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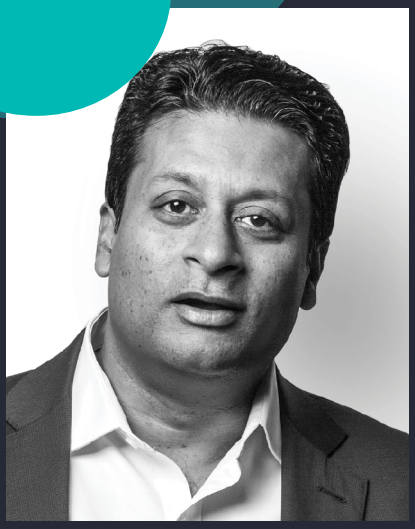
THE FUTURE FOR QUANTUM TECHNOLOGY IN FINANCIAL SERVICES



Anirban Bose
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FOREWORD

The financial services industry has always had to respond quickly to changing business environments, and the need for robust solutions to all manner of risks is perhaps greater than ever before. In the near future, one new and important risk management enabler may be quantum technology, and already many large financial institutions are investing and experimenting in this arena.

A plethora of potential use cases are being explored:

- In banking and capital markets, quantum technology may be brought to bear on multiple challenges including financial risk management, fraud detection, and derivative pricing.

- And for the insurance industry, quantum technology may lead to more accurate quantification of risk exposures and help translate that into better insurance premium, premium reinvestment, and reinsurance decision-making.

Despite growing excitement about possibilities, the true potential for quantum technology in financial services remains unclear: there are not yet any actual quantum-powered applications in production today. And so while moving forward with caution makes sense, Capgemini also believes strongly that inaction is not the right approach. As you will read, we recommend three steps that financial services companies should take today, to help ensure a balanced approach to quantum technology readiness.

We hope you find this paper of interest, and that it sparks further thoughts and discussion within your organization. Experts from the Capgemini Quantum Lab would welcome opportunity for dialogue: let us help guide and collaborate with you during this exciting transformation journey for the industry.

Sincerely,
Anirban Bose

WHAT IS THE REAL VALUE OF QUANTUM TECHNOLOGY, NOW AND IN THE FUTURE?

The financial services (FS) sector has always been dominated by risk, uncertainty, and the need to respond quickly to a changing business environment. Today, this is truer than ever, with financial stability affected by climate-related risks such as the increasing likelihood of natural disasters, a growing threat of cyber-attacks, and other disruptive economic and political events. More than ever before, the financial sector needs robust solutions to promote growth and maintain trust.

Quantum technology may become an important enabler of these solutions since it will offer a completely new paradigm for computing. Already, large financial institutions are investing and experimenting with this technology.

Despite the excitement, some caution is needed. Many of the applications currently being researched require quantum computers that are beyond (hundreds of) thousands of qubits to deliver stable results.

Therefore, we are a long way from having quantum models or quantum-powered solutions in production. It is still hard to say whether a clear advantage will arise soon for financial institutions, and overenthusiasm now could be followed by disappointment later – especially as no clear timelines can be given on which applications will be ready for use when.

However, that does not mean that financial institutions should just wait and see. In this paper we will investigate the opportunities and challenges of quantum technologies for the financial sector, what is being done in the industry right now, and what actions should already be taken now to prepare a balanced approach to a quantum future.

WHY IS THERE SO MUCH INTEREST IN QUANTUM FINANCE?

The financial services industry has a strong focus on managing risk to ensure financial stability and security. Risk management typically relies on computationally intensive processes and complex algorithms to simulate scenarios and predict possible events.

Financial markets that rely on real-time decisions – for example, securities trading – could benefit from quantum computers' potential ability to simulate complex events faster, more accurately, or more energy-efficient than classical computers. The advanced simulations used for analysing risk and external events could benefit greatly because less sampling may be needed for a similar level of accuracy in the risk models. Due to the size of models used in financial institutions, even small improvements in speed-up times could bring substantial returns. Finally, as financial models are often so complex that running them takes a long time – sometimes weeks, a potential quantum advantage could be found in bringing down computing time.

