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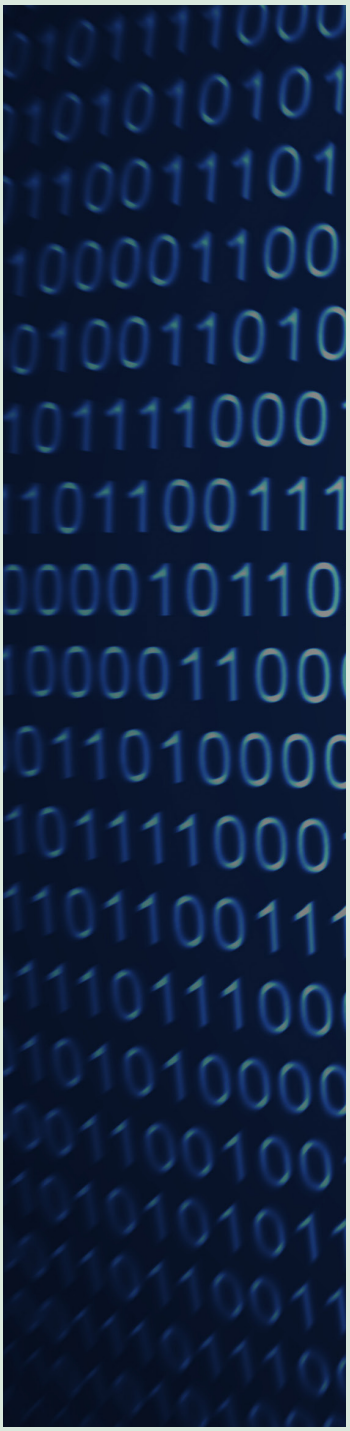

QUEST FOR QUANTUM

in Next Generation of Banking and Financial Services

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Introduction

"Imagine riding **'The Great Leonopteryx',** the flying creature from the movie 'Avatar', a complete package of power, performance and speed. Quantum computing is the modern Leonopteryx, the beast that will completely transform the classical computing world."

Quantum computing, fundamentally different from classical computing, is built to solve complex computing that even supercomputer could never solve. It is established on quantum mechanics phenomena known as **'Superposition', 'Entanglement'** and **'Interference'.** Unlike classical computing which relies on long bits of 1 or 0, in quantum computing the quantum bit or qubit can take superposition with both 1 and 0 enabling exponential ability 2^n. Thus, computing power is expected to increase exponentially in quantum computing in comparison to classical computing. The quest for harnessing quantum computer has started with supply chain, logistics, optimization problem, pharma and drug discovery, crypto analytics, banking and finance industry.

Globally, banking and financial industry is undergoing an era of radical change driven by emerging technologies. Artificial Intelligence, Machine Learning, and Cloud have become the new strategic accelerators in the digital transformation of the banks. Advanced machine learning models are data-hungry and need enormous computing ability which is beyond classical computers. Financial industry is sitting on a gigantic volume of data which is the true fuel for computing and steering digital performance. Along with customer expectation, banks are constantly chasing improvement in performance of their applications in a **cost-efficient** manner. As the volume of the data grows exponentially due to the digital channels, real-time analytics on the massive amount of data that the bank accesses and generates is becoming challenging as we move forward. To perform **hyper-personalization** and recommendation of the right product or services to a bank's customers, classical computers had to compromise on several dimensions, features and many important attributes. Also, most often classical computing narrow down the dataset to a subset of the entire available data or randomly select a sample to deal with current computational limitations. Business scenarios like real-time fraud detection, high-speed trading, arbitration, product pricing, optimization need large volume of data to be analyzed on a real-time basis, which is the ultimate limitation of classical computers as of today. This has brought quantum computing into the limelight into the financial services domain.

In the last few years, the progress has been phenomenal since John Preskill in 2012 established the theory of quantum supremacy. In 2019, Google marked the history with superconducting qubits enabling output in 200 seconds that classical supercomputer could potentially do in 10000 years.

Today quantum computing platform has become an active research and investment field for technology giants as well as startups in order to solve the computing bottleneck that the classical system is facing. The recent trend assures that the mystery will unfold very soon. Financial industry will be one of the topmost sectors to derive maximum benefits. The intent of this paper is not to contest the ability of quantum computing but to unleash the potential of quantum computing in banking and financial industry. Many incumbents have already realized the need for immediate digital adoption, especially due to the COVID-19 impact. Customer behavior and expectations have changed faster than expected. Therefore, banks and FIs have an option to tap the benefit from economy of scale through faster computing.

