

Beyond the Hype:
A Critical Look at
Quantum Computing's
Potential for Business and
Society in Asia-Pacific



EY

Building a better
working world

Contents



Foreword

To some people, quantum computing is science fiction; to many others, it is already science fact and profoundly impacting lives today. But more importantly, what does quantum computing mean to us as individuals, businesses and countries? And why does it matter?

From optimising logistics networks and energy grids to simulating molecular interactions, quantum computing is without doubt, a defining technology of the future.

This report reveals the principles and capabilities of quantum computing, while exploring the real world use cases that demonstrate significant impact. Whether you're an expert in the field or simply curious, this report will provide comprehensive and insightful analysis on this generational shift in technology.

The report focuses primarily on quantum computing, but also covers related topics such as quantum sensors, post quantum security, and quantum communications, providing an expansive overview of the exciting and rapidly advancing world of quantum technology.

01

Why do we need quantum computers?

We live in an age where supercomputers have beaten world champion grandmasters at chess and solve highly complex scientific and engineering problems that were once beyond conventional computers. The Human Genome Project saw supercomputers reduce calculations from hundreds of years to less than a month. However, even today's advanced supercomputers have their limits.

Problems of scale and complexity, such as climate change and recent health crises, are demanding more attention and in critical need of immediate solutions. From optimizing modern interconnected global supply chains to complex financial modeling, or data analysis in the latest clinical trials for potentially life-saving drugs. These problems are extremely challenging for classical computers, even for today's most powerful supercomputers.

Bounded by limitations of computational power, when faced with such complex computational problems, scientists and engineers must make trade-offs. One way out is to simplify the problem, but that can lead to less accurate or less relevant results, potentially hindering progress. Quantum computers hold the potential to overcome these computational limitations and deliver superior and more optimal solutions.

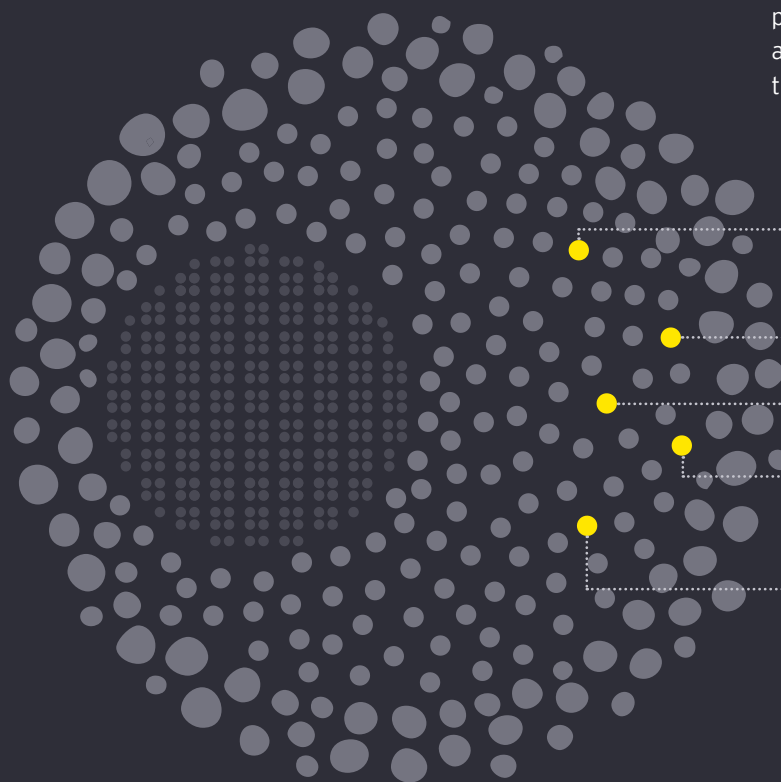
Some problems that interest us today simply cannot be solved on a classical computer of any size.

The classical binary-based computer, with its ability to perform specific computations with lightning speed, has played a critical role in shaping the technology landscape we know today. From powering the internet and breathtaking computer games to taking us to the moon, these machines have been the workhorses of the digital age. But what

can be done when the limitations of classical computing render critical and life changing problems unsolvable?

Quantum computing offers exciting new possibilities for solving previously unsolvable problems.

From health care to finance, quantum computing has the potential to solve some of society's most complex issues. Below are five examples of the many possibilities that demonstrate the transformative power of this cutting-edge technology.