On the other hand, financial institutions are vulnerable to the threat of a quantum attack. Therefore, post-quantum cryptography (PQC) – the implementation of quantum-safe encryption – should certainly be on the radar today.

Large banks have already started on their quantum journeys and are building dedicated teams to research potential use cases for quantum computing. Articles that have been published by leading banks have indicated that there is a lot of interest in testing quantum algorithms, getting an understanding of their applicability to certain use cases and how these are scalable. Insurers, large brokers and reinsurers have started on their quantum journeys by hiring talent and starting to understand relevant use cases.

Much of the current focus is on quantum computing. However, other quantum technologies could provide value too. For example, quantum communication could be used to secure payment infrastructures or establish new ways of communication between financial institutions. Quantum sensing could be used to synchronize time between financial systems to maintain consistency, compliance, and efficiency. In addition, PQC should be adopted to keep financial institutions safe from eventual quantum attack and start working on their PQC roadmaps to ensure data security.

Some examples of applications for the banking and insurance sectors are described in panel 1 and panel 2, respectively.

"The following use cases are indicative. As of 2023, no quantum computing use cases are in production, and it remains to be seen which use case will work out"

PANEL 1. Deep dive: Quantum potential for banking and capital markets

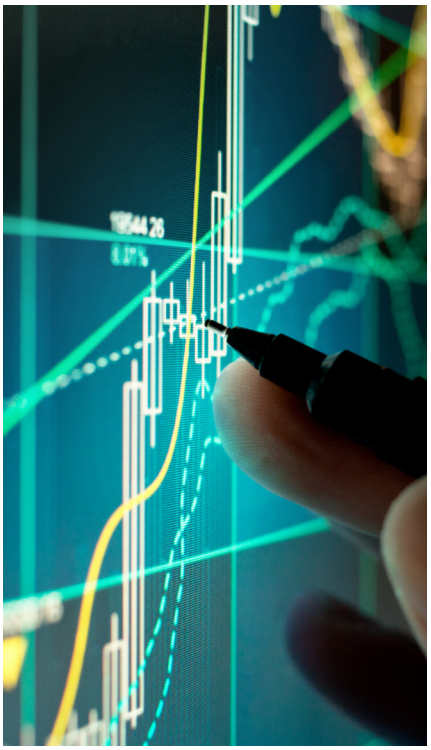
Quantum technology could help banks model risk and volatility in financial markets to better support financial stability. Challenges within the banking industry, such as financial risk management, fraud detection, and derivative pricing, are interesting for further exploration with quantum technology.

Risk management

Financial markets are dealing with different types of risks, and risk management plays an important role in banking. Many different events can have an impact on, for example, a financial market crash. Quantitative models can easily become complex and require a significant amount of computing power. Quantum computers can be used to simulate possible risk scenarios better and pinpoint the interconnectedness of these risks. Quantum computers could also be of benefit in calculating the probability of default risk on outstanding loans, giving banks better leverage to manage their liquidity, which is of high importance for maintaining healthy balance sheets

Combating financial crime

With the rise of digital payments and e-commerce, financial crime – in the form of fraud, cybercrime, and anti-money laundering – has increased rapidly in recent years. One of the main challenges with fraud detection is that it is generally difficult to detect suspicious activity from data. As a result, models in current use often work with lower precision rates to avoid the risk of unjustly accusing a client of showing suspicious or fraudulent behavior. Using quantum to improve pattern recognition will help financial institutions to detect new methods of financial crime as soon as they emerge with higher certainty.



Derivative pricing

Overall, derivative pricing is a complex process requiring advanced techniques. Factors that need to be considered in pricing include interest rates, volatility, and correlations between assets, often over a longer timeframe. Inaccurate pricing can lead to significant losses for multiple institutions – an effect that could cascade through the whole financial system. With quantum, it becomes easier to simulate conditions that may influence the underlying asset over time and hence to better predict future prices.

Quantum communication

Quantum communication also has potential for the banking sector. Quantum communication protocols, such as Quantum Key Distribution (QKD), are an area of research in several other industries, such as defense and telecom. One of the applications of QKD is security. However, classical solutions with PQC should be prioritized for immediate protection against quantum attacks.