Classical computer vs quantum computing

Quantum computers work on the quantum mechanics principle and use quantum bits or qubits to store both 0 and 1 at the same time.

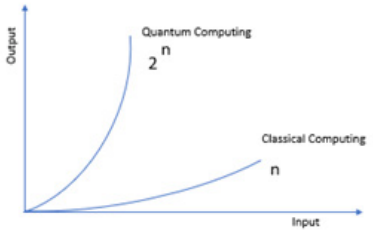


Fig 1: Outcome of Classical Computing vs Quantum Computing

Contrasting features of Quantum Computers & Classical Computing:

CPU	GPU	Quantum
• CPUs have limited ALUs, but contain cache, memory and other interfaces. • CPU performs better with generic tasks.	• GPUs have lots of ALUs but limited Cache and other interfaces. • GPU performs better to execute parallel tasks like image manipulation etc. It can do same calculation across a bunch of GPU units	• Quantum CPUs with n qubits can have 2n simultaneous states at a given time. • Quantum CPU can generate results for certain applications with correct algorithm because it can be in multiple state all at once. • Quantum algorithms must exploit the quantum parallelism for speed.

Fig 2: CPU, GPU and Quantum Computers – Limitations & Differences

Quantum supremacy has proven that tasks that classical computer take years, quantum computing can achieve in minutes. As per Bloomberg, Google's latest quantum computer named Sycamore solves a specific computational task in 3 minutes that a traditional supercomputer might take 10,000 years to solve.

Type of Scaling	Time to Solve Problem				
Classical algorithm with exponential runtime	10 secs	2 mins	330 years	3300 years	Age of the Universe
Quantum algorithm with polynomial runtime	1 min	2 mins	10 mins	11 mins	~24 mins

Fig 3: Time difference to solve problem between Classical and Quantum Algorithm

In classical computers, statistical calculation increases proportionately with the increase in data volume and this perhaps collapses the ability of computing in given timeframe. On the contrary, quantum computer can perform on all the permutations and combinations simultaneously. Also, machine learning and artificial intelligence takes up the laborious work of data sorting integrated to quantum computing.

Quantum Computer Language (QCL) is the most advanced implemented quantum programming language with quantum register as the elementary built-in quantum data type. Quantum computers can operate on superposition of 1s and 0s. This unique state of one particle cannot be described independently without another quantum particle which is referred as **Entanglement.** These particles are correlated, even at a great distance. This helps quantum computers to store, process a huge amount of data.

For instance, in banking **entanglement** and **superposition** can assist in completing an electronic money transfer by splitting a photon into two with the laser technology. Also, security is ensured in any attempt of breach, as any intercept in transit can be monitored with the state of the other photon of the pair.

In the real-world, one sector which could benefit widely from potential of quantum computers, is banking sector.

Challenges in the banking & financial services industry

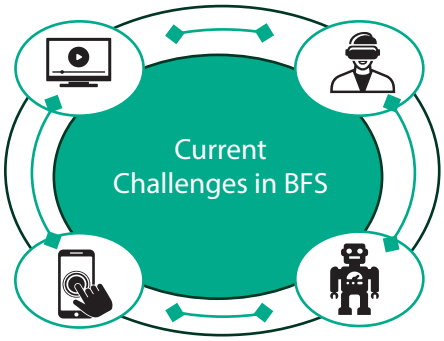
Past few years have shown many new technologies driving the banking and financial services domain, for instance Artificial intelligence, Machine Learning, Blockchain, Data analytics, Robotic Process Automation. However, there are several **bottlenecks** to be considered in some areas, for banks and financial institutions in order to unleash the future growth.

Asset Valuation
This involves a lot of data analysis, regulatory compliances, risk analysis, which can be a very tedious and time-consuming process.

Credit Scoring
Many SMEs are unable to grow their businesses because of the faster processing, higher accuracy and heavy data analytics requirements of the models.

Data Security
Encryption of personal data is being done with RSA-2048 at the highest levels, and researchers have found different ways to decrypt it.

Financial Downtime Prediction
Forecasting financial crisis, downtime is a challenging task requiring lots of historical data crunching and top-notch predictive analysis.



Portfolio Optimization
When constructing a multi-asset portfolio, coming up with a strategy to allocate weights to a portfolio needs a lot of permutations and combinations to manage the return to risk ratio, which is a daunting task.