- Personalized drug design

- Complex supply chain optimization

- Material design

- Financial portfolio optimization

- Environmental simulation



Problems we can address today **classically**



Problems we hope to address with **quantum** and classical computing



Problems we **cannot** adequately address today, even with quantum computing

02

— **What** is a quantum computer?

Unlocking the secrets of a quantum computer is undeniably captivating, but what truly sets these devices apart is their superior computational model, which surpasses that of classical computers. Unlike a mere upgrade, quantum computers represent an entirely new breed of computing. They're designed to tackle problems that classical computers, no matter how powerful, simply cannot solve.

By harnessing the multiple state and entanglement properties of quantum mechanics, quantum computers perform calculations in a way that classical machines simply cannot. This allows them to work simultaneously with all possible answers to a problem at once and gradually zero in on the correct answer. Quantum computers can process massive amounts of data at lightning fast speeds, juggling multiple variables and arriving at solutions in a fraction of the time taken by a classical computer.

Quantum computers are not another bigger classical computer. They represent a completely new paradigm that necessitates a different approach to computing and problem-solving, distinct from the evolution of classical computing.



How does a quantum computer work?

Quantum computers use quantum mechanics principles to perform calculations.

Traditional computers use bits, units of information which are limited to two states (0 or 1). Quantum computers, on the other hand, use qubits, which can exist in a superposition of both states at the same time, allowing for multiple calculations to occur simultaneously. This, combined with the power of quantum entanglement, allows qubits to interact and solve problems with multiple variables at an unprecedented speeds.

The basic operation of a quantum computer is to manipulate the state of qubits using quantum gates compiled together in a quantum circuit (algorithm). Quantum gates are operations performed on qubits to change their state, while quantum circuits put gates in order to solve specific problems.

As for the hardware implementations, the world of quantum computing is diverse, with various hardware modalities being utilized. Unlike classical processors, which rely on a unified hardware architecture, quantum computers are built using a variety of architectures (i.e., superconducting qubits, trapped ions), each with its own set of pros and cons.



Why are quantum computers faster?

While classical computers are used to solve a myriad of computational problems, not all problems are equally easy to solve. Depending on how difficult it is to solve a problem, they are grouped into computational classes. It's a bit like sorting books into different genres based on their themes or styles.

A classical computer is designed to efficiently solve problems of certain styles, certain computational classes, and is unable to effectively solve problems outside of these boundaries. For example, adding two numbers of any size is really easy. Finding the shortest route for a travelling salesman visiting multiple cities introduces a level of complexity that makes the problem significantly more challenging. And simulating molecular interactions is so complex that solving them with a classical computer can be impractical due to the enormous amount of time required, even with today's most powerful classical supercomputers.

But solutions to these complex problems are in demand today. Researchers have attempted to approach these problems by introducing other forms of computing, like wave computing, analog computing or quantum computing. While these models seemed promising in theory, their hardware implementation fell short of expectations. However, quantum computing has shown great potential for sustainable scalability, making it the most viable solution for addressing such complex problems.

With the latest advancements in quantum technology, there is potential to build quantum computers that can step in for tasks that classic computers cannot address. Their potential ability to solve classically unsolvable problems is attracting the attention of technology companies, investors and governments.



Are quantum computers “all powerful”?

There is a misconception that quantum computers are “all powerful” in their ability to solve problems.

In theory, while quantum computers can solve certain problems much faster than classical computers¹, there remain many problems that classical computers can solve much more efficiently and at much less cost than quantum computers. The reality is that quantum computers will not replace classical computers.

Quantum computers will work in tandem with classical computers, complementing their strengths and compensating for their weaknesses. In this partnership, classical computers will continue to serve as the control center, managing the flow of data and guiding quantum computers to solve specific problems. When it comes to handling routine tasks and basic computations, classical computers will remain the go-to option, while quantum computers will be called upon to tackle the most challenging problems that classical computers cannot handle alone.

¹ <https://www.nature.com/articles/d41586-019-03213-z>



What are the obstacles to using quantum computers today?

Unlocking the potential of quantum computers has long been a goal of researchers and enthusiasts alike. The possibilities hold great promise, but the path to practical applications is riddled with challenges. While a handful of use cases have been successfully implemented today, most problems still need a large scale fault tolerant quantum computer to be solved.

Quantum computing hardware is still in its infancy, and devices available today are limited in scale and prone to errors during program execution. This means that longer and more complex programs that can tackle real-world problems remain out of reach.