Beyond security, QKD can be seen as a steppingstone for further quantum internet applications. Potential applications of quantum internet that can be interesting for banks will be for timing synchronization in transaction settlement or smart contracts.

PANEL 2. Deep dive: Quantum potential for insurance and reinsurance

One of the biggest challenges within the insurance industry is accurately quantifying exposure to risk and translating that into insurance premiums, premium investment, and reinsurance. Therefore, exploring the possibilities of quantum technology will be beneficial for better resilience.

Risk management

With tornados becoming more common in the United States, and floods becoming more frequent in Europe than initially expected, (re)insurers face a challenge in their risk modelling. Due to the historically low probability, modelling for large-scale catastrophic events is difficult. Quantum computers could be used to simulate such risks better and give a better understanding of the impact on individual insurers.

Cyber risk

The expectation that quantum computers will be powerful enough to perform complex calculations also poses a significant threat to cyber security. There is a 1 in 7 chance that quantum computers will be able to break current public-key encryption in 2026, and a 1 in 2 chance by 2030, according to Michele Mosca, co-founder and deputy director of the Institute for Quantum Computing at the University of Waterloo1. This presents insurers with both the challenge of dealing with these new risks and the opportunity to offer insurance products that take account of quantum technology. For example, insurers could reduce clients' premiums when they show they have implemented PQC algorithms to protect themselves as much as possible against quantum cyber-attacks.

Product pricing and insurance underwriting

Another challenge is the proper pricing of insurance products. Customers are demanding more specialized products which may require personalized components. Especially in the life and health sectors, many different risk measures – both internal and external to the individual – should be taken into consideration, while still making the product affordable and attractive to them. Finding the right balance between the insurance premium, exposure to risk, and business profitability is a calculation-heavy process of the type that seems to be well suited to quantum computing.

LOOKING BEYOND THE HYPE

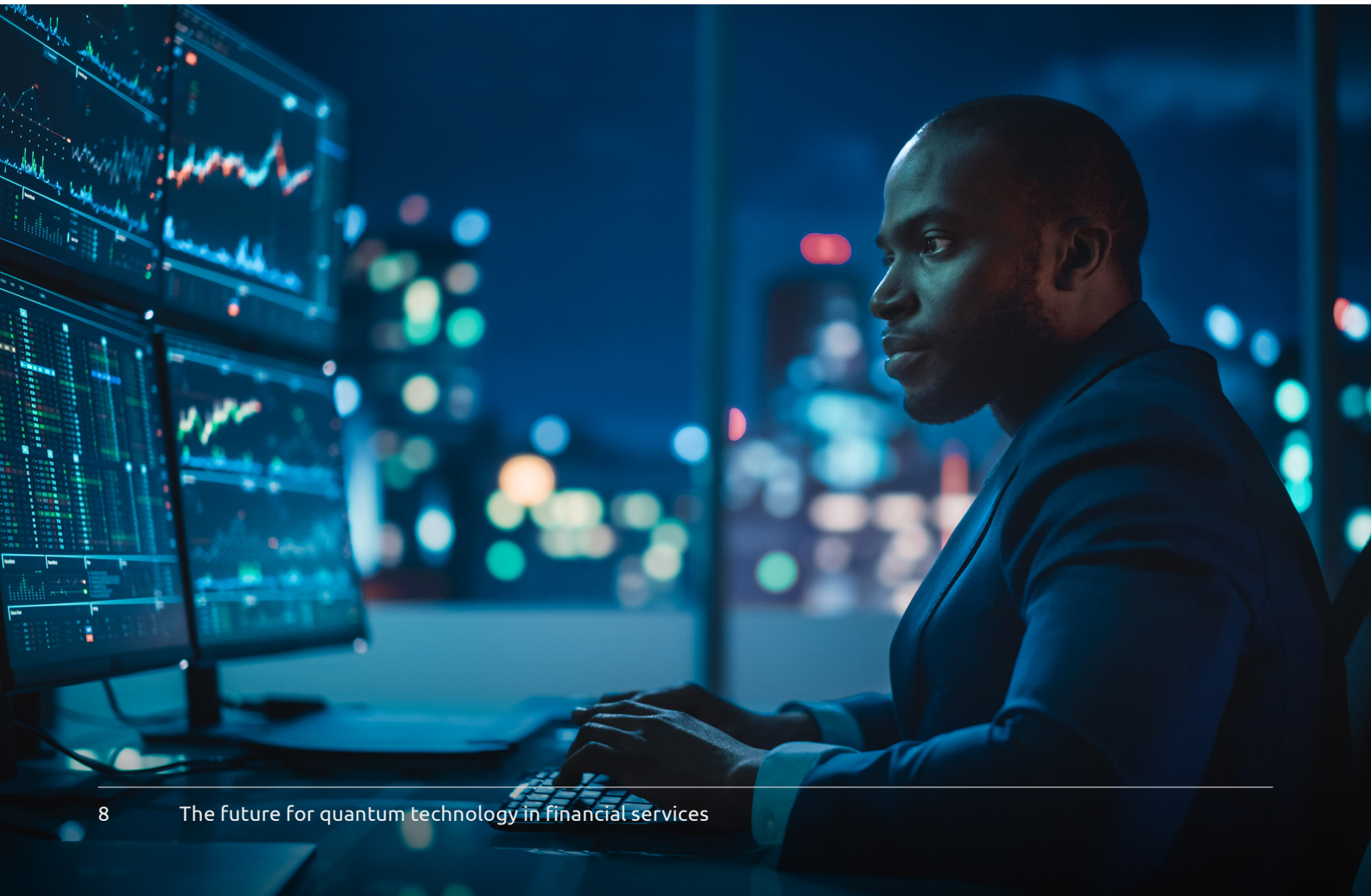
WHAT IS HAPPENING WITH QUANTUM IN THE FINANCIAL SECTOR RIGHT NOW?