Arbitrage Opportunity
Multi-thread processing and lots of data analysis is required in finding the arbitrage opportunities which is used in various aspects of banking, like in trade finance.

High Frequency Trading
It is very challenging and important ask for the financial firms to execute trades quickly, which requires significantly higher transaction speed and lower processing costs.

Risk profiling and Product Recommendation
Financial services institutions are under increasing pressure to balance risk and hedge positions more effectively and at the same time, real time analysis is required to recommend products and features. This requires heavy data analysis and faster processing.

Fig 4: Bottleneck areas in Banking and Financial Industry

Quantum computing- a market differentiator in banking & financial services industry

Banks and FIs are gearing up for potential solutions towards handling high volume transactions, data with utmost speed and accuracy. The next technology after AI-ML and cloud computing, which is likely to turn the wave around is Quantum Computing. This can be targeted to **resolve** some of the existing challenges being faced by the banking and financial service industry today. McKinsey forecasted the quantum computing market to reach $1 trillion by 2035, out of which a larger share will be driven by banking and financial markets. There are several scenarios where quantum computing can be a game changer.

In applications where heavy data processing and computation is involved, data flows from multiple sources through real-time integration, quantum computing will certainly bring a significant difference. The impact of quantum computing will be high on use cases where banks are not able to achieve much with classical computers today due to computing limitations. While in some cases the impact is relatively low as banks are still able to achieve the desired outcomes to some extent.

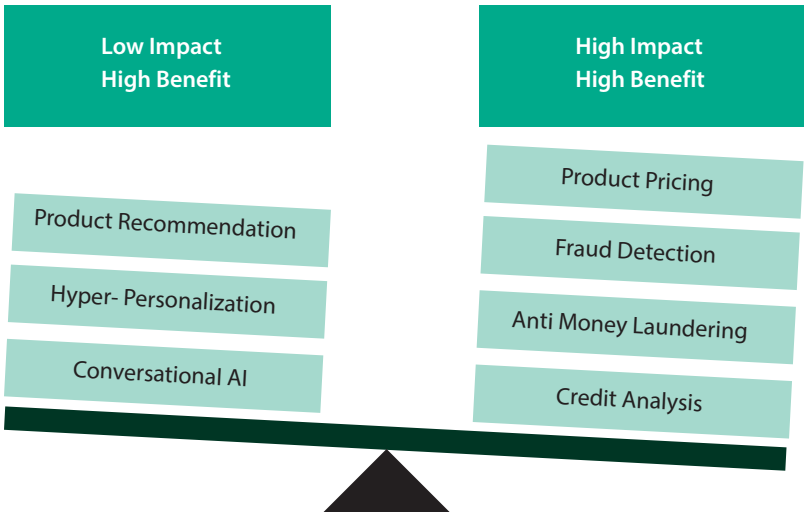


Fig 5: Quantum Computing Use Cases in Banking and Financial industry

Quantum computing can be used to improve on many critical operational processes in banking, such as Client Onboarding, KYC, AML, Fraud Detection, Loan Origination Process, Cash Management, Asset valuation, etc.

Below are applications of quantum computing in banking and financial industry elaborated:

- **Hyper-Personalization & Product Recommendation:** Banks today are prioritizing to **enhance customer experience** by offering personalized products or services, driving personalized conversation and predicting customer next best action. Personalized product recommendation and increasing CSAT score (customer satisfaction) is key to their sustainable business growth. Quantum Computing is set to eliminate the constraint due to data volume, increase the speed of data sourcing from multiple sources and processing.
- **Credit Assessment:** Credit assessment and scoring, which is data dependent and relies on multiple sources, requires heavy processing and an instant response. Singapore Management University (SMU) is collaborating with a Fintech Tradeteq, to analyze credit scores with the help of quantum computing algorithms. The aim is to improve on the accuracy of the real-time credit scoring process with predictive machine learning model.
- **Fraud Detection:** Every year banks and financial institutions lose significant revenue of millions and sometimes billions due to the subpar data management and fraudulent activities. Quantum computing will certainly be a game changer in this space. Quantum computing on top of current fraud detection capabilities can help banks in efficient and accurate fraud detection using heavy real-time heavy processing pattern recognition algorithms.
- **Data security:** Data encryption and decryption using quantum cryptography will be way superior than today's modern-day security available. Data in quantum states is constantly shifting shapes and hence impossible to be interpreted. Big Banks are already integrating with quantum cryptography.
- **Portfolio Optimization:** Lowering portfolio risk and computing the correlation between assets leads to portfolio optimization. Quantum computing can speed up analyzing the data sets of the assets and determining the dependency or interconnectivity among assets. Barclays, JP Morgan Chase already started use of quantum technology in Monte Carlo simulations to optimize portfolio.
- **Risk profiling:** Banks and financial institutions are under increasing pressure of more advanced risk profiling and strict regulatory checks. Quantum technology with its ability to faster data processing, can better assist in the management of compliance.
- **Currency Arbitrage:** Quadratic unconstrained binary optimization (QUBO) is a pattern matching technique, combined with quantum annealer (a meta-procedure for finding a global minimum of a given objective function), can assist in finding various arbitrage opportunities.