But hardware is not the only challenge. Another obstacle is the immaturity of the software layer. Each use case requires the adoption of an existing algorithm and the development of bespoke data pre and post processing mechanisms. This is not an easy task and requires a unique mix of skills. Furthermore, unlike with classical computers, where one program can be written and run on any laptop or smartphone, quantum developers find themselves anchored to a particular quantum processor. Transferring high performing quantum circuits, or programs, between devices is not a straightforward task and often requires hardware specific adjustments.

These issues are all being actively worked on, but they still present significant challenges to the more pervasive use of quantum computers.



When will quantum computers become a part of everyday technology?

Quantum technology will not become mainstream overnight. The adoption of quantum technology is a gradual process. What is clear is that quantum computing is here today. But the use of quantum computers is a complex and costly exercise, and currently quantum computing resources are limited. The computational problems that might be solved by today's quantum computers require a significant initial investment and limit the range of viable quantum computing applications. As quantum computing software and hardware evolve, the range of applications will increase while implementation complexity will decrease and help make quantum computing more accessible and widespread.

There is no way to precisely predict when quantum computers will become a standard technology. But ultimately, the timeline for the mass adoption of quantum computers will depend on several factors. These range from technological advancements in hardware engineering and software development to venture capital flow and government investment.

03

How can quantum computers be **useful**?

Quantum computers have the potential to be used for a wide range of applications, including optimizing complex systems, improving machine learning algorithms, simulating quantum systems. Some specific examples of potential uses for quantum computers include:

- ▶ Optimizing supply chain logistics
- ▶ Designing new materials
- ▶ Developing more effective drugs and medical treatments
- ▶ Energy grid optimization
- ▶ Fraud detection optimization

Unlocking the full potential of quantum computing remains a tantalizing prospect, but many of the most promising use cases – from drug discovery to supply chain optimization – require fault tolerant quantum computers that are not yet available. Nevertheless, organizations worldwide are already testing the waters and preparing their internal environments for the arrival of this revolutionary technology.

As quantum computing continues to evolve at pace, we can expect to see a raft of new and exciting applications emerge. But there is one use case that stands out from the rest, and it demands our immediate attention: **cybersecurity**. Even at today's relatively early level of maturity, quantum computing poses a current threat to the security of digital infrastructure and data assets. As such, it's essential to take proactive steps to mitigate these risks before they can be exploited by malicious actors.

03

How can quantum computers be useful?

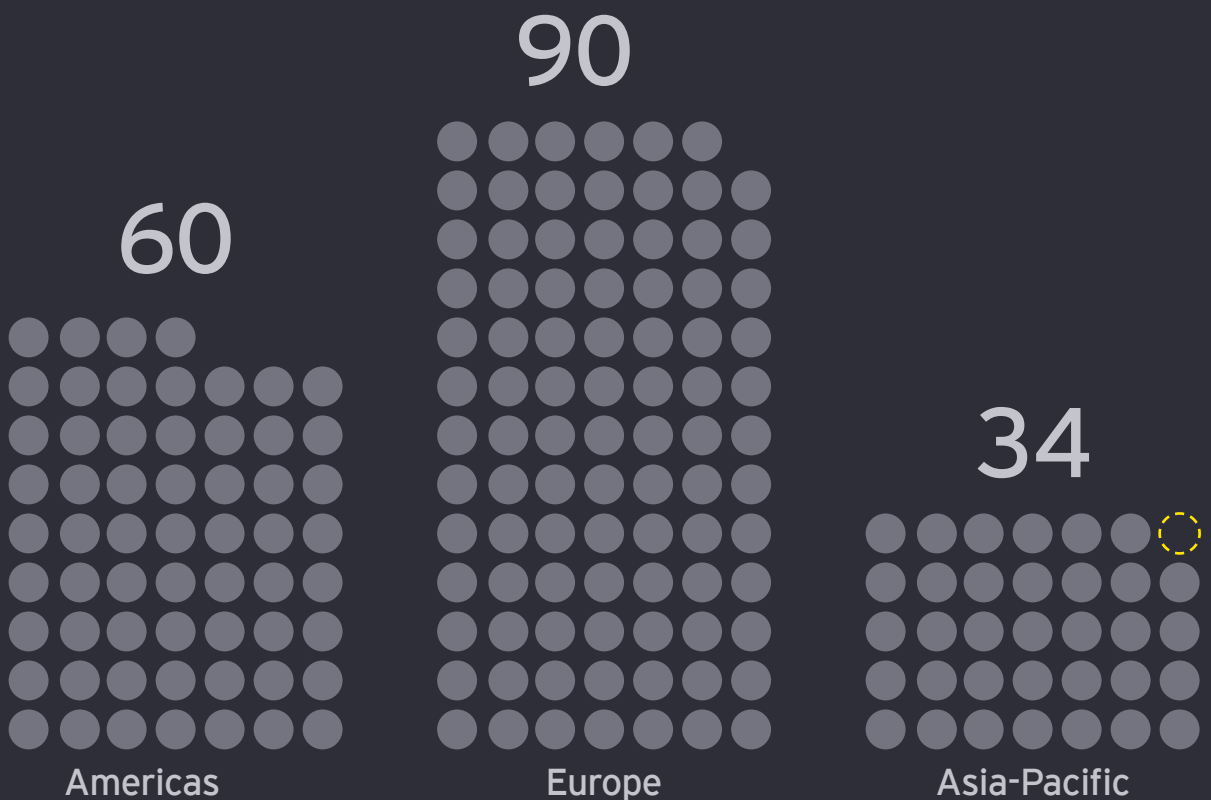
Quantum technology has been gaining increased attention in recent years due to its potential to revolutionize various industries. From telecommunications to finance, organizations from various sectors actively explore quantum technology and its potential applications.

