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Accelerating Quantum Computing Readiness: Risk Management and Strategies for Sectors

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Abstract

The potential impact of quantum computing on various industries such as finance, healthcare, cryptography, and transportation is significant; therefore, sectors face challenges in understanding where to start because of the complex nature of this technology. Starting early to explore what is supposed to be done is crucial for providing sectors with the necessary knowledge, tools, and processes to keep pace with rapid advancements in quantum computing. This article emphasizes the importance of consultancy and governance solutions that aid sectors in preparing for the quantum computing revolution. The article begins by discussing the reasons why sectors need to be prepared for quantum computing and emphasizes the importance of proactive preparation. It illustrates this point by providing a real-world example of a partnership. Subsequently, the article mentioned the benefits of quantum computing readiness, including increased competitiveness, improved security, and structured data. In addition, this article discusses the steps that various sectors can take to achieve quantum readiness, considering the potential risks and opportunities in industries. The proposed solutions for achieving quantum computing readiness include establishing a quantum computing office, contracting with major quantum computing companies, and learning from quantum computing organizations. This article provides the detailed advantages and disadvantages of each of these steps and emphasizes the need to carefully evaluate their potential drawbacks to ensure that they align with the sector's unique needs, goals, and available resources. Finally, this article proposes various solutions and recommendations for sectors to achieve quantum-computing readiness.

Keywords

Quantum Computing, Consultancy, Governance Solutions, Quantum Readiness, Benefits of Quantum Readiness, Increased Competitiveness, Improved Security, Structured Data, Quantum Algorithms, Quantum Service

Provider, Cybersecurity, Data Management

1. Introduction

Quantum computing has the potential to change the future by solving problems that are currently impossible to solve by using classical computing. Sectors need to be proactive in their preparation for technology and explore their exponential growth if they are looking to get ahead in their field. If a sector wants to remain competitive and benefit from the opportunities presented by quantum computing, it needs to understand the risks and benefits of quantum computing, determine where it could be applied, and develop strategies to take advantage of its power. According to Mario Piattini, Guido Peterssen, and Ricardo Pérez-Castillo in their paper titled "Quantum Computing: A New Software Engineering Golden Age," they state, "We are sure that quantum computing will be the main driver for a new software engineering golden age during the present decade of the 2020s" [1]. Here is the essence of readiness, and governance solutions in quantum computing have come into play. Whether they are public or private sectors, large or small, the importance of quantum computing readiness cannot be overstated. Providing consultation with the correct knowledge, tools, and processes can ensure that they are ready to take advantage of quantum computing. This article addresses the need for quantum computing readiness and its benefits. Moreover, will also highlight the importance of risk management and provides specific recommendations for sectors to mitigate the potential risks associated with quantum computing. With the accelerating pace of quantum computing development, it is essential that sectors now act and prepare for the future.

2. Need for Quantum Computing Readiness

Quantum computing is a field that will eventually evolve in the future. Advancements in technology have changed the way businesses operate over the past decade. However, some sectors struggled to keep up with the rapid pace of change and to obtain advantages. Quantum computing is one such area that has the potential to significantly disrupt industries and markets. To avoid being left behind, it is crucial for organizations to take proactive steps to prepare for the future of quantum computing. The author of "An Environmentalist's Guide to Quantum Computing" argues that falling too far behind in technological advancements, such as AI, has clear consequences. Therefore, sectors should proactively prepare for the future of quantum computing by seeking guidance from specialized experts and investing in early adoption strategies. The goal is not just to study the risks but also to prevent them, encourage innovation, and accelerate the introduction of sustainable technologies into the marketplace, rather than hinder it (Rejeski, 2022) [2]. This suggests that organizations should not just wait and watch but should also take action to keep up with fast-paced technolo-