There is a lot of hype around quantum technology, the reality however, is more difficult. Quantum is sometimes referred to as a "supercomputer", speeding up or improving current technology and able to handle many calculations or large amounts of data to solve any business problem. In fact, though, quantum is a fundamentally different way of computing, able to do complex calculations, but definitely not suitable for every problem that companies face.

Papers on quantum finance are proliferating with increasing speed, and the development of proofs of concept (POCs) at large banks is not lagging. Bold claims are made about proving early quantum

advantages and implementing commercial applications in the near future. These claims need to be taken with some caution. As crucial as R&D is for emerging technology, it is important that early adopters continuously monitor their roadmaps to ensure they stay aligned with overall business strategy. What often happens is that R&D and business are disconnected. Ultimately, this results in research that will not be seen as valuable by the business, hindering further investment and eventually lacking corporate commitment. Finding a balanced approach to investment in quantum remains challenging.

Despite the excitement, the potential for quantum advantage in financial services is not yet obvious. For the use cases mentioned before, we can expect

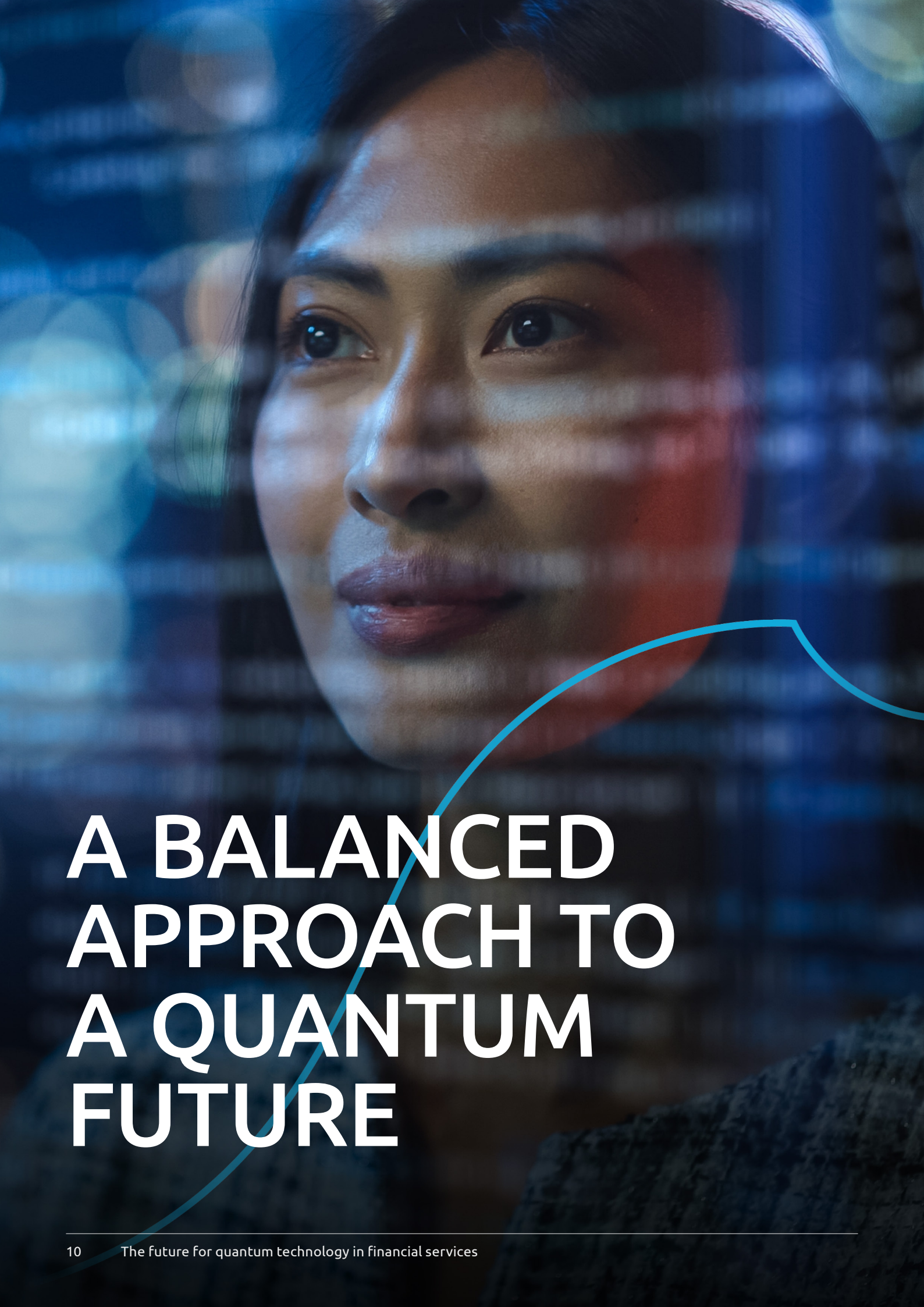


hardware requirements well beyond what near-term machines will be capable of. In the medium to long term, we are cautiously optimistic that the large compute requirements from financial services will translate into valuable use cases.

The key questions to ask are: "What are the intractable problems in the industry that currently cannot be solved in a reasonable time?" and "Can I find sub-processes within those use cases that could be accelerated with quantum processors?" The answers to these questions remain unclear, and more research is needed to get a good perspective on meaningful use cases and their impact on banking and insurance.