Despite the significant upfront cost of researching potential use cases, identifying

addressable problems and the lack of a guaranteed return on investment, organizations globally have embraced the revolutionary potential of quantum computing. The promise of genuine competitive advantage has ignited a worldwide race to unlock its full potential and explore its many applications.

Global landscape of innovative use case

Dotting the global landscape, nearly 200 innovative use cases have been launched by organizations across a kaleidoscope of industries, shining a light on the limitless potential for progress. Whether in the status of production or cutting edge research, each dot represents a unique application.



○ Is the next project yours to execute?

Source: the data is based on the results of EY teams internal research, Dec 2022.

Cybersecurity

- Quantum Key Distribution (QKD)
- Post Quantum Cybersecurity
- Quantum Random Numbers

Finance

- Portfolio optimization
- Pricing of financial derivatives
- Currency arbitrage

Health care

- Drug design
- Protein folding
- Simulation of molecular interactions

Industry

- Development of new materials
- Optimization of industrial designs
- Incidence management

Retail

- Recommendation systems
- Customer segmentation
- Campaign optimization

Environment

- Environmental simulation
- Decarbonization
- Solar power capture

Supply Chain

- Fleet management optimization
- Supply chain optimization
- Stock optimization

Insurance

- Premium rating/valuation
- Fraud detection
- Risk analysis

Energy

- Energy efficiency
- Power grid optimization
- Consumption predictions

Defense

- Secure communication lines
- Improved radar systems
- Enhanced navigation systems

Cybersecurity



As quantum computers become more powerful, they present both a significant threat and an opportunity for the cybersecurity industry.

1. Data security risks

One of the biggest risks posed by quantum computing is the potential for quantum computers to break existing encryption algorithms. This could potentially make highly sensitive data and information accessible to malicious parties.

Hackers could harvest encrypted data today and store it for future use, not attempting to decrypt it. This harvesting could be done at scale with today's minimal storage costs. As more powerful quantum computers or new decryption algorithms are developed, hackers could decrypt data as needed and use it for malicious purposes. As data retains value over time, new protection mechanisms from such an attack must be established today.

2. New security techniques

Ironically quantum technology is both the source of the problem and solution. Advancements in quantum technology will help develop new security device types like *Quantum Key Distribution* and *Quantum Random Number Generators* that could enhance specific cybersecurity developments.

As quantum computing continues to mature, the need for post quantum secure algorithms becomes increasingly urgent. The transition to post quantum security will not happen overnight. It requires a fundamental shift in the way we think about encryption and data protection. As such, businesses need to test their cybersecurity strategies and update them to ensure they remain resilient to emerging threats.

Securing networks with QKD technology

EY teams became the first customer to participate in the trial of the world's inaugural commercial quantum-secured metro network in 2022. The infrastructure will be able to connect numerous customers across London, helping them to secure the transmission of valuable data and information between multiple physical locations over standard fiber optic links using quantum key distribution (QKD). EY teams will use the network to connect two of its sites in London, one in Canary Wharf, and one near London Bridge. It will demonstrate how data secured using QKD can move between sites and will showcase the benefits this network brings to its own customers.

https://www.ey.com/en_uk/news/2022/04/bt-and-toshiba-launch-first-commercial-trial-of-quantum-secured-communication-services

Smartphones with quantum random number generators

In 2022, Samsung Electronics, a multinational electronics corporation, launched a smartphone equipped with quantum random number generator (QRNG). The new phone features the QRNG chipset, which advances authentication and encryption algorithms, allowing users to access applications and services more securely. This QRNG chip improves the security of various services and provides added protection for a wide range of services, from financial apps to social media and games, offering users a higher level of trust.