gical changes and innovate accordingly. In 2021, NEOM recognized the benefits and risks of quantum computing; thus, they partnered with Arqit to seek expert guidance in building the foundations of NEOM. The development of a quantum secure cognitive-city system by Arqit and NEOM is a clear example of the potential applications of quantum computing in different sectors and industries. Therefore, sectors need to have a deep understanding of quantum technology, its implications, and its potential applications in their respective industries. Despite the novelty of quantum computing and the lack of qubits, which may impede its ability to yield significant results, advances in this field are rapidly occurring and require immediate preparation. The optimal approach is to utilize scientific knowledge and adapt to changes by consulting those who specialize in quantum computing to determine potential benefits and risks. Consultants can help provide sectors with guidance regarding their preparation. For example, consultants can identify areas where quantum computing can be applied, and change the sector's strategy to avail its power and prevent the risks associated with its use. Moreover, they can create quantum-ready data management and security frameworks as well as prepare teams to work with quantum technologies. With the aid of accelerating quantum readiness for sectors, they will be confidently ready to exploit the benefits of quantum computing.

3. Benefits of Quantum Computing Readiness

Quantum computing is a revolutionary innovation that offers tremendous potential for solving complex problems with large datasets, thereby optimizing processes and boosting productivity and efficiency in various sectors. However, many companies face challenges in implementing this cutting-edge technology, owing to the intricate technicalities and lack of a skilled workforce. Seeking quantum computing readiness consultancy can help overcome these hurdles and facilitate the effective adoption of quantum technology. With the growing realization of quantum computing benefits, an increasing number of companies are likely to partner with quantum computing providers or specialists to enhance their operations. Moreover, the constantly increasing number and quality of quantum computing use cases are opening up new avenues for its widespread application in solving previously intractable challenges in diverse industries. By proactively preparing for the implementation of quantum computing technology, sectors can gain a competitive advantage and become better equipped to solve complex problems. The benefits of quantum computing readiness range from increased efficiency and productivity to the ability to tackle challenges that were previously considered unsolvable. With the help of quantum computing specialists and consultants, sectors can ensure a smooth transition to the new technology and maximize the potential advantages it offers, in the subsequent sections, an explanation for some of the benefits.

3.1. Increased Competitiveness

Preparing for quantum computing enables sectors to reach their highest level of

performance earlier or once the service is available from the quantum service provider. Sectors can make informed decisions about the future and process them to take advantage of the quantum computing benefits. Therefore, reducing the cost of services or opening new avenues will allow sectors to gain a competitive advantage. The implementation of quantum algorithms can reduce the cost of data processing by increasing efficiency or reducing the number of resources used. Staying up-to-date with the latest advancements helps sectors differentiate themselves from their competitors by discovering new innovative applications and services to leverage quantum computing or prioritize the sharing of knowledge and resources as an accredited sector.

3.2. Improved Security

Improved security is a critical aspect of sectors seeking to harness the power of cutting-edge technologies. Sectors with large amounts of data can avoid cyberattacks by having robust data management and security frameworks in place. Thus, they must ensure that the environment is secure and that the data are protected from unauthorized access. As the emergence of quantum computing also introduces significant risks, particularly to traditional cybersecurity protocols such as RSA encryption, readiness consulting by experienced readiness consultants is a way to identify the potential security risks of quantum computing. This includes conducting a thorough risk assessment of the IT infrastructure, systems, and data to identify vulnerabilities and potential threats to quantum risks. In addition, governance solutions can help sectors establish secure and compliant quantum computing environments, such as guiding data privacy, security regulations, and best practices for data management. Sectors should consider adopting post-quantum encryption standards, start planning for the adoption of quantum key distribution (QKD), and develop quantum-safe software and hardware as part of their risk management strategy. This includes developing existing policies and procedures for data protection and management as well as protocols for incident response and disaster recovery.

3.3. Structured Data

Formatting big data to be easily processed by quantum computers accelerates the benefits to take advantage of increasing efficiency, solving problems, and analyzing data. However, structuring and managing data compatible with quantum computing is complex and time-consuming. This often requires significant overhaul by sectors without the necessary expertise. Experienced in quantum computing can provide valuable guidance and support to help sectors make the transition smoothly. This can be accomplished with some key steps, such as the following:

1) Structuring the data in a manner that can be easily analyzed and processed by quantum algorithms by cleaning, formatting, and transforming it as necessary.