Fusion with artificial intelligence

Artificial Intelligence and Machine Learning often require enormous volume of data in order to build a model for decision making. In past few decades, there has been a steep advancement in these emerging technologies. It's common to have millions of parameters in deep learning models. However, the improvement in infrastructure and processing speed is not proportionate to the advancement in models and architectures. Due to the limitations in classical computing, often AI-ML models are executed with limited data set, features, parameters, model selection and model fitment.

Below are four quadrants where quantum computing can expedite the future of artificial intelligence:

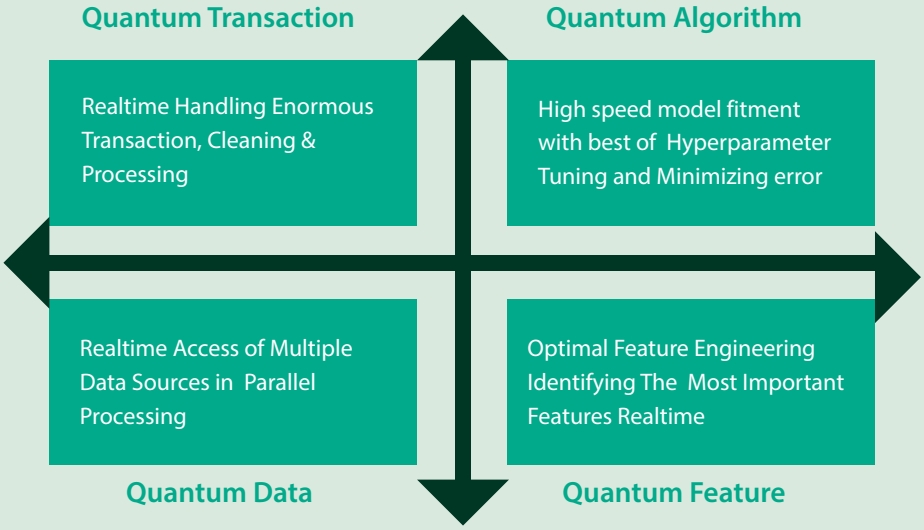


Fig 6: Quadrants of Quantum Computing in AI

Impediments in the path of quantum computing

Nearly every part of quantum computing technology needs re-engineering to make it work as there are **challenges** such as speed of connectivity, maintaining extreme low cryogenic temperature and building the related infrastructure.

Decoherence: The quantum states in quantum computer are more vulnerable to errors than a traditional computer. Such errors are due to decoherence, a process in which the environment interacts with the qubits. Changing quantum states are unmanageable and adversely impact the information storage.

There are four more key hurdles technology companies are focusing on in order to deliver a potential quantum computing platform:

Qubit Quality	Qubits should be able to generate useful instructions or gate operations on a large scale. But after a certain number of instructions or operations, today's qubits produce the result which is indistinguishable from noise.
Error Control	Implementing error correction algorithms to check and then correct for random qubit errors as they occur.
Optimization	In order to implement complex algorithms, we must control multiple qubits and develop optimal solutions with right number of qubits.
Scalability	We need to address how to scale up the number of qubits within a quantum chip. Today, we require multiple control wires or multiple lasers to create each qubit.

Fig 7: Current Hurdles in Quantum Computing

How far are we from day zero??

McKinsey anticipated that the work on quantum computers will start between 2022 and 2026. It's expected to build more optimization functionalities using quantum computers during this time, and that would drive the market to produce ~2000 to ~5000 quantum computers worldwide.

Growth Forecast

The quantum computing market is at valued $507.1 million.

It is projected to grow at a CAGR of 56.0% during 2020-2030, to ultimately reach $64.9 billion by 2030.

Artificial Intelligence integrated with quantum computing is expected to progress at the highest CAGR, during 2020-2030.