<https://www.idquantique.com/sk-telecom-and-samsung-unveil-the-galaxy-quantum-3-world-most-secure-5g-smartphone-featuring-idq-qrng-chip/>

Finance



Quantum computing is slowly being adopted in the finance industry to solve complex problems beyond the capabilities of classical computing. In many areas, such as risk analysis, portfolio optimization or fraud detection, implementing new solutions leads directly to higher profits. This pursuit for profit has driven the financial industry to the edge of what can be achieved with classical computers. Quantum computers offer a path to improve existing algorithms and provide a unique advantage to the finance industry, enabling it to make more informed and accurate decisions in a fraction of the time required with a classical computer.

1. Improving risk modeling

Risk modeling is a crucial problem for financial institutions since risk metrics determine the probability and amount of loss under various financial scenarios. The current classical approach of Monte Carlo methods is computationally intensive. A quantum computing approach could improve solutions to this problem and provide more accurate and timely simulation results.

2. Enhancing portfolio optimization

One of the most commonly seen optimization problems in finance is portfolio optimization. Modern portfolio theory focuses on the trade off between risk and return to produce an efficient portfolio that balances risks versus expected return. Due to the large scale of this optimization problem, classical solutions in the finance sector consume considerable computational resources and significant time. Quantum computing offers techniques that could speed up this optimization process.

Quantum computing can benefit the financial industry in many other use cases, like derivative pricing, options pricing, collateralized debt obligations, value at risks, capital requirements and anomaly detection. Please refer to the Financial Markets Survey for more details – <https://arxiv.org/pdf/2201.02773.pdf>.

Analyzing credit scores

Tradeteq, a private debt global marketplace, embarked on a project in 2020 to leverage quantum machine learning for credit scoring. The project aims to develop quantum computing-based credit scoring methods that enhance accuracy. This may eventually enable faster credit assessment taking into account the increasing volume and variety of data that flows.

<https://news.smu.edu.sg/news/2020/04/27/singapore-management-university-and-tradeteq-develop-quantum-computing-credit>

Accurately predicting customer's behavior

Itaú Unibanco, Latin America's largest bank, is embarking on a journey to harness quantum computing algorithms for the banking sector. The project's goal is to boost customer retention by developing quantum machine learning algorithms that improve the accuracy of models used to predict customer churn. Throughout the project, the teams discovered a method to implement the tested approaches on current classical computers, raising the overall precision of Itaú Unibanco's model from 71% to 77.5%. The algorithm can continue to operate on classical computers for now and is also primed to run on future quantum hardware.

<https://www.prnewswire.com/news-releases/qc-ware-applies-quantum-computing-principles-to-increase-customer-retention-at-itaun-unibanco-301538741.html>

Health care

In health care, multiple problems exist today that are beyond the capabilities of classical computers. With quantum computing, complex problems such as genome data and drug discovery analysis can be addressed at speed and in a more efficient and accurate manner.

1. More accurate medical treatments

Personalized medical treatment requires the analysis of massive data sets, which becomes impossible at scale using classical computing capabilities. Quantum computers could rapidly process such data to develop more accurate and personalized medical treatments.

2. More effective drug development

Drug development requires the extensive simulation of biological systems in multiple possible states that classical supercomputers quickly become swamped. These problems, at their core, are quantum mechanical problems. Quantum computers could simulate complex biological systems, such as proteins and genes, which could lead to new medical discoveries and faster drug testing.

3. Better understanding of diseases

Understanding diseases requires large and numerous simulations of molecular systems, such as proteins and enzymes. Insights into the underlying mechanisms of diseases enable the development of more effective treatments. Quantum computers present an opportunity to model and analyze systems that could not be modeled before.



Genomics, drug development and single-cell transcriptomics

In 2021, Cleveland Clinic in the US, started a ten-year program to use high-performance computing, artificial intelligence and quantum computing technologies to speed up health care and life sciences research. The program aims to create a vital research and clinical infrastructure to advance big data medical research, discoveries for patient care, and innovative approaches to public health threats such as the COVID-19 pandemic. The team will use high-performance computing combined with quantum computing capabilities to generate and analyze data to improve research in genomics, single cell transcriptomics, population health, clinical applications, and chemical and drug discovery.