2) Understanding the data and identifying the parts that may be suitable for

quantum processing using statistical analysis techniques to identify trends, correlations, and other key features.

3) Quantum algorithms are used to uncover insights and relationships within data that may not be visible to traditional processing methods.

4) Evaluating the effectiveness and efficiency of quantum computing results in handling big data compared to those obtained using traditional processing methods.

4. How to Achieve Quantum Readiness

To prepare for the emergence of quantum computing, sectors should take five concrete steps, including following industry developments and screening quantum-computing use cases, understanding the significant risks and opportunities in their industries, considering partnerships or investments in quantum-computing players, recruiting in-house quantum-computing talent, and building the digital infrastructure that can meet the basic operating demands of quantum computing. These steps are essential to achieving quantum readiness, according to a report by McKinsey & Company (Biondi *et al.*, 2021) [3]. Sectors should accelerate quantum computing readiness by preparing for its emergence. The challenge is to ensure that sectors are fully prepared for quantum risks and to obtain the advantage of all available opportunities. In this regard, this article proposes several solutions for preparing a sector for quantum computing readiness by consulting for process governance. The proposed solutions ultimately lead to providing guidance for the sector to attain quantum computing readiness.

4.1. Quantum Computing Office

Sectors could establish an office specializing in quantum computing and hire an in-house team who works more closely with other departments, which offers numerous advantages:

1) Develop a strategy and solutions tailored to fulfill the sector's needs.

2) Investment in a specialized team can pay dividends in the long run.

3) Maintaining confidentiality and control over sensitive information.

4) Investing in the necessary equipment and expertise allows for better cost management.

5) Facilitating integration and collaboration within a sector.

The decision to establish an in-house team specializing in quantum computing depends on a variety of factors, including the sector's size, resources, expertise, and long-term goals. Therefore, several drawbacks must be considered.

1) High startup costs that require significant investment in infrastructure, hardware, software, and talent.

2) Difficulty in acquiring and retaining skilled professionals in the field of quantum computing due to high demand and intense competition.

3) Risk of obsolescence, which requires a long-term commitment to stay up-to-date with the latest advancements and technologies.

4) Limited access to expertise, which may be restricted to the knowledge and

experience of in-house team members.

In order to take the first step towards leveraging the potential benefits of quantum computing, it may be advisable for sectors to engage the services of a consulting company with expertise in this field. Boston Consulting Group (BCG) is an example of such a company that offers specialized consulting services related to quantum computing. While the establishment of an in-house team specializing in quantum computing can offer substantial advantages, it is essential to carefully evaluate the potential drawbacks of consulting or hiring experts. The decision to establish such a team should be based on a comprehensive analysis of the sector's unique needs, goals, and available resources.

4.2. Quantum Computing Contract

Sectors can contract with major quantum computing companies to provide access to the best-proven results and technology. Partnering with major companies accelerates the achievement of the desired results or the results agreed upon before starting work. Sectors can determine the appropriate partner based on their need. For instance, sectors that have sensitive data and want to secure it may partner with KETS, Toshiba, or Honeywell. "In July 2020 JPMorgan Chase revealed that they put Honeywell's quantum computer…that may help the financial industry secure accounts and make better investing decisions" [4]. However, sectors that want to develop urban services may collaborate with Arqit where they have previous use cases that have already been applied in NEOM. Figure 1 shows quantum market maps [5] that categorize companies based on their areas of expertise within the quantum computing market. This map did not mention all existing companies but could help sectors determine the appropriate partner for their specific needs.