Apart from the larger banks and (re)insurers that are setting the trend – and perhaps fueling the hype that exists around quantum technology – many are watching and waiting. This is understandable as quantum does not yet deliver real returns on investment. Nor has quantum any useful applications in production. However, doing nothing is also risky because finding the right talent and building capabilities takes time.

Companies embarking on quantum five years from now will incur a significant disadvantage compared to others in the industry that joined the party early and learned from doing research and working on POCs.



A BALANCED APPROACH TO A QUANTUM FUTURE

There are three actions that financial institutions should initiate today to ensure a balanced approach to quantum readiness.

1. Prepare for migration to post-quantum cryptography (PQC)

Quantum computers will, in the future, be able to break current cryptography. Countering this quantum threat will be vital, particularly for financial institutions that are carriers of sensitive data or that regulate payment infrastructures.

In fact, organizations are already at risk from "harvest now, decrypt later" threats. This treat is substantial to valuable information with a relatively long shelf life. For example, pension payout information and medical records that are used by health and life insurers typically have a shelf life of decades.

Therefore, every organization needs to set up a PQC roadmap to ensure that it remains safe when quantum computers become cryptographically relevant. Now is the time to start gaining visibility of current encryption, identifying red flag areas, and preparing a PQC migration strategy, instead of having to rely on last-minute crisis management.