<https://www.fiercehealthcare.com/tech/cleveland-clinic-ibm-to-develop-premise-quantum-computing-system-to-accelerate-health-research>

Brain Scans

Cerca Magnetics, a spin-off from the U.K. Quantum Technology Hub, developed a wearable brain imaging system for innovative autism research in 2021. The system, which utilizes quantum-enabled sensors to measure magnetic fields above the scalp through a process known as magnetoencephalography (MEG), is being used by researchers to scan children with a higher probability of developing autism due to having siblings with the neuro-developmental disorder.

<https://quantumsensors.org/news/2021/08/24/wearable-brain-imaging-system-installed-in-toronto-for-autism-research>

In this example, we referred to quantum sensing technology, not quantum computing. Quantum sensing is all about measuring minuscule quantities with unprecedented accuracy. It enables scientists to study biological systems at a level of detail that was once unimaginable and finds its implementation in the growing number of problems.

Industry

Today, the manufacturing process features multiple interconnected production stages and processes that present increasingly complex optimization and simulation problems some of which even today's supercomputers cannot solve. However, quantum computers have the processing power to potentially address these problems and transform the way goods are manufactured, delivered and recycled.

1. Creating new materials

Producing new manufacturing materials requires detailed and accurate simulation of molecular building structures. Efficient simulation of these molecular compounds is beyond the capacity of current technology. However, quantum computing allows us to harness the power of large simulations and perform comprehensive molecular modeling.

2. More accurate supply chain optimization

Classical computers can provide only an approximate solution to complex optimization problems in the supply chain, leading to inefficiencies and redundancies. Quantum computing could approach optimization problems and provide much more accurate solutions, thus improving the efficiency of the supply chain and reducing costs.

3. Improving the accuracy of demand forecasting algorithms

Quantum computing algorithms could analyze large amounts of data from various sources, such as sales data, weather patterns, and economic indicators, to more accurately predict demand for goods and services. This could help reduce waste and improve inventory management.



Quantum computing for simulating OLED displays

OTI Lumionics, a renowned innovator in organic light-emitting diode (OLED) materials, has turned to the cutting-edge realm of quantum computing to address the intricate and resource-intensive challenges of developing OLED displays for consumer electronics. OTI Lumionics has devised its own sophisticated iterative qubit coupled cluster (iQCC) quantum method to simulate OLED display emitter materials, capitalizing on the inherent advantages of quantum computing-based simulations over classical computing methods currently employed by the company. By leveraging its proprietary theories and emulator, OTI Lumionics has achieved remarkable expediency in obtaining results, surpassing the prolonged processing times of traditional quantum computing hardware, which can take days to tackle a single problem.

<https://www.fierceelectronics.com/embedded/oti-lumionics-shows-quantum-simulations-can-help-oled-display-development>

Computer aided software boosted with quantum computing

In 2022, Siemens Digital Industries Software, a computer software company from the U.S. started the development of the computer aided product with quantum computing capabilities integration. Such an integration pushes forward the field of quantum computational multiphysics simulation. A quantum computing module is planned to solve intricate nonlinear differential equations that will boost the performance of the product suit. As computer aided software is used for design and testing in various industries, including automotive, electronics, energy, and aerospace, integration of quantum computing capabilities may have a far-reaching effect.

<https://thequantuminsider.com/2022/04/07/siemens-collaborates-with-pasqal-to-research-quantum-applications-in-computer-aided-engineering-simulation-and-testing/>

Retail



Success in the retail industry is closely tied to the ability to efficiently analyze consumer behavior optimize supply chain management, and streamline operational processes. These are all large-scale complex optimization problems. Quantum computing provides a platform that enforces retailers' capability to solve these problems.

1. Improving supply chain logistics

Due to the size and variety of constraints, classical computers struggle to approach logistical optimization problems in the retail environment. Quantum computers could be used to overcome these limitations and deliver superior solutions making it easier for retailers manage their inventory and deliver goods to customers more efficiently.

2. More personalized and targeted marketing

Deployment of a targeted marketing campaign is a computationally demanding problem, with trade-offs taking place. Quantum computers could be used to analyze large amounts of data and develop more personalized and targeted marketing campaigns, which could help retailers to better engage with their customers.