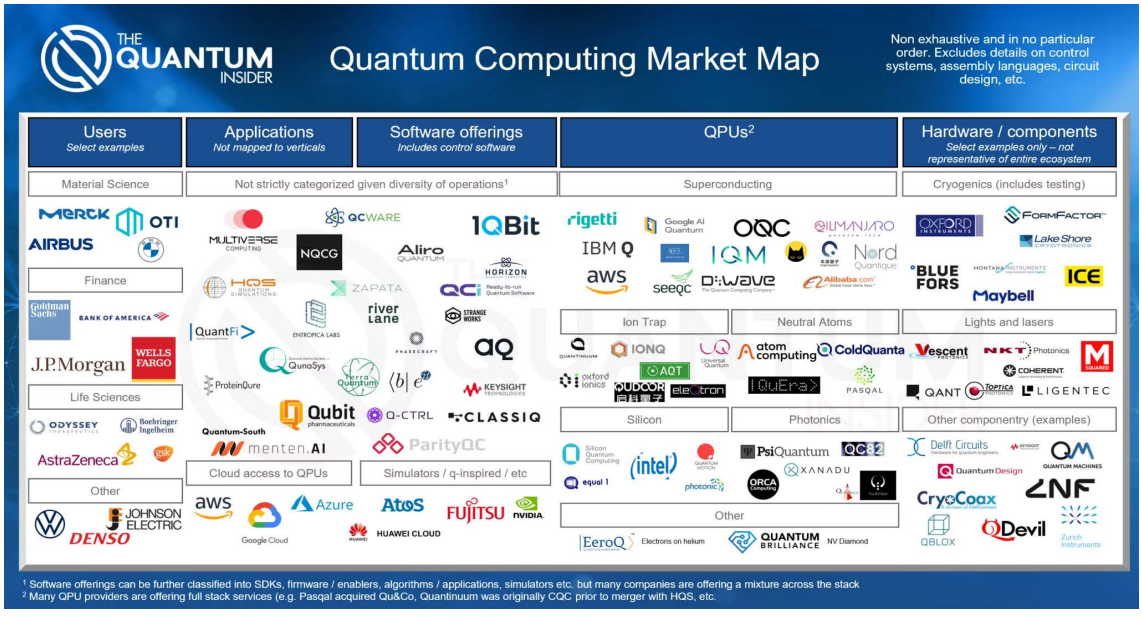

Figure 1. The map is sourced from the Quantum Insider website and was published in the article "Quantum Computing Market Map and Data 2022" by Alex Challans.

A sector may gain several advantages when it contracts with major quantum computing companies.

1) Access a technology that has already been applied to get the best-proven results.

2) Accelerating achieving the desired results by quantum companies' expertise and experience.

3) Evaluate the sector's status and assess its real requirement to focus on obtaining the best results.

The decision to contract with major quantum computing companies also depends on various factors, including the sector's size, resources, expertise, and long-term goals. Therefore, there are some potential disadvantages to contracting with major quantum computing companies.

1) The risk of sharing sensitive information with a third-party company could limit its ability to fully leverage the benefits of a partnership.

2) Dependency on that company for continued support and development without access to critical resources and expertise.

3) Limited access to intellectual property could limit the sector's ability to innovate or commercialize products and services.

In summary, partnering with major quantum computing companies can provide several benefits and potential drawbacks. Thus, the decision to contract with a major quantum computing company should be carefully evaluated to ensure that it aligns with the sector's needs, priorities, and resources.

4.3. Quantum Computing Organization

Most countries have an organization responsible for computer technology, and in recent years, many of these organizations have started to focus on quantum technology as well. Quantum computing organizations represent a strategic approach to guide the quantum computing sectors in many countries, as they provide various services that accelerate quantum development to win the global race to lead the quantum computing revolution. Governmental and nonprofit organizations within a country can guide sectors to prepare fully for quantum risks and opportunities. One effective way to achieve this is learning from quantum computing organizations. The following are a few examples of quantum computing organizations from different countries, established for various purposes:

4.3.1. National Quantum Coordination Office (United States)

The National Quantum Coordination Office (NQCO) was established in 2020 to coordinate quantum activities across departments, US government agencies, industry, and academia. Its goals include promoting collaboration, accelerating development and commercialization, and educating the public and policymakers about the potential of quantum technologies [6].

4.3.2. European Quantum Flagship (European Union)

The European Quantum Flagship is a 1 billion euro research and innovation initiative launched by the European Union in 2018. It supports research in areas

such as quantum computing, communication, simulation, and sensing, and aims to accelerate the development of quantum technologies for the benefit of society and the economy [7].

