

What would a Quantum Strategy look like for a Fortune 500 Company?

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In an era where computational power defines the competitive edge of corporations, quantum computing (QC) emerges as a pivotal technology with the potential to revolutionize various sectors. Not only does it come with various opportunities like faster computations, improved optimization, enhanced simulation capabilities, advanced machine learning & AI, quantum cryptography, and climate-friendly innovation, but it also has various risks associated with it, especially related to data and cybersecurity.

For Fortune 500 companies, formulating a robust quantum strategy is essential not only to leverage these advancements but also to safeguard their technological futures. Though AI has recently been outpacing quantum in terms of raising more capital and more companies investing in AI, the global quantum computing market is projected to reach between \$45 billion and \$131 billion by 2040, emphasizing its immense economic potential. This document examines the implications of quantum computing for large corporations and proposes a strategic framework for integrating QC into their business operations.

The US Quantum Computing Landscape

Considering that the US has many big companies working on quantum computing, including Microsoft, Google, IBM, etc, the US is a leading player in the field of quantum computing. With respect to government initiatives, quantum computing comes under the legal ambit of the National Quantum Initiative Act, under which there are 14 major National Quantum Initiative Research Centers and Institutes, and more than 150 companies currently participating in the Quantum Economic Development Consortium.

Considering the rapid rise in quantum, it is extremely important to have a skilled workforce in this field, which can be seen in the rise in the number of US universities offering master's programs in quantum from 29 in 2021 to 50 in 2022. Apart from this, we can also see industry collaboration, such as IBM's Quantum Educators program, Microsoft Quantum Development Kit, Microsoft & Classiq partnership, Google Cirq framework, and so on. Considering that there are various workforce challenges like limited qualified candidates, longer training periods, and competition from other countries, the US government through The CHIPS and Science Act makes key investments in quantum education and workforce development through the Next Generation Quantum Leaders Pilot Program. There can be better progress with rapid upskilling, collaboration with academia, and internal training programs in order to make better advancements in this regard.

Sector-Specific Insights on Quantum Computing

Quantum has the potential to impact all the possible sectors. However, the literature suggested that the most significant impact would be on pharmaceuticals, finance, defense and aerospace industries, and automotive manufacturing. Accordingly, we focus on them.

Pharmaceutical industry:

- Pharma is seeing rapid growth with respect to quantum in terms of the market size as well as the number of patents. This can be attributable to the immense opportunities that this sector

has considering that quantum can be utilized in all pharma stages including R&D, production, logistics, supply chain, and market access (holds primary value in R&D). Further, it is very easy to integrate, considering that pharma already embraces Computer-Assisted Drug Discovery, AI, ML, non-quantum Computing Density Function Theory, etc. However, there are also specific challenges, like sensitivity to quantum noise, workforce gap, and patient data privacy and bias concerns.

- With respect to the progress, it is expected that the next 5 years can see Quantum inspired Computer Aided Drug Discovery with improved Error mitigation and circuit optimization for accuracy. After this, it is expected that there would be virtual screening and optimization using Quantum capabilities, while end-to-end in silico drug discovery is expected about 10-20 years down the line.
- With respect to collaborations and use cases, we can see M Ventures, Merck's venture arm, investing in quantum startup Seeqc, Cleveland Clinic collaborating with IBM for biomedical discoveries using quantum computing, and Biogen partnering with 1QBit to use quantum computing for drug discovery. We can also see QuPharm and Qubit Pharmaceuticals partnering for better research.
- Considering the above scenario, the recommendations for pharma include the usage in drug discovery, priority investment in AI and ML, and joint development with other players in quantum.