The financial regulators' role is important with respect to quantum security. Financial organizations will hesitate to go ahead with their own strategies without clear guidelines from local regulators. Hence, regulators and industry need to work closely together to ensure a quantum-safe financial system.

2. Influence direction of research

Quantum technology is not yet mature enough for financial organizations to say for certain which use cases will deliver the most benefit. Despite this uncertainty, institutions need to develop an adequate understanding of how quantum technologies work, to position themselves to act swiftly when the time is right. Failure to invest early on will bring a risk of talent shortages as well as a significant competitive disadvantage. One way to increase understanding and influence research breakthroughs is by continuous investment in building POCs.

Working on POCs is valuable provided that the organization has clear and realistic expectations. A first step to identifying possible use cases for POCs is to highlight all activities within the organization that require significant computing power as well as problems that cannot currently be solved within a reasonable period. The next step is to map each activity onto the organization's strategic objectives. That information can be used to prioritize use cases based on their impact on the organization and the expected quantum advantage derived from them. This prioritized list can drive further research and subsequent POC development.

Beyond practical implementations of quantum algorithms and models, another important opportunity is investment in quantum startups. In this way, financial institutions can play a crucial role in the development of quantum startups that will work on progressing relevant hardware and software.

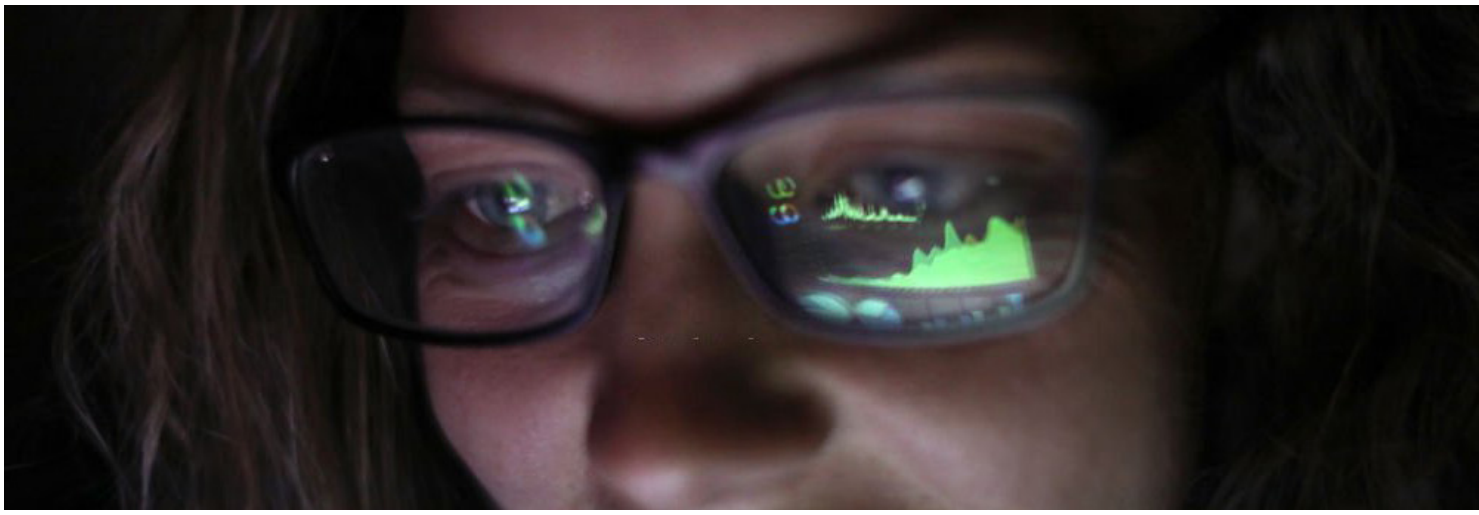
3. Participate in ecosystems

As mentioned earlier, it can be difficult to allocate the right amount of investment at the right time to the right use cases, because the technology is still developing. Participating in ecosystems representing academia, startups, and industry can help organizations to be involved without having to do all the work by themselves.