4.3.3. National Laboratory for Quantum Information Sciences (China)

The National Laboratory for Quantum Information Sciences is a $10 billion research facility established by the Chinese government in 2017 as part of its push to advance the development of quantum science and technology. This laboratory has played a significant role in China's advancements in the field, particularly in quantum communications, and has created the prototype quantum computer called Jiuzhang. In 2019, Tencent also established a Quantum Lab that aims to connect fundamental theory with practical applications in quantum information technology [8].

4.3.4. Quantum Industry Canada (QIC) (Canada)

Quantum Industry Canada (QIC) is a consortium of Canadian companies specializing in quantum technologies. Its goal is to ensure that Canadian quantum innovation and talent are translated into Canadian business success and economic prosperity. QIC members collaborate to promote Canada's quantum readiness globally, support quantum start-ups and established companies, and provide expertise in intellectual property and go-to-market strategies. The consortium works with federal and provincial governments to support the emerging quantum industry in Canada [9].

4.3.5. The Vision of Quantum Future Society (Japan)

The Vision of Quantum Future Society is a new strategy formulated by the Japanese government in April 2022 to expand on initiatives for social innovation through quantum technology. The vision aims to embed quantum technology throughout social and economic systems, creating opportunities for industrial growth, achieving a carbon-neutral society, and addressing social issues raised by the SDGs. Quantum computing is seen as an important technology for achieving these goals, and the Japanese government is accelerating research and development in this field as part of the vision [10].

4.3.6. Russian Quantum Center (Russia)

The Russian Quantum Center (RCC) is a scientific research center that focuses on the development of quantum technologies. It was established in 2012 as a collaboration between the Russian Federation's Ministry of Education and Science, the Russian Academy of Sciences, and the private investment company Rusnano. The RCC is located in the Skolkovo Innovation Center and currently has 17 scientific groups working on fundamental research in the field of quantum technologies, which include Russian and international scientists, as well as students and graduates of the RCC department at MIPT [11].

After listing a few examples of quantum computing organizations from different countries, it is important to note that many more organizations have a

connection to quantum technology. The list provided is by no means exhaustive, and there are likely more organizations in the mentioned countries as well as in other countries. Sectors interested in quantum computing should reach organizations in their respective countries to see what they can provide. These organizations established to help sectors prepare for the future and take advantage of quantum computing. As the development of quantum computing continues, more organizations are expected to emerge in the future.

5. Recommendations

As quantum computing continues to grow and develop, it is becoming necessary for the legislative authorities to intervene to unify efforts and support the country to achieve the hoped-for progress in the field of quantum computing technology. This provides a supportive environment for quantum service providers, which will help in innovation and rapid development. Moreover, working together can promote the growth and success of the quantum technology industry. By pooling their resources, knowledge, and expertise, sectors can achieve common objectives that may be difficult or impossible to achieve individually. The following two recommendations will help sectors accelerate quantum computing readiness by following the standards as a guide for full preparation.

5.1. Governmental Standardization for Quantum Computing

The first recommendation is setting standards by the government for all stakeholders in the quantum computing field. Standardization will ensure that everyone is working towards the same goals and following the same guidelines, promoting a cohesive and productive ecosystem. By establishing such standards, the government can also help mitigate risks associated with quantum computing, such as the potential for cyber threats and ethical concerns surrounding the use of sensitive information. Additionally, the adoption of these standards can help foster collaboration between sectors, and facilitate the exchange of knowledge and expertise, ultimately benefiting the quantum computing ecosystem. Standardization in the field of Quantum Computing is crucial as it allows stakeholders to unify their efforts to maximize gains. "The availability of a supply chain of such modules from different vendors will enable research teams to concentrate their research on breaking new grounds, without spending much effort on duplicating known solutions. This is where standardisation can play an important role" (van Deventer *et al.*, 2022) [12]. The establishment of standards for quantum computing by the government can lead to the achievement of quantum readiness by providing guidelines and promoting a cohesive ecosystem, mitigating potential risks, fostering collaboration between sectors, and facilitating the exchange of knowledge and expertise.