3. The ability to improve fraud detection

Fraud detection is a classic optimization problem. Quantum computers could be used to develop more effective algorithms for detecting fraud, which could help retailers protect themselves and their customers from financial crime.



Supply chain and inventory optimization

Coca-Cola Bottlers Japan are testing how quantum computing can better optimize its delivery servicing of approximately 700,000 vending machines. Supply chain optimization algorithms powered by quantum technology could decrease costly downtime and provide timely updates by quickly adapting to changing circumstances. Continuous route optimization, which accounts for multiple external constraints, like inventory stockouts, vehicle performance, traffic patterns, and weather conditions, could save numerous resources.

<https://www.quantumtechdigital.co.uk/blog/interview-christopher-savoie-founder-ceo-zapata-computing>

Freight optimization

In 2020, Trimble Transport & Logistics, a logistics company, started the exploration of the potential of quantum computing in optimizing the freight industry. The project aims to utilize the power of quantum algorithms and optimization to tackle complex logistics problems and streamline the transportation of goods. The goal is to create more efficient and sustainable supply chain systems, resulting in reduced costs, improved delivery times and a decrease in the carbon footprint of the freight industry.

<https://quantumzeitgeist.com/microsoft-and-trimble-work-together-to-explore-quantum-computing-in-freight-optimisation/>

Environment

Environmental challenges, at their roots, require novel materials and advanced optimization techniques. A few examples include energy usage optimization and new, sustainable materials development. Quantum computing could catalyze a breakthrough in these areas, help tackle environmental challenges, and shape a sustainable future.

1. Alternative energy

The positioning of alternative energy farms and energy distribution is a multivariable optimization problem. The complexity of this problem is beyond conventional computer capability; in many cases, imprecise methods are applied. Quantum computing provides a path to solve such complex optimization problems and analyze historical and geographical data to get more accurate predictions and weather trends and find the best location for farms. These new energy sources will improve grid distribution and resolve supply issues.

2. Expanding battery life

Expanding battery life requires the discovery of new materials. This process is an expensive trial and error process. Classical computing capabilities fail to simulate such complex systems effectively. Quantum computing provides means for materials simulation or can help simulate each element of the battery to find the electrolyte combination that will enable us to power larger projects for extended periods.

3. Reducing CO2 from the environment

Current CO2 reduction techniques require either rare metals or are prohibitively expensive. Quantum computers provide a platform to simulate chemical reactions and enable the development of new techniques.



Development of sustainable hydrogen fuel

ENEOS, an energy firm from Japan, is researching different energy sources, including alternative fuels, and is focused on developing sustainable hydrogen fuels. Hydrogen transportation presents a challenge because of hydrogen's light weight, so ENEOS needs to convert it to a liquid (methylcyclohexane). To help achieve this, the company started catalyst research, which requires a tremendous amount of computational power. ENEOS joined forces with quantum technology industry companies to perform material simulations on quantum computers to achieve overcome these limitations.

<https://customers.microsoft.com/en-us/story/1508526643598641548-eneos-energy-azure-quantum>

Truck transport optimization

Japan Post, the country's largest postal and logistics company, has utilized quantum computing to optimize truck transport. With the help of quantum algorithms, the company was able to streamline its delivery routes, reducing fuel consumption and cutting down on carbon emissions. This was achieved by analyzing vast amounts of data, including road conditions, traffic patterns, and delivery schedules, to determine the most efficient routes for their delivery trucks. Implementing a quantum solution resulted in new optimized routes that circulate trucks among multiple post offices, improving the loading rate and reducing the company's carbon footprint.

<https://corporate-blog.global.fujitsu.com/fgb/2020-01-30/data-ai-accelerates-dx-realization-part-2-case-studies-in-producing-business-results/>

Supply Chain



The supply chain industry is filled with complex optimization problems where classical computers struggle to provide fast and accurate solutions. The ability to optimize schedules or compile better delivery routes differentiates companies from one another. With greater data processing capacity, optimization issues could be solved faster, with higher accuracy and also account for a much higher number of factors. This helps improve supply chain efficiency and reduce overall costs.

1. Better route optimization

Route optimization is a classical optimization problem that quickly grows beyond classical computing capabilities once real world constraints are accounted for. Quantum computing provides a way to overcome these limitations and deliver close to real-time, more accurate solutions that account for a wider range of factors.

2. Improving the accuracy of demand forecasting

Classical demand forecasting algorithms have limited reach for external factors. Quantum computing algorithms could be used to analyze large amounts of data from various sources, such as sales data, weather patterns, and economic indicators, to more accurately predict demand for goods and services.