There are numerous opportunities to join existing ecosystems as well as to create partnerships with the right players in the value chain. Within an ecosystem, R&D costs can be shared among different parties and the talent gap can be temporarily closed.

With the whole field of quantum computing still maturing, there is not a clear outlook on which technology (qubit modalities) will turn out to be leading. A trusted transformation partner is therefore important for the development of a quantum roadmap. It is also essential to understand what is available now in terms of hardware and software, and what can be done today versus what is on the horizon.

CONCLUSION



The potential applications of quantum technology for financial services certainly look promising, but the path toward gaining an applied quantum advantage is not straightforward.

The potential applications of quantum technology for financial services certainly look promising, but the path toward gaining an applied quantum advantage is not straightforward. There has been significant hype around financial services, especially about when the first commercial applications of quantum computing will be implemented at scale. Quantum computing is still far from mature and the first real commercial applications for financial services might be further away than has been suggested. This makes timelines very uncertain, which means that it is challenging for businesses to know how to act.

Realistically, the most immediate value lies in quantum security – it is essential to protect existing systems and encryption against a future quantum attack. Other interesting opportunities that have immediate impact and faster returns could be found is working on new product development - for example on cyber insurance - or capital investments in quantum startups. At the same time, organizations should embark on their quantum journeys and understand the specific challenges they want to tackle with quantum technology and learn from POCs.

Whatever path they expect to follow, organizations need to position themselves to move on quantum when the time is right. And when it comes to preparing for quantum, that time is now. Working with partners who understand both the financial sector's requirements and the emerging potential of quantum could be the fastest and best way to identify what will really benefit the industry.

The Capgemini Quantum Lab researches opportunities to apply quantum. Our thorough understanding of the technology and its business implications equips us to distinguish hype from reality. With in-depth knowledge of the financial services industry and of quantum technology, we are our clients' trusted advisors for unlocking the potential of quantum technology in financial services.

Endnotes:

1. Forbes, "Quantum Safe Cryptography – a quantum leap needed now." Jan 25, 2023

ABOUT THE AUTHORS

Nadine van Son
Quantum Finance Lead
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Nadine is passionate about emerging technology and understanding their impact on business and society. She helps clients understanding the current and future impact of new trends and technology. She is specialized in Quantum technology and their impact for the financial sector and works as a quantum finance lead for the Capgemini Quantum Lab. "There are still so many possibilities when it comes to quantum technology that are not imaginable today. It's exciting to be at the forefront of this new technology. Nobody can predict the future, but we should be able to shape the future!'

Julian van Velzen
Quantum CTIO and
Head of Capgemini's Quantum Lab

Julian is passionate about the possibilities of quantum technologies and proud to be putting Capgemini's investment in quantum on the map. He has established Capgemini's Quantum Lab, a global network of quantum experts, partners, and facilities, focused on three key areas: computing, security and sensing. From this Lab, we're exploring with our clients how we can apply research and solve business and societal problems that up until now have seemed intractable. 'It's exciting to be at the forefront of this disruptive technology, where I can use my background in physics and experience in digital transformation to help clients kick-start their quantum journey. Making the impossible possible!'

OUR TECHNOLOGY LEADERS

Sudhir Pai
CTIO, Financial Services

Sudhir is the EVP and Chief Technology & Innovation Officer (CTIO) for the Global Financial Services business at Capgemini. He is also a thought leader, speaker, blogger and business advisor for the CXO's in the finance industry.

Muhammed Ahmed
Portfolio Manager,
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Ahmed leads strategic initiatives around emerging technologies for the global financial services business at Capgemini. As a strategy consultant, he has rich and diverse experience in helping enterprises become future-ready leveraging the power of disruptive technologies such as blockchain, quantum computing, artificial intelligence, 5G and IoT.

OUR INDUSTRY LEADERS

Nilesh Vaidya
Global Industry Leader
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Nilesh Vaidya is the global industry leader - retail banking and wealth management. His responsibilities include industry strategy and solutions.

Nilesh works closely with several industry organizations like American Bankers Association and Indian Banks Association on industry initiatives. Nilesh advises early-stage fintechs on their products and services.

