should represent comprehensively sovereign states - not just a few powerful ones - but more equally the sovereign states of the world. The more equal standing of the sovereign states in this possible "Mandatory Reporting and Supervision Body" would allow actions to be taken with less political and historical impact, that is quite the opposite, for instance, to the unfortunate situation with the United Nations Security Council (that is mostly comprised of the War winning countries). The historical burden and political impact have frequently caused the United Nations Security Council to be toothless in taking appropriate measures and actions in reply to threats on international peace and security. Often, a mere "condemn" is insufficient to resolve the incidents occurring at the international arena. The former challenges with international organizations and supervisory bodies should be converted into knowledge for anticipatory and precautionary practices. Therefore, we could learn from the past to ensure the future peace and security.

However, it is challenging to foresee the future development of all different quantum technologies, and the underlying incentives do not help in estimations, as it is not always in the best interest of operators to fully, accurately and in real to reveal what is their progress within these technologies. Their development is also impacted or supported with other technologies, and thus how one specific technology will come up, depends on various different factors. Therefore, it is not in the scope nor the intention of this paper to advocate designed guidelines for specific quantum technologies based on ambiguous estimations of what the future will hold. Nevertheless, we can recognize some whole-field-broad trends, like the hastening emergence of the technologies itself. As it currently stands with different branches of quantum technologies, we herald the urgency to ignite the discussion about taking anticipatory measures that ideally would follow the quantum roadmap reasoning presented earlier in this paper.

In general, our vision about a bright society of tomorrow is founded upon broad scientific capabilities in a coordinated symbiosis with the tech industry to push the cutting-edge quantum technologies forward. At the same, we see an importance to deepen the dialogue within the trinity of industry, academia and government so that social-level actions are taken in the 'right' direction. In the process, a virtuous circle may be set up. Public and private funding stimulates basic research yielding blooming quantum hubs and eventually connecting into a thriving quantum ecosystem. On the other hand, some money will flow back into research to generate more knowledge we can transform into further advantageous innovation[23] , and into more benefits to society.

CONCLUSION

The anticipated benefits of quantum technologies are already upon us! As we are entering into the new quantum era, the whole legal sphere with governmental authorities, institutes, and commercial operators should reflect upon the legal significance of quantum. Unequivocally, quantum innovations will have a system-level

[23] J. A. Schumpeter, R.V. Clemence and R. Swedberg, *Essays: On entrepreneurs, innovations, business cycles, and the evolution of capitalism* (Routledge 2017).; Joseph Schumpeter, Joseph, *The theory of economic development: An inquiry into profits, capital, credit, interest and the business cycle* (Harvard Economic Studies, trans. Redvers opies, v. 46: 66-68, 1934).; K. Śledzik, 2013. *Schumpeter's view on innovation and entrepreneurship* (Management Trends in Theory and Practice, (ed.) Stefan Hittmar, Faculty of Management Science and Informatics, University of Zilina & Institute of Management by University of Zilina 2013) 89-94.

impact: a new quantum-boosted society requires a new legal order. For this purpose, this paper has introduced an approach on addressing quantum opportunities and challenges to society.

The paper is divided into three sections. It follows the proposed ideal manner of approach on quantum technologies, namely *the A-cubic approach - awareness, analysis, and action.* We try to recognize the best characters so that the flourishing new technology will maximally benefit the whole humankind and how we can avoid possible pitfalls on the way toward a bright quantum future. However, this process is ongoing by its nature and learning is a continuous path; we do not offer complete, fool-proof solutions, but encourage further discussion and debate.

In the first section of the paper, we presented the framework of awareness, discussing the basics of quantum computing and some other promising quantum technologies. In the second section, we introduced analyses in the context of the applications and implications from quantum in relation to law, economics, and society. In the third section, and last section of the paper, we proceeded discussing calls for actions, and the incentives and benefits to take advantage of quantum technology in various settings in society.

Further, we have put forward our Quantum Roadmap aiming to provide sustainable and ethically conscious policy guidance in a solution-centric manner for various operators with varying incentives. We discussed every suggested Quantum Roadmap principle and their practical implementation in detail. The paper ended with motivation for further discussion and academic research on the area of quantum technologies with the message: the time is ripe for awareness, analysis, actions!