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Some Ethical Issues of a Potential "Quantum Internet"

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Some Ethical Issues of a Potential "Quantum Internet"

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The "Quantum Internet" is a project for a new "network of networks" that has been discussed as such since at least 2008[2] and occasionally presented – sometimes with a certain communication intent – as the future of the current Internet[3].

This idea is based on the exploitation of quantum mechanics and particularly some remarkable properties such as quantum entanglement and superposition, whose theoretical existence has been known since the 1930s but which have only been empirically demonstrated – particularly concerning entanglement – in the 1980s[4]. Since then, a true global race for quantum technologies has begun[5]. Since the mid-2010s, with a notable acceleration since the beginning of the 2020s[6], states with the economic and scientific capacity to do so have multiplied

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[2] H. J. KIMBLE, « The quantum internet », *Nature*, vol. 453, 2008 (doi:10.1038/nature07127), pp. 1023-1030.
[3] See for example P. VERMAAS, D. NAS, L. VANDERSYPEN, D. ELKOUSS CORONAS, *Quantum internet. The internet's next big ste*p, Delft University of Technology, 2019, 61 p.
[4] For further insights into the physical foundations of quantum technologies, refer to the works of Julien Bobroff, particularly his website "La Physique Autrement" (https://vulgarisation.fr/bobroff/; link accessed on June 3, 2025) and his book: J. BOBROFF, *Bienvenue dans la nouvelle révolution quantique. Ordinateurs, cryptographie, Internet, spatial: pourquoi le XXI[e] siècle sera quantique*, Champs, 2025, 336 p. See also R. MAUREL, "Transformations quantiques et transformations du droit. Premières pistes de réflexion", *Revue générale de droit*, 2024, n°65119 (available online); L. ADATTO, "Enjeux et prospectives du développement des technologies quantiques", *Technologie et innovation*, vol. 8, n°1, 2023 (doi:10.21494/ISTE.OP.2023.0914) or R. MAUREL, "Les technologies quantiques", in M. CARON, R. MAUREL (eds.), *Penser la transition numérique. Vers un monde digital durable*, Éditions de l'Atelier, 2023, pp. 99-104.
[5] A. PANNIER, « La course aux technologies numériques. Accélération après-Covid », *in* T. DE MONTBRIAL, D. DAVID, *Ramses 2022 : Au-delà du Covid*, 2021 (doi:10.3917/dunod.colle.2022.01.0090), pp. 90-95 ; M. JULIENNE, « La Chine en quête d'un saut quantique », IFRI, 2024 (doi:20.500.12592/2v7f06o).
[6] An overview of national quantum strategies from various countries around the world can be found on the CevoteQ website: https://www.cevoteq.com/ressources-et-donnees/strategies-quantiques-nationales.html (link accessed on June 3, 2025). See also R. MAUREL, "Les stratégies quantiques des États du monde," in O. BICHSEL, O. DELAS, M. MONDELICE, R. OUELLET (eds.), *L'Union européenne, puissance numérique globale*, Bruylant, forthcoming in 2026.

investments to achieve mastery of various technologies derived from current knowledge in quantum physics: quantum computers, quantum sensors, and quantum communication methods. As these technologies are being developed, legal scholars are gradually addressing the major issues that will arise from this future technological revolution. Several researchers already emphasize the need to develop quantum technologies responsibly, integrating ethical, legal, social, and political considerations (an "ELSPI" conceptual framework for responsible quantum technology) into quantum research and development[7].

Noting that some of these "total innovations"[8] are transitioning from theory to commercial reality[9], Mauritz Kop and several of his colleagues thus present a number of ethical, legal, and social questions, particularly regarding national security, dual civil and military use[10], privacy protection, product security, intellectual property, fair (or unfair) competition, or equality among states and populations[11]. These issues are gradually emerging in the international political agenda, as evidenced by the proclamation of 2025 as the "International Year of Quantum Science and Technology" by the United Nations General Assembly[12]. Researchers are particularly advocating for the integration of quantum issues into the debates of the G7 organized in Canada in 2025[13].