Finance:

- Finance is seeing rapid growth with respect to quantum, with an expected 200-fold increase till 2032. There are various opportunities in this, especially in risk profiling, trading optimization, and targeting and prediction. It also comes with many challenges, including the vulnerability of public key cryptography, the immediate impact on financial security protocols, the complexity of the transition, and the need for proactive measures.
- With respect to collaborations and use cases, we can see JPMorgan Chase collaborating with the Chicago Quantum Exchange on researching quantum algorithms, AI optimization, and cryptography. Goldman Sachs is partnering with QC Ware to explore using quantum computing for risk evaluation and price simulation in financial services. HSBS partnered with the EU's Horizon 2020 program exploring quantum computing applications for solving complex medical problems. Wells Fargo also initiated its venture into quantum computing and AI in 2019 through a partnership with IBM and MIT, joining the IBM Quantum Network to explore practical applications.
- Considering the above scenario, the recommendations for finance include engaging with regulatory bodies, collaborating with leading quantum computing companies and academic institutions and identifying and prioritizing vulnerabilities to quantum decryption, particularly in public-key encryption protocols

Defense and aerospace industry:

- This industry is seeing rapid growth with opportunities in weapon targeting, enhanced cryptography, and more effective data analysis, intelligence processing, and advanced simulation and modeling to solve optimization problems, such as vehicle routing, resource allocation, and mission planning. However, there are also various challenges such as Vulnerability to Espionage and Sabotage, and incorrect operational behavior.
- With respect to the progress, it is expected that the next 5 years can see a focus on quantum-resistant cryptography and secure communication networks. The medium term is expected to see exploration in quantum simulation and quantum algorithms for logistics, supply chain management, and mission planning. About 10-20 years down the line is expected to see more resilient and innovative supply chains and technologies, and secure and robust protection against quantum threats.
- With respect to collaborations and use cases, Lockheed Martin partnering with D-Wave Systems to focus on quantum computing applications that could enhance the capabilities of various defense systems. Northrop Grumman is investing in quantum infrastructure and workforce development, and Raytheon Technologies partnered with IBM to develop quantum encryption and secure communications systems to ensure data security against quantum attacks.
- Considering the above scenario, the recommendations for the defense and aerospace industry include establishing partnerships with academia and startups to foster innovation, pilot quantum projects, and build a quantum-savvy workforce.

Automotive Manufacturing Industry:

- This industry is expected to see a 10-year compound annual growth rate of 45.9% growing to more than \$5 billion in quantum computing in automotive. There are various opportunities including vehicle design, electric vehicles, autonomous driving, routing optimization, etc. There are also various risks including cyber security, traffic safety problems, and data privacy issues.
- With respect to the progress, the next 5 years expect to see product development and R&D. Key areas of development in the medium term include vehicle design and electric vehicles. The 10-year long-term expectations include autonomous driving, routing optimization
- With respect to collaborations and use cases, Mercedes is collaborating with IBM, expecting to apply the advanced quantum computer to enhance battery performance. BMW is collaborating with Zapata to optimize its complex vehicle production schedule across multiple plants, minimizing assembly line idle time while maintaining monthly vehicle production targets. Toyota is collaborating with QM's quantum computing expertise to provide access to innovative quantum control solutions.
- Considering the above scenario, the recommendations for the automotive manufacturing industry include strengthening cooperation with quantum computing enterprises, reducing safety hazards, preventing cybersecurity, and establishing rigorous data protection policy

Overall recommendations

With respect to the further course of action, we have two frameworks in place for the companies to adopt. One is to safeguard against the risks associated with quantum, and another is to leverage the advantages of quantum.

- We recommend that all the companies should definitely adopt the safeguarding framework. This includes assessing quantum readiness, identifying quantum use cases, developing a quantum talent pipeline, developing prototype quantum solutions, and creating a quantum technology roadmap.
- While the first framework will protect a company, the second framework will advance the company. This includes data security and protection, streamlining vendor enterprise updates, upskilling the existing workforce, conducting quantum risk assessments, and developing quantum partnerships.

Based on these frameworks, the current actionable steps include, focusing on data security by investing in New Quantum-Resistant Algorithms and data protection against 'harvest now decrypt later attacks' using Quantum Key Distribution (QKD). There should also be workforce management including training programs. The companies should conduct a Quantum Risk Assessment (QRA) to develop company-specific protocols. While collaborating with quantum companies to explore specific applications and use cases is important, there should be a near-term investment in AI.

As quantum computing continues to evolve, it will become a cornerstone of corporate strategy among the world's largest companies. By understanding the potential applications and challenges of quantum technology, Fortune 500 companies can position themselves to capitalize on its benefits while mitigating risks. Strategic investments in quantum computing will not only provide a competitive edge but also ensure resilience and relevance in a rapidly changing technological landscape.