Govt Support

Government supporting the technology is a prominent trend in the quantum computing market, realizing the importance of a coordinated funding strategy.

The National Quantum Initiative Act became a law in December 2018, included a funding of $1.2 billion from the U.S. House of Representatives for the National Quantum Initiative Program.

Global Market

By 2030, Europe and North America are expected to account for more than 78.0% in the quantum computing market.

The National Security Agency (NSA), NASA, and Los Alamos National Laboratory are engaged in quantum computing technology development.

An increasing number of collaborations and partnerships are being witnessed in these regions, along with the entry of several startups.

Fig 8: Future prospect in Quantum Computing

There has been a major breakthrough in the field of quantum computers, as only a year after Google, China has come up with a milestone, quantum supremacy and claims to have built a quantum computer which performs computations nearly 100 trillion times faster than the most powerful modern-day supercomputer. China researchers also claimed to have used a completely different setup and is billions of times faster than Google's quantum computer. IBM is expecting to come up with over 1000-qubit quantum computer by 2023. Currently, IBM with the latest 65-qubit quantum processor is not too far behind its biggest competitor Google.

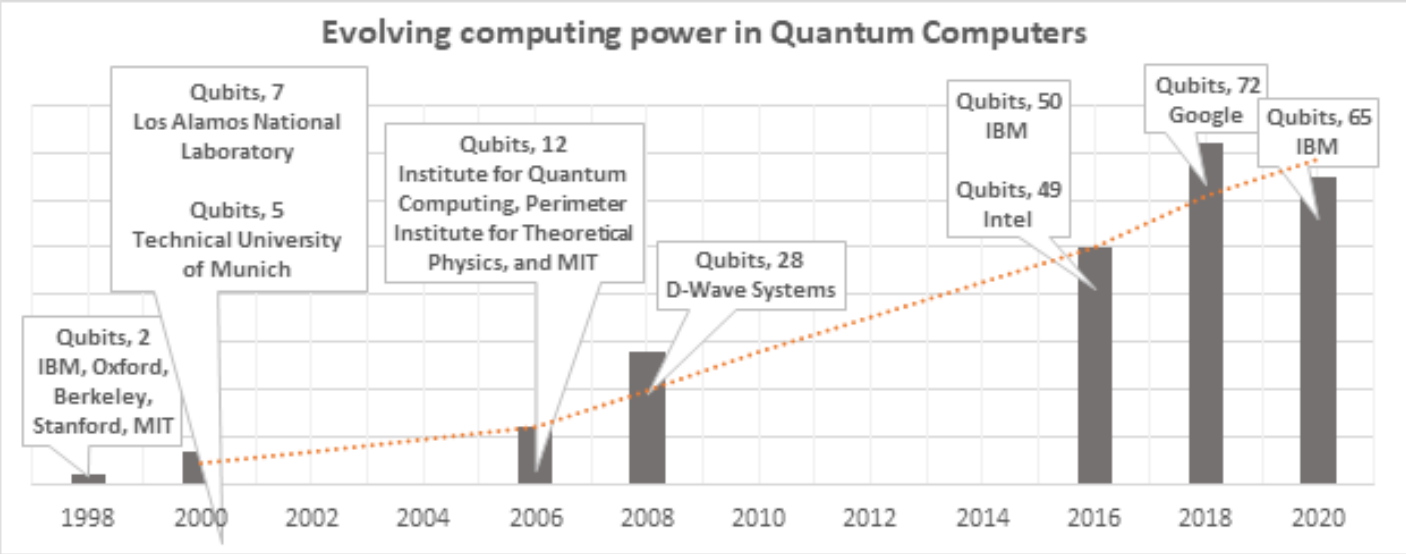
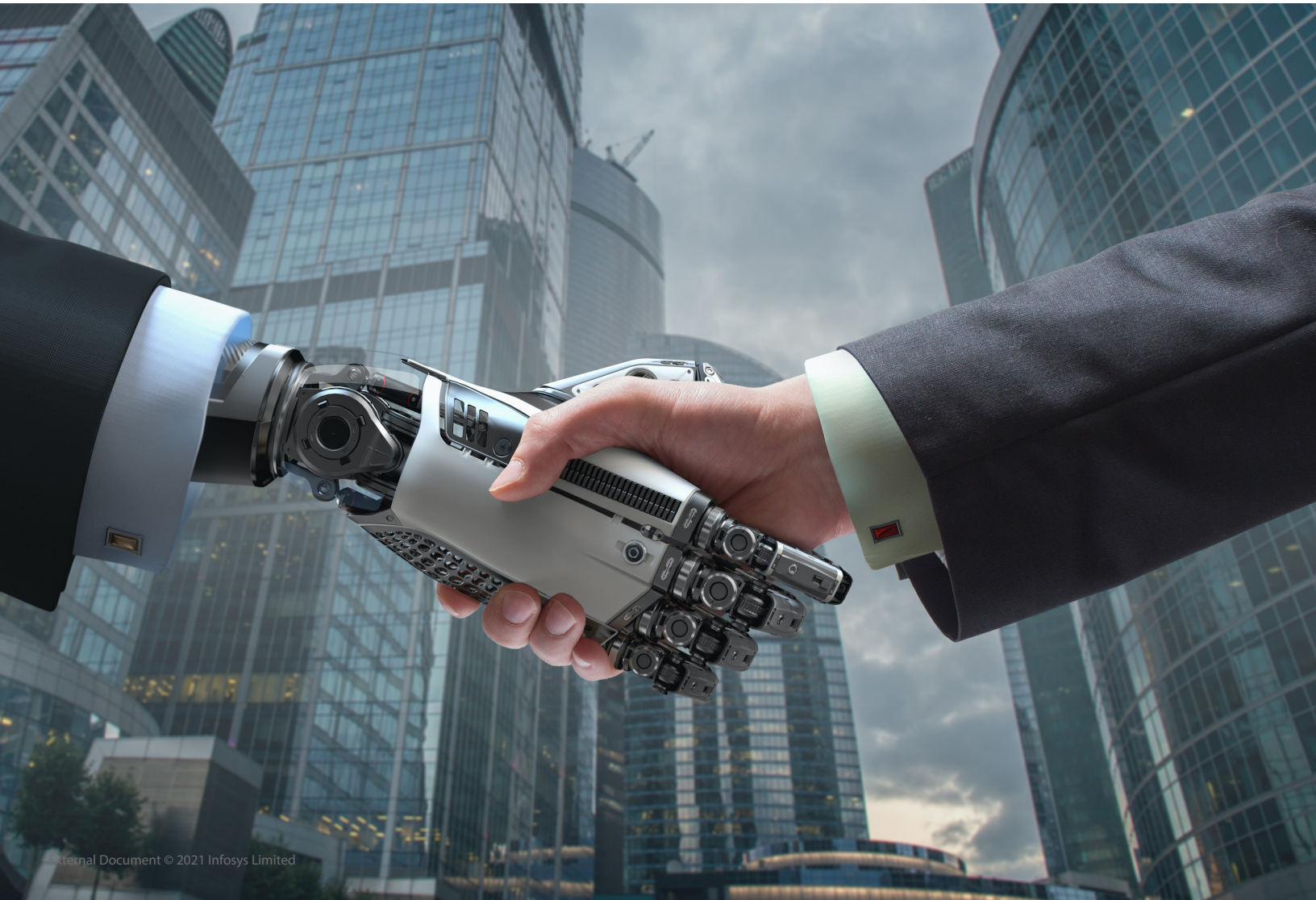