3. More precise inventory levels optimization

Inventory management is a challenging optimization problem with manifold constraints requiring supercomputing capabilities to solve it quickly. Quantum computing could reduce computational burden and analyze sales, demand, and production data faster with more real-world constraints. That allows for determining the optimal inventory level for a given product, reducing the risk of overstocking or running out of stock.

Insurance



There are a myriad of optimization problems in the insurance industry, and in many cases, insurers' success depends on the ability to effectively and accurately address these problems. As solutions to optimization problems directly impact profits, the industry's computing capabilities have been stretched to the limit, but classical methods can only take the industry so far.

Quantum computing has the potential to provide major benefits compared to current approaches, enabling faster and more accurate risk analysis, improved fraud detection and better personalized product offerings for customers.

1. Improving risk modeling

Quantum computers can be used to process large amounts of data and simulate complex systems, which could help insurers better understand risks they are facing and make more informed decisions about which of them to take on.

2. More accurate trends prediction

Quantum computers can quickly process large amounts of data where classical computers would fail, which could help analyze complex financial systems and predict future trends in the real time.

3. Developing new products and services

Quantum computing could lead to the development of new products and services more tailored to the needs of the customers, for example, create personalized insurance policies that are more accurate and cost effective.

4. Enhancing fraud detection

Quantum computers can run more advanced fraud detection and prevention algorithms by analyzing large amounts of data and identifying patterns that classical computers cannot handle because of the volume of data being processed.

For a more detailed overview please refer to the Potential Applications of Quantum Computing for the Insurance Industry – <https://arxiv.org/abs/2210.06172v1>



Quantum Computing for Financial Portfolio Optimization and Machine Learning Models

In 2020, Standard Chartered bank, a British multinational financial organization, announced the start of a research program in the quantum computing applications area. Potential use cases include quantum machine learning models for synthetic data generation and discriminative models that could be used for credit scoring. As quantum computing technology matures, the bank plans to provide clients with faster service execution, better risk management and the creation of new financial products.

<https://thequantuminsider.com/2020/07/14/standard-chartered-and-universities-space-research-association-partner-on-quantum-computing/>

Driving risk score classification

In 2021, Aioi, a global insurance company, explored quantum computing capabilities to enhance machine learning models for binary classification tasks. Aioi now analyzes telematics data from vehicles to predict driving risks. The vehicles are equipped with a multitude of sensors collecting data. Using the data, Aioi assigns each vehicle a binary score (safe or fail) that indicates the driving risk score for the vehicle.

<https://aws.amazon.com/blogs/quantum-computing/aioi-using-quantum-machine-learning-with-amazon-braket-to-create-a-binary-classifier/>

Energy

The energy sector is undergoing a major transformation with sustainability demand and new energy sources being introduced. Quantum computing could play a key role in solving potential issues these changes could bring. From optimizing energy production and reducing waste to developing more efficient energy storage systems and streamlining energy distribution, quantum computing can drive a cleaner, greener, and more sustainable energy future for us all.

1. Optimizing the design of new materials

Simulating and optimizing the design of new materials for use in renewable energy technologies, such as solar panels or batteries, could help improve the efficiency and performance of these technologies, making them more cost-effective and widely adopted.

2. Optimizing the routes of energy distribution grids

With quantum computers' ability to simulate systems much more complex than what classical computers can handle, many factors like terrain, weather, and demand can be considered when developing new algorithms to find the most efficient routes for energy flow.

3. Better electricity demand forecasting

The ability of quantum computers to solve higher-order optimization problems could help energy companies better predict and respond to fluctuations in demand, reducing the need for costly reserves and improving the power grid's reliability.

4. More efficient IoT data analysis

Myriad IoT devices (i.e., sensors) are used in the energy industry. Quantum computing can enable development of new algorithms for data analysis to help energy companies gain insights into the performance and efficiency of their operations and identify areas for improvement.



Finding alternative sources of clean, safe, and abundant energy

U.S. Department of Energy (DoE) started a quantum simulation project for fusion energy in 2021, in collaboration with universities and quantum technology companies. Fusion energy research aims to harness the same nuclear reactions that power the sun as an alternative source of clean, safe, and abundant energy. The funding is part of an initiative sponsored by the Office of Fusion Energy Sciences (F.E.S.) to further the scientific understanding of plasma physics, the foundation of fusion