5.2. Quantum Computing Standards Organization

The second recommendation is to create an international Quantum Computing

Standards organization (QCS) that publishes standards and provides guidance and qualification for public and private sectors. Similar to ISO, B Corp SDG, etc., the organization provides sectors with a diverse group of experts and a framework for preparing for quantum technology. Experts will help the sectors apply quantum services by following the guidance and then giving them certification when a sector is qualified. The main goal is to follow the most effective approach using quantum computing technology. The existence of such an organization will provide a sense of trust and assurance for both sectors and consumers. Moreover, the QCS will encourage sectors to activate in-house quantum computing protocols and test quantum services. This will motivate quantum computing companies to develop more services owing to high demand.

Responsible Research and Innovation (RRI) aims to align research and innovation processes with societal values, needs, and expectations to ensure that the outcomes are beneficial and acceptable to society [13]. The QCS can use the RRI to direct its criteria and encourage sectors to be involved in its program. Therefore, the alignment will proactively address challenges, future uncertainties, ethical issues, and implications of a particular decision to prepare for the potential consequences of different choices.

Providing QCS certification can provide a competitive advantage among sectors by demonstrating to customers and investors that the sector is taking a proactive approach to staying ahead of the curve, reducing its risks, and taking advantage of opportunities. The following are suggested steps that a Quantum Computing Standards organization (QCS) may take to award a certification:

1) Assessing the status quo: QCS evaluates a sector's current technological capabilities, including hardware and software, to determine where quantum computing can provide value.

2) Building a strategy and framework: Based on the evaluation, the QCO provides a standard guide for developing a roadmap for building and implementing quantum computing into the sector's existing technology and business processes.

3) Implementation: The QCS supports the execution of the plan, provides consultancy, trains employees, and ensures that new technology is integrated into the existing systems.

4) Evaluation: Once the implementation is complete, the QCS evaluates the sector to determine whether it meets the standards set forth by the QCS. Thorough evaluation is essential to serve as the basis for certification. Thereafter, a sector can proudly demonstrate its readiness for a quantum era through QCS certification.

Despite the idea of establishing a QCS to provide guidance and certification for sectors that are compelling, it also has its disadvantages. One major drawback is that creating such an organization will take time, require significant financial resources, a global consensus on the standards it provides, and political support. Moreover, it may take a considerable amount of time for sectors to comply with the QCS's certification requirements, which may deter some from seeking certification. However, despite these challenges, creating a QCS will be a

significant step towards ensuring that quantum computing technology is applied effectively and safely across various sectors in different countries. The QCS can empower sectors to leverage quantum services based on their individual requirements, thereby prompting quantum computing companies to develop various quantum services in response to increasing demand.

6. Conclusion

As we continue to witness the advancement of quantum computing, sectors across various industries must take steps to prepare for this technology's impact. Quantum computing is a promising technology with the potential to transform our lives and industries. However, it also introduces significant risks, particularly to traditional cybersecurity protocols. The emergence of quantum computing threatens to render current encryption methods obsolete, putting sensitive data at risk. To address these potential risks, sectors must develop a comprehensive risk management strategy for quantum computing. This strategy should include risk assessment, planning for the adoption of post-quantum encryption standards, the adoption of quantum key distribution, the development of quantum-safe software, and the adoption of quantum-safe hardware. Conducting a thorough risk assessment is crucial to identifying potential vulnerabilities and threats to quantum risks. This process involves analyzing infrastructure, systems, and data to identify weaknesses that could be exploited by hackers. Software developers and hardware manufacturers must also start planning for the development of quantum-safe software and hardware that are resistant to quantum attacks. Sectors should start planning for the adoption of these solutions as part of their risk management strategy. Additionally, governance solutions can help sectors establish secure and compliant quantum computing environments, such as guiding data privacy, security regulations, and best practices for data management. In conclusion, sectors across various industries should be aware of the potential risks and benefits of quantum computing and take steps to prepare for its impact. By developing a comprehensive risk management strategy that includes risk assessment, planning for the adoption of post-quantum encryption standards, the adoption of QKD, the development of quantum-safe software and hardware, and adopting governance solutions, sectors can mitigate potential risks effectively and take advantage of the transformative power of quantum computing.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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