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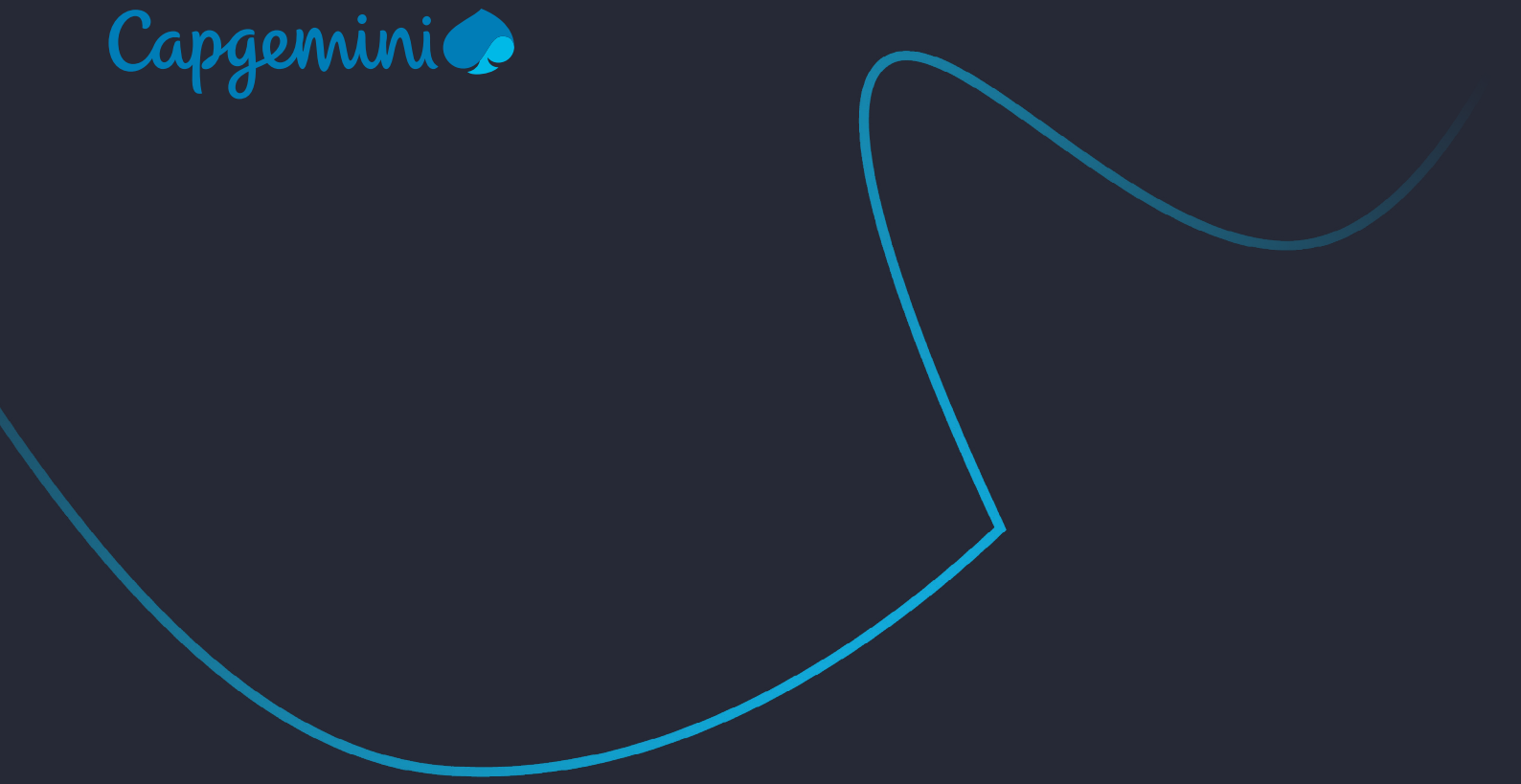
Kiran Boosam leads Capgemini's Global Insurance strategy and portfolio. A P&C and life insurance expert, Kiran envisages the industry dynamics and shapes innovative solutions for the Global Insurance CxOs leveraging the power of Capgemini Group, external partners, and emerging technology.



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