It therefore seems relevant, within the framework of a reflection on the governance of the "classical" Internet, to question the future forms it could take or, in this case, the manner in which another model of the Internet could be envisaged and, perhaps one day, regulated. To do this, and given the technical and prospective nature of the subject, it is desirable to attempt to concretely define the quantum Internet (1). Since it is a scientific objective and therefore a developing object, there is still time to deploy a comprehensive ethical reflection regarding it,

[7] M. KOP, M. ABOY, E. DE JONG, U. GASSER & al., « Towards Responsible Quantum Technology: Safeguarding, Engaging and Advancing Quantum R&D », *UC Law Science and Technology Journal*, v. 15, n°1, 2024, pp. 63-94 ; v. également M. KOP, « Establishing a Legal-Ethical Framework for Quantum Technology », *Yale Journal of Law & Technology (YJoLT)*, *The Record*, 2021, online : https://yjolt.org/blog/establishing-legal-ethical-framework-quantum-technology (link accessed on June 3, 2025).
[8] J. CHARPENET, M. TELLER, « La régulation des technologies quantiques : un cas d'école pour la régulation des innovations “totales” », *Dalloz IP/IT*, n°9, 2024, p. 459.
[9] Notably, we think of French companies such as Pasqal, a startup specializing in the construction of neutral atom quantum computers, Alice & Bob, a startup specializing in the design of qubits, and Quandela, specializing in quantum photonics. Additionally, many international companies like IBM, Google, and Meta are making massive investments in quantum research.
[10] For more information on this specific topic, watch the conference by Anne Millet-Devalle, held on February 17, 2025, as part of the Lundi Quantique webinar series on "Le contrôle des technologies quantiques dans le cadre du Règlement 2021/821 de l'Union européenne sur le contrôle des biens à double usage". The replay is available (in french) at this link: https://www.cevoteq.com/le-media/2025/lundi-quantique-5.html (link accessed on June 3, 2025).
[11] M. KOP, M. ABOY, E. DE JONG, U. GASSER & al., « Towards Responsible Quantum Technology: Safeguarding, Engaging and Advancing Quantum R&D », *op. cit.*
[12] Resolution 78/287, June 7, 2024 “2025 as the International Year of Quantum Science and Technology" A/RES/78/287.
[13] T. DEKKER, L. LAMBERT, F. MARTIN-BARITEAU, « Enabling Quantum Technology Cooperation: A Strategic Priority for the G7 Ecosystem in the Global Race », *Think 7 Canada*, Policy Paper, April 2025, pp. 1-12.

which is sometimes referred to as the wish of researchers identifying the need for a "responsible[14]" quantum Internet (2).

1. Attempt to Characterize a Quantum Internet

To understand the contours of the future "quantum Internet" (1.2), it is necessary to understand how it requires mastery of quantum communications and their difference from quantum cryptography (1.1).

1.1. From Quantum Cryptography to Quantum Communications

Currently, quantum technologies are already used to secure classical communications over existing networks. In this regard, Quantum Key Distribution (QKD) is the most well-known application of quantum-secured exchanges, although other applications may emerge. The fundamental principle of QKD involves using the quantum states of multiple photons to share secret keys between two distant parties wishing to communicate[15]. The encoding of information in QKD is done using the quantum properties of photons, such as their polarization or phase: each bit of information in the secret key is encoded on a photon using different polarization orientations to represent the classical binary values 0 and 1[16]. Classical information (in bits) is thus translated into a series of polarized photons, which is then sent from a transmitter to a receiver via a classical channel such as fiber optics. Thanks to a remarkable quantum property, the two communicating parties can detect any eavesdropping attempt aimed at intercepting the message or gaining knowledge of the key; measuring the state (here, the photon's polarization) by a potential eavesdropper would indeed modify the particle's state, making the eavesdropper's presence detectable—furthermore, the "no-cloning" theorem states that the eavesdropper cannot simply copy the intercepted qubit[17]. The security of QKD thus relies on the laws of quantum physics rather than computational complexity[18], making it a prized solution for addressing communication encryption challenges. Companies such as IDQ, a Swiss firm, already offer quantum cryptography solutions to secure classical communications of

[14] For example, see K. L. VAN DER ENDEN, G. PROFITILIOTIS, D. CROESE, « Advancing a Responsible Future Quantum Internet », *IEEE International Conference on Quantum Computing and Engineering*, 2024 (doi:10.1109/QCE60285.2024.10254).

[15] A secret key is a sequence of bits used to encrypt and decrypt messages. The security of the communication depends on the confidentiality and integrity of this key.