Fig 9: Progressive Quantum Computing Space



Why Banks & FIs should start investing in quantum computing

There is already an increasing interest among the private investors globally in the quantum technology. A significant investment has been already pumped into over 50 quantum-inclined businesses in last few years. According to the "Quantum Computing Technologies & Global Market – 2018-2024" report, the global quantum computing market is expected to reach **$10.7 billion by 2024.** While banking and financial services industry will be the largest one to adopt and generate the highest opportunity in the quantum computing space. To keep up with the competition and harness the benefit being an early adopter, banks and FIs must start investing in quantum computing.

Here are some of the breakthrough quantum computing events across the globe in the banking and financial services industry:

- Wall Street giant, Goldman Sachs funded $40M in series-B funding round to US based Rigetti Computing.
- JP Morgan Chase partnered with Honeywell and IBM in overcoming business challenges in the financial sector such as lowering risk and optimizing portfolio.
- Citigroup along with Goldman Sachs invested heavily in quantum startup QC Ware to enable connecting the enterprise users with the quantum computing hardware platforms and simulators on calculation of option pricing.
- HSBC joined the quantum consortium, four-year project fully funded by the European Union's horizon 2020 research and innovation program is bringing together different commercial banking customers to work on quantum technology.
- Caixa Bank in Spain is working on calculating credit risk with the help of ML combined with quantum computing technology.
- Wells Fargo joining IBM Q Network, a community of Fortune 500 companies, startups, academic institutions and research labs working to explore the potential benefits of quantum computing.
- Banco Bilbao Vizcaya Argentaria (BBVA), based in Madrid and Bilbao, Spain, is working with Zapata Computing on areas like arbitrage opportunity and complex valuation problems.
- DGB Daegu Bank along with SK Telecom intend to update their mobile app security with quantum cryptography.
- Mizuho and Mitsubishi Financial Group in Japan is working with IBM on quantum computing adoption
- D-Wave, very recently, launched its next-generation quantum computing platform available via its leap quantum cloud service. The company calls Advantage "the first quantum computer built for business." In that vein, D-Wave also debuted the launch of a jump-start program for businesses that want to begin building hybrid quantum applications.

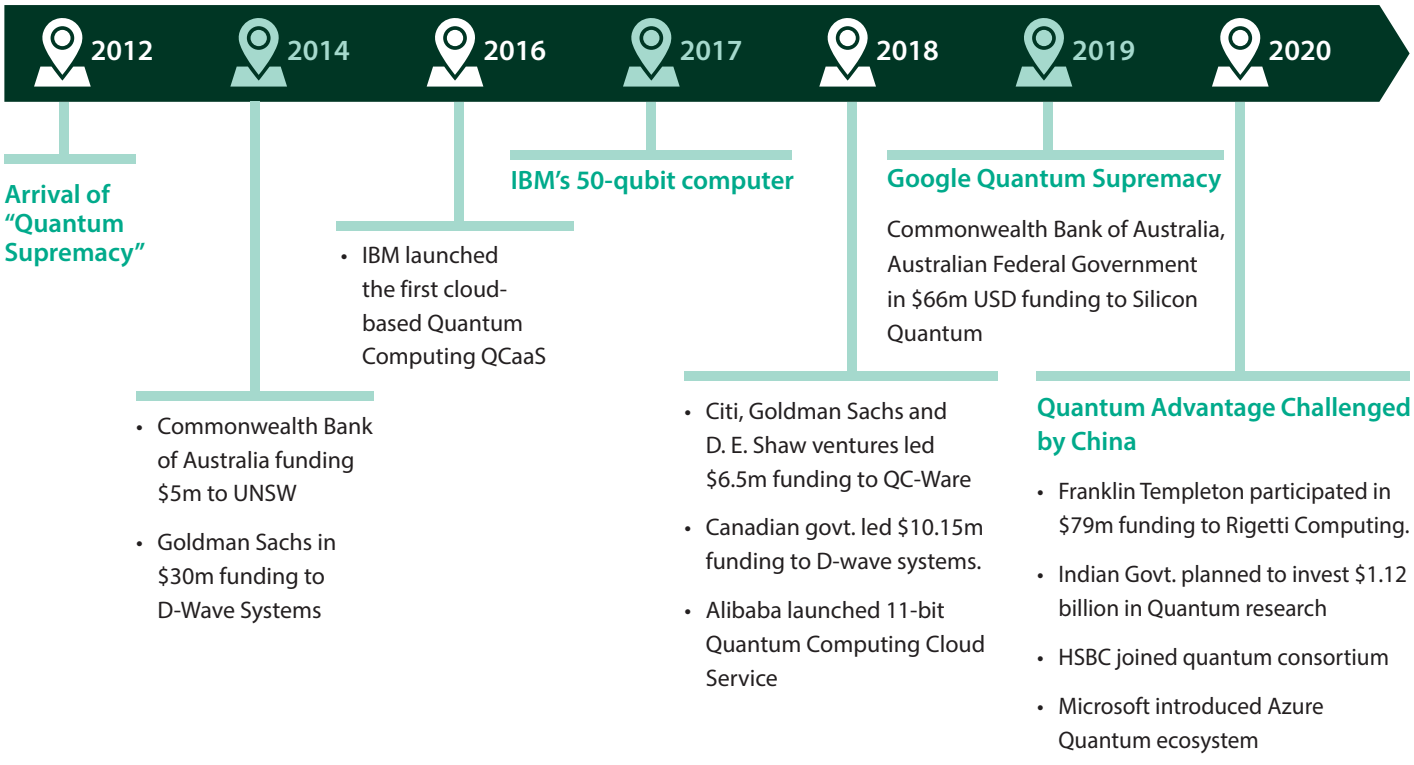


Fig 10: Major Milestones and Participating Banks & FIs in Quantum Computing

Conclusion:

Undoubtedly quantum computing will be a turnaround for banks and financial institutions in their current speed of data processing and responding to customer needs. However, one size does not fit all, banks and financial institutions which have already adopted emerging technologies and digitization will be able to potentially reap the benefit of quantum computing. At the same time, **adopting quantum computing to solve the right business problem is the key to success.** Customer experience and operational efficiency will continue to be the topmost priority for most of the banks and FIs. Thus cloud-based **Quantum Computing as a service (QCaaS)** will be largely popular due to the large establishment and maintenance costs associated with quantum infrastructure. The degree of impact of quantum computing will transform the banking and financial industry to a **real customer-centric business model** from current process-centric. Financial institutes need to wisely take the strategic decision on the roadmap of quantum computing adoption. Rather than looking at low hanging fruits, banks must take top-down approach and start with the most vulnerable processes. **Critical areas like fraud detection, high frequency trading, AML should be picked by as priority areas for quantum computing.** Quantum computers are still going through continuous research and improvements, current outcome is still error-ridden to compute consistently. In addition, financial institutions are currently adopting best of digitization, AI-ML based computing power and intelligence at their fingertips. A quantum computer might well be faster than an individual GPU and will beat many unresolved issues, but for sure in many scenarios financial institutions could be better off with state-of-the-art GPUs in a supercomputer.

Recent advancement clears the pathway towards potential breakthrough for commercially viable quantum computers in coming years. Right time for banks and financial institutions to tighten their belt and prepare themselves to embrace the latest developments in this technology, at the same time discover new revenue stream and business models for the post-quantum world.

References:

- Bloomberg.com: "Google Says Quantum Computer Beat 10,000-Year Task in Minutes" [https://www.bloomberg.com/news/articles/2019-10-23/google-says-quantum-computer-beat-10-000-year-task-in-minutes], 2019
- Richtopia.com: "Future Use-Cases of Quantum Technology in Financial Services" [https://richtopia.com/emerging-technologies/quantum-computing-financial-services-fintech/], 2020
- Ibm.com: "Applying emerging quantum technology to financial problems" [https://www.ibm.com/thought-leadership/institute-business-value/report/exploring-quantum-financial], 2019
- CBInsights.com: "Research Report on Quantum Computing" [https://www.cbinsights.com/research/report/quantum-computing/], 2019
- McKinsey Forecasts Quantum Computing Market - The Quantum Daily [https://thequantumdaily.com/2020/04/15/mckinsey-forecasts-quantum-computing-market-could-reach-1-trillion-by-2035/], 2020
- Aranca.com: "Can Quantum Computing Transform the Financial Services Industry" [https://www.aranca.com/knowledge-library/articles/business-research/can-quantum-computing-transform-the-financial-services-industry#:~:text=Banks%20and%20institutions%20such%20as,to%20speed%20up%20portfolio%20optimization.&text=This%20can%20be%20achieved%20by,higher%20returns%20at%20low%20risk.], 2019
- IEEE Spectrum: "An Optimist's View of the 4 Challenges to Quantum Computing" [https://spectrum.ieee.org/tech-talk/computing/hardware/an-optimists-view-of-the-4-challenges-to-quantum-computing], 2019
- The Quantum Daily: "Companies Investing in Quantum Computing" [https://thequantumdaily.com/2020/04/13/tqd-exclusive-20-companies-investing-in-quantum-computing/], 2020
- The Quantum Daily: "Four Ways Quantum Computing Will Change Artificial Intelligence Forever" [https://thequantumdaily.com/2020/01/23/four-ways-quantum-computing-will-change-artificial-intelligence-forever/], 2020
- The Gartner: "The CIO's Guide to Quantum Computing" [https://www.gartner.com/smarterwithgartner/the-cios-guide-to-quantum-computing/], 2019
- Finextra.com: "HSBC joins European quantum consortium" [https://www.finextra.com/newsarticle/36686/hsbc-joins-european-quantum-consortium],2020
- Independent.co.uk: "China achieves Quantum Supremacy in Major Computing Breakthrough" [https://www.independent.co.uk/life-style/gadgets-and-tech/quantum-computing-china-us-b1766133.html], 2020
- SingularityHub.com: "IBM plans to have a 1000-Qubit computer by 2023" [https://singularityhub.com/2020/09/25/ibm-plans-to-have-a-1000-qubit-quantum-computer-by-2023/], 2020

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