[16] Ch. H. BENNETT, G. BRASSARD, « Quantum cryptography: Public key distribution and coin tossing », *Theoretical Computer Science*, vol. 560-1, 2014 (doi:10.1016/j.tcs.2014.05.025), pp. 7-11.

[17] Due to the properties of quantum physics, it is therefore impossible to intercept a quantum communication without the message recipient being informed.

[18] Currently, the cryptography of communications relies on the theoretical and practical difficulty for a computer to decipher a complex code. However, the emergence of quantum computing fundamentally challenges current cryptographic methods, leading to the development of two disciplines to address this issue: quantum cryptography, which involves using quantum technologies to encrypt information and ensure security, and post-quantum cryptography, which aims to counteract the use of quantum computing with conventional means by exploiting certain vulnerabilities that make decryption difficult or even impossible, even with a quantum computer.

governments[19] or businesses over distances of up to 150 km[20]. These solutions are generally interoperable with classical networks, as they secure conventional data rather than transmit quantum data.

Unlike classical networks that use "bits," quantum communication networks indeed use "qubits," which can exist in a superposition of two different states, thus enabling fundamentally different quantum computations compared to classical ones. In other words, it is no longer about transmitting classical information (bits) while ensuring their security through quantum techniques, but about transmitting quantum information (qubits), enabling distributed quantum communications and computations. Quantum communication thus uses certain principles of quantum mechanics (superposition, entanglement) to secure data but also and especially opens the way to unprecedented functionalities—for example, distributed quantum computing between several quantum computers "connected" via this quantum communication pathway itself. Future quantum networks must thus allow for the generation of long-distance quantum entanglement, which currently constitutes a technical challenge. While the theory has been known for a long time, its field of application is gradually being verified, with successful communications over increasingly longer distances. They have thus gone from a few hundred meters in 1998[21] to 2 km in 2004[22], to 1200 km in 2017[23], and to over 2000 km in free space in 2019[24].

These successful quantum communications now pave the way for the emergence of a "quantum Internet".

1.2. Towards a Quantum Internet

Beyond the principle of quantum communications, the idea of a "quantum Internet" implies that several quantum machines are connected to each other.

The first step, once the technique of quantum communications is mastered, is to create a local network or "quantum intranet" within which several quantum machines could communicate information in a closed circuit. Such a network relies on "nodes," fundamental elements of the

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[19] The company explains, for example, that as early as 2007, it secured the data transfers for the canton of Geneva during their elections (see online: https://marketing.idquantique.com/acton/attachment/11868/f-020f/1/-/-/-/-/Geneva%20Govt_%20DCI%20QKD%20Use%20Case.pdf, link accessed on June 3, 2025).

[20] Such is the announced range of the Clavix XG QKD System, although it is specified that the key distribution rate is higher at shorter distances: https://www.idquantique.com/quantum-safe-security/products/clavis-xg-qkd-system/ (link accessed on June 3, 2025).

[21] J.-W. PAN, D. BOUWMEESTER, H. WEINFURTER, A. ZEILINGER, « Experimental Entanglement Swapping: Entangling Photons That Never Interacted », *Physical Review Letters*, vol 80, n°18, 1998 (doi:10.1103/PhysRevLett.80.3891), pp. 3891-3894.

[22] H. DE RIEDMATTEN, I. MARCIKIC, J. A. W. VAN HOUWELINGEN, W. TITTEL, H. ZBINDEN, N. GISIN, « Long-distance entanglement swapping with photons from separated sources », *Physical Review A*, vol. 71, n°5, 2005 (doi:10.1103/PhysRevA.71.050302).

[23] J. YIN, Y. CUAO & al., « Satellite-based entanglement distribution over 1200 kilometers », *Science*, vol. 356, n°6343, 2017 (doi:10.1126/science.aan321), pp. 1140-1144.

[24] Y.-A. CHEN & al., « An integrated space-to-ground quantum communication network over 4,600 kilometres », *Nature*, vol. 589, 2021 (doi:10.1038/s41586-020-03093-8), pp. 214–219.

quantum Internet: each node would be a small quantum computer capable of storing, processing, and transmitting quantum information. These nodes must ultimately be interconnected via optical fibers, free space, or other systems allowing the transmission of quantum information over long distances[25]. An example can be found in the quantum network recently developed in the United States: in 2023, physicists at Harvard University succeeded, using existing telecommunications fiber in the Boston metropolitan area, in entangling two quantum nodes located in two neighboring floors of the Harvard Science and Engineering Laboratory. These two nodes, consisting of two small two-qubit quantum computers (one used for communication and the other for storage), were connected by an optical fiber loop of about 35 kilometers through several cities between Boston and Cambridge[26].

However, a "quantum Internet" goes much further than just quantum communications between two nodes, as it involves designing a system that allows quantum computers to operate in a network and thus cooperate to potentially solve problems that a single quantum computer might not necessarily be able to solve. In other words, it is about creating a kind of "quantum supercomputer" without even having to develop powerful quantum computers: the connection of several tens, hundreds, or thousands of small quantum computers could, according to this model, allow for performing staggering computations. The exact designation of the "quantum Internet" is therefore subject to caution: it is not really a projection of the classical Internet into the quantum era, but rather a system for distributing quantum entanglement between nodes with the aim of constituting, through accumulation, a certain form of quantum computer. The terminology here plays a certain marketing role, with "quantum Internet" being more evocative – but less clear – than the more accurate expression of "distributed quantum computing." Expectations remain considerable, as noted by an author whose technosolutionist perspective cannot be overlooked:

> *"It is expected that once the quantum internet almost becomes a global reality, its speed would be so astonishingly fast that far-flung clocks could be synchronized about a thousand times more precisely than the best atomic clocks available today. This would make GPS navigation much more precise than it is today (accuracy would increase from meters to millimeters) and map Earth's gravitational field in such great detail that scientists could spot the ripple of gravitational waves. In addition, the existence of such a system would make it possible to teleport photons from distant visible-light telescopes all over the Earth and link them into a giant virtual observatory. Thus, it would be possible to build ultra-sharp telescopes using widely separated observatories. Then there is the possibility of networking super-powerful quantum computers across the globe to work together and create incredibly complex simulations. This could enable researchers to better understand the behavior of molecules and proteins[27]".*

[25] W. LUO, L. CAO & al., « Recent progress in quantum photonic chips for quantum communication and internet », *Light: Science & Applications*, vol. 12, n°175n 2023 (doi:10.1038/s41377-023-01173-8), p. 2.
[26] C. M. KNAUT, A SULEYMANZADE, Y.-C. WEI & al., « Entanglement of nanophotonic quantum memory nodes in a telecom network », *Nature*, vol. 629, 2024 (doi:10.1038/s41586-024-07252-z), pp. 573-578.
[27] A. LELE, *Quantum Technologies and Military Strategy*, Springer, 2021 (doi:10.1007/978-3-030-72721-5), p. 68.

A number of difficulties remain to be resolved to imagine the deployment of a quantum Internet. First, even if quantum communications between nodes can rely on the use of existing optical fibers, similar to those used in classical telecommunications, quantum signals remain fragile and cannot be copied or amplified, which requires the development of specific solutions such as "quantum repeaters" to enable the transmission of qubits over long distances. Since this raises a number of difficulties, other works already propose alternatives, such as using a constellation of low-orbit satellites equipped with inter-satellite laser links: the satellites would carry sources of entangled photons and/or have a mirror relay system to redirect the path of photons in space, thus reducing dependence on repeaters[28]. The classical limits of using qubits must also be overcome. In particular, qubits are very sensitive to "noise," meaning interactions with their environment, generate errors (including bit flips), and easily "exit" their quantum state in the face of these interferences—this is called "decoherence." These difficulties, which also constitute as many obstacles to the development of quantum computers, are the subject of much research, which has, for example, led to the emergence of the notion of a "logical qubit," meaning a set of several "physical" qubits storing the same information to ensure the continuity of the computation operation. The stated goal of some particularly advanced companies, such as Alice & Bob, is to achieve a universal and error-tolerant computer, comprising 100 reliable and entangled logical qubits, by 2030[29].

The challenge then consists of enabling the interoperability of the various emerging small quantum networks to constitute a true quantum Internet. The Quantum Internet Alliance project aims, in this sense, to develop quantum repeaters based on announced entanglement to efficiently distribute entanglement and entangle long-lived qubits in a future European-scale quantum Internet[30]. A European, and therefore local, quantum Internet could thus see the light of day as early as 2030 – if we are to believe the enthusiastic communication of the Alliance[31]. However, interoperability, on a European and global scale, can only be guaranteed by the existence of international cooperation. In other words, building a quantum Internet requires international collaboration for the development of technologies, standards, and common infrastructures, which brings the subject into the disciplinary field of law.

However, before addressing the legal aspects of the development of a future quantum Internet (which will not be done here and calls for future work), it is desirable to discuss some underlying ethical questions – understanding that, in our conception, ethical reasoning is not

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[28] A. SCHABANI, « Building a global quantum internet using a satellite constellation with inter-satellite links », *Quantum Physics*, 2025 (doi:10.48550/arXiv.2505.08075).

[29] N. COPPOLA, R. LESCANNE, L. PROST, M. ZESKO, *Think Inside the Box. Quantum computing with cat qubits. An Introduction to Useful Quantum Computing by Alice & Bob*, Alice & Bob, December 2024, en ligne : https://alice-bob.com/wp-content/uploads/2024/12/Think-Inside-The-Box-Alice-Bob-Whitepaper.pdf (link accessed on June 3, 2025).

[30] The project is particularly ambitious: "We are pushing the frontier of technology in both end nodes (trapped ion qubits, diamond NV qubits, neutral atom qubits) and quantum repeaters (rare-earth-based memories, atomic gases, quantum dots), and is set to demonstrate the first integration of both subsystems. Our world-leading and multidisciplinary team of academic, industrial, and research technology organizations puts us in a strong position to make this a reality by 2030" (homepage of the Quantum Internet Alliance, https://quantuminternetalliance.org/, link accessed on June 3, 2025).

[31] *Idem*.

necessarily a mandatory prerequisite for the creation of legal rules, in the sense that it should continue to exist once the legal norm is adopted, but that it remains desirable at all stages of technological development.

2. Some Ethical Issues Specific to the Development of a Quantum Internet

The definition of ethics is about as complex as that of law and will not be discussed here. We will limit ourselves to distinguishing it from morality[32] by postulating its contingent and relative character: whereas, in our conception, morality is a universal and absolute normative order, ethics is contextual, situational, and evolving[33]. Moreover, we will limit ourselves here to considering it exclusively from the angle of the "ethical questioning" proposed by Ricoeur[34], by posing two questions: the precise one of the necessity of developing such a technology (2.1) and the more general one of its existential framing by an ethical framework (2.2).

2.1. The Question of the Necessity of Developing a Quantum Internet

The emergence of a quantum Internet raises questions similar to, or at least not entirely different from, those posed, most of the time only a posteriori, by the development of generative artificial intelligence (gAI[35]). The first of these is the question of the concrete interest, for Humanity, of this technology – that is, a strictly utilitarian questioning.

In our contemporary societies, the constant pursuit of innovation is based on an aspiration inherited from capitalism: "[I]t is the promise of consumer society: happiness linked to the purchase of a new product. [...] Progress is a desire and can become a certainty"[36]. In this context[37], we must "beware of scientific and technical solutionism. It is the old adage: science always finds answers to the problems it poses. This works rather well, but not always, which calls for caution. Today, with a small genetic manipulation, we can grow wings on a baby, but just because we can do it doesn't mean we should do it"[38]. In other words, our social models

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[32] This position is not unanimous. See, for example, the contrary view in R. BRAGUE, *La morale remise à sa place*, Gallimard, 2024.
[33] For further details, see R. MAUREL, *Introduction au droit international de l'éthique des affaires*, Mare & Martin, coll. droit international, 2025, 184 p., specifically the general introduction.
[34] P. RICOEUR, *Soi-même come un autre*, Seuil, 1990, 448 p.
[35] We use the abbreviation "gIA" here, which should not be confused with GenAI, the latter more commonly referring to general-purpose artificial intelligence as defined by Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024, which establishes harmonized rules on artificial intelligence and amends Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) Nos 168/2013, (EU) 2018/858, (EU) 2018/1139, and (EU) 2019/2144, and Directives 2014/90/EU, (EU) 2016/797, and (EU) 2020/1828 (Artificial Intelligence Regulation). See specifically Chapter V of the Regulation.
[36] P.-H. TAVOILLOT, « La ligne de fracture entre ceux qui pensent que c'était mieux avant et ceux qui sont convaincus du contraire imprègne encore tous nos débats d'aujourd'hui », *in* N. BOUZOU, C. FLEURY, É. KLEIN, K. SAFA, C. SENIK, P.-H. TAVOILLOT, J. VIARD, *Peut-on encore croire au progrès*, L'aube, 2023, p. 24 (our translation from french).
[37] We will not distinguish here between "progress" and "innovation". However, the same author does differentiate between them and writes that "[i]nnovation and progress are like decline and decadence. The decadence of a country is very difficult to demonstrate and contains a moral dimension. Whereas the decline in GDP, we know how to measure it. [...] For progress, it's the same, whereas innovation, we know how to evaluate it. Not every innovation is progress, but progress cannot do without innovation" (*ibid*., p. 41, our translation).
[38] *Ibid*., p. 38 (our translation).

encourage us to desire new technologies, with any individual or collective awareness of the fragility of the perceived need being compensated by a technosolutionist discourse providing a solid utilitarian basis: innovation will lead to the economic enrichment of its authors, promoters, and more broadly the collateral social group (a company, a region, a state, an international organization, a continent...), and more broadly solutions to contemporary problems affecting said group or Humanity as a whole (strategic and military weakness; unavailability of natural resources; climate change, *etc*.).

This being known, it is pertinent to take a "step back" and clearly question the interest of a new technology such as the quantum Internet. What are the concrete uses it could offer? Do these advantages justify the massive investments and efforts necessary for its deployment, at the expense of other technological advancements or the resolution of situations requiring public and private investments (world hunger, conflicts, access to water...)? If this innovation is intended for global commercialization, it is also desirable to ask whether it meets a societal need or a political and social imaginary making it desirable within a given human group. These questions cannot be answered by a legal scholar but could, or should, be asked. To do this, we can rely on the insights of philosophy. Thus, Thierry Ménissier writes enlighteningly:

> *"[...] the approach of ethical evaluation of innovation finds the typical requirement of utopian aspirations, in which it is a matter for a collective to re-give itself, through its own imaginary resources, open future options. Several criteria for enlightened uses and practices then appear—here are four possible ones. First, a meta-criterion valid for any innovation acceptable within our so-called information and knowledge societies can be found in 'publicity' in the sense that democracy relies on the space of publicity described by Kant: according to this criterion, an innovation can be said to be acceptable if and only if, in its conditions of emergence, diffusion, and use, information concerning its 'social and environmental cost' is made available. [...] Here are three other possible specific criteria: affordance, conviviality, and inclusivity. Firstly, based on work in perception psychology, the notion of 'affordance' can be used, as it designates, according to its promoter James J. Gibson, a quality of the object or device that constitutes an 'invitation' to use them. Secondly, an innovation can be said to be acceptable due to its convivial character, referring to a theme characterized by Ivan Illich as the triple capacity of a device to be open to user control, to allow their autonomy, and to connect them in a non-constrained interdependence. Thirdly, a criterion can be found in inclusivity, that is, referring to the work of Iris Marion Young, in the capacity of an innovation to effectively counter one of the flaws of contemporary societies, the double individualistic and communal withdrawal"*[39].

The environmental impact of a quantum Internet constitutes, in light of the above, another relevant point of discussion regarding its necessity and thus an issue in the ethical reflection

[39] Th. MÉNISSIER, *Innovations. Une enquête philosophique*, Hermann, 2021, pp. 204-205 (our translation from french), citing E. Kant, *Réponse.à la question « Qu'est-ce que les Lumières »* (1784), translation J.-F. Poitier & F. Proust, Flammarion, 1991, pp. 45-47 ; J. J. GIBSON, *Approche écologique de la perception visuelle* (1979), translation O. Putois, Editions Dehors, 2014 ; I. ILLICH, *La Convivialité*, Seuil, 1973 ; I. M. YOUNG, *Inclusion and Democracy*, OUP, 2002.

concerning the development of this innovation. The question is all the more important as it emerges from the previous elements that the quantum Internet will not replace the classical Internet but will superimpose itself on it, adding an additional layer of energy consumption and technological complexity to the contemporary digital environment. At a time when the weight of the digital sector in the consumption of energy and natural resources is the subject of particular attention worldwide[40], it is to be feared that this superimposition will further increase the pressure on these resources.

Two remarks can be made in this regard. On the one hand, it is remarkable that the question of the energy consumption of quantum computing is an integral part of current research on this subject. For example, in a recent thesis defended in Grenoble, it can be read that the energy cost of quantum computing should be a criterion for evaluating the potential for scaling quantum computers[41]. The objective of the work carried out was to determine the minimum amount of resources (for example, energy power) necessary to perform a quantum computation, taking into account the constraint that the quantum algorithm must provide a correct answer with a targeted probability. This type of research, promoted by calls not to repeat certain past mistakes – for example, among others, researchers proposed in 2024 a carbon-conscious quantum computing (CQC)[42] framework—allows for optimizing by design the overall architecture of the functional quantum computer with the stated goal of minimizing the resources used. Multidisciplinary reflections are part of the same dynamic[43]. On the other hand, recent research tends to demonstrate that quantum computing would have an exponential advantage, in terms of energy consumption, over classical computing to solve a certain number of problems[44]; concrete techniques to demonstrate the energy consumption of computing are also emerging[45].

These initial elements should not lead to considering the issue as resolved. On the contrary, they call for collective reflection, which can only take place to the extent that the broadest possible information is disseminated about quantum technologies. Once the subject is spread in civil society, the question of the social reaction to potential abusive or problematic uses of the quantum Internet will likely arise.

[40] See on this subject the enlightening update of the ADEME-ARCEP report from 2022: ADEME-ARCEP, "Évaluation de l'impact environnemental du numérique en France. Mise à jour de l'étude ADEME-Arcep", Final Report, 2025, 35 p.
[41] M. FELLOUS ASIANI, "The resource cost of large scale quantum computing", Thesis publicly defended on November 9, 2021, Université Grenoble Alpes. See specifically Chapter 4.
[42] N. ARORA, P. KUMAR, « Sustainable Quantum Computing: Opportunities and Challenges of Benchmarking Carbon in the Quantum Computing Lifecycle », *ArXiv abs/2408.05679*, 2024 (doi:10.48550/arXiv.2408.05679).
[43] See in particular the resources provided by the QuantAlps program at Université Grenoble Alpes, which integrates human and social sciences into the reflection, including the Quantum Technologies and Sustainability Seminar Series, available online: https://quantalps.univ-grenoble-alpes.fr/tiqua/sustainable-quantum/quantum-technologies-and-sustainability-seminar-series-1475484.kjsp?RH=1680003510689 (link accessed on June 12, 2025).
[44] For example F. MEIER, H. YAMASAKI, « Energy-Consumption Advantage of Quantum Computation », *PRX Energy*, vol. 4, 2025, n°023008 (doi:10.1103/PRXEnergy.4.023008).
[45] *Idem*.

2.2. The Question of the Modalities of the Ethical Framework of a Quantum Internet

The following reflection is based on the observation that the turn towards the ethics of artificial intelligence (AI), specifically generative, has been taken in Europe and elsewhere essentially from a discursive angle – which has led to significant political and even legal confusion in the debate regarding its framework[46].

The risk posed by the emergence of quantum technologies in civil markets is that of rapid economic valorization, leading to the generalization of their uses without their concrete impacts having been measured. Reasoning by analogy with generative AI certainly has limits that cannot be ignored here. On the one hand, generative AI is not a "technological revolution" comparable to quantum technologies. If generative AI is essentially a commercial declination of probabilistic language models based, in computer science, on otherwise known automatic learning methods—that is, a software evolution—quantum technologies rely on physical sciences and entail a material paradigm shift based on the mastery of hitherto theoretical knowledge in quantum mechanics. On the other hand, quantum technologies are first developed for military purposes[47], and the flooding of markets by their commercialization is at least uncertain. However, it is reasonable to assume that commercial uses will be developed in the future, if only to finance the quantum infrastructures necessary for the hoped-for technological leap.

In the hypothesis, whose prospective nature we thus assume, of a commercialization of access to the quantum Internet, tools allowing access to it, or even platforms enabling the development of private quantum Internets for personal or collective use, one of the main identifiable risks is the regulation of uses in urgency. This could manifest, by analogy with reactions to the emergence of generative AI since the commercialization of ChatGPT by OpenAI in November 2022, through the emergence of lists of more or less clear principles intended to frame these uses. If the existence and reflection around principles of responsible use – that is, a "principle-based"[48] approach – is not inherently problematic (it is, moreover, already underway within the doctrine[49]), at least two pitfalls are possible. The first consists of limiting oneself to this approach without developing alternative and complementary ethical approaches – whether they be axiological, deontological, or others. The second consists of constructing one or more principle-based approaches by confusing the origin and nature of the identified principles. As we have had the opportunity to write elsewhere, the desire to regulate the uses of AI, generative

[46] On this point, see R. MAUREL (in french), "Démystifier l'IA et en dessiner une éthique pour sortir de la confusion ambiante," *The Conversation*, February 11, 2025, available online: https://theconversation.com/demystifier-lia-et-en-dessiner-une-ethique-pour-sortir-de-la-confusion-ambiante-249299 (link accessed on June 10, 2025).
[47] This is evidenced by the speech "Plan quantique: une stratégie ambitieuse et souveraine" by the French Minister of the Armed Forces, Sébastien Lecornu, at the closing of the France Quantum forum on June 11, 2025 (https://www.defense.gouv.fr/actualites/plan-quantique-strategie-ambitieuse-souveraine (link accessed on June 14, 2025).
[48] In french, "approche principiste".
[49] M. KOP et al., « Ten Principles for Responsible Quantum Innovation », *Quantum Science and Technology*, vol. 9, n°035013, 2024 (doi:10.1088/2058-9565/ad3776).

or not, has led to the juxtaposition, within several official lists[50] of principles sometimes qualified as ethical, of technical principles (robustness), sociological or even anthropological principles (diversity), psychological principles (human control, societal well-being), legal principles (respect for privacy), or even transversal principles ("responsibility", "human action")[51]. The result is massive and widespread confusion between the field of ethical framework and AI law, which overall harms society. It is therefore, to think about the ethics of the quantum Internet—and by extension of the quantum computer—to avoid repeating the mistakes, determined by an overly principle-based approach, made regarding the framework of previous technologies such as the Internet or AI.

Another approach, complementary yet perfectly distinct from any principle-based approach to uses, would be to base itself on the idea of common goods to frame the development of the quantum Internet. The idea would be to recognize this technology as a collective heritage, belonging to all of humanity, and to guarantee collective governance based on principles of equal and free access. It is based, moreover, on the theoretical foundations that guided the creation of the free Internet, a "common 'by design'[52]" where the primary objective was to provide universal and transparent access to the network while preserving values such as neutrality, openness, or freedom of use. Envisaging the quantum Internet from this perspective from the outset would prevent it from being captured by large private actors or serving solely economic interests. By adopting such an approach, states, companies, and international institutions could collaborate to steer the development of these technologies towards morally acceptable, collectively defined, and sustainable uses. Such an approach, certainly imbued with a certain optimism or even idealism which is, moreover, not irreconcilable with a legal analysis of the positive law of these technologies, would offer the opportunity to create a quantum Internet at the service of Humanity while preserving common goods for future generations.

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The preceding remarks imply strong political choices. These will determine the law that will be applicable, when the time comes, to the quantum Internet. This should logically revolve around two major axes. On the one hand, a law governing the infrastructure of the emerging quantum Internet will develop, whether it involves, depending on the technologies adopted, using existing or new infrastructures (undersea cables, quantum satellites) or defining an international framework for the interoperability of quantum systems. On the other hand, a law concerning the uses of the "quantum Internet" object should emerge, whether it involves the associated military or civilian issues. These will be determined, as mentioned, by the choices made

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[50] These can be documents produced by international organizations (such as UNESCO, the European Union), independent administrative authorities (such as the CNIL, the data protection authority in France), or judicial bodies (such as the Conseil d'État or the Cour des comptes in France).

[51] R. MAUREL, « Éléments pour une éthique de l'IA simplifiée », *Note n°40 de L'Observatoire de l'éthique publique*, February 2025, spéc. p. 8.

[52] V. PEUGEOT, « Biens communs et numérique : l'alliance transformatrice », in L. CALDERAN, P. LAURENT, H. LOWINGE, J. MILLET, *Le document numérique à l'heure du web*, ADBS, 2012, pp. 141-154, spéc. point 2.

beforehand, which will allow, or not, access to these technologies for the greatest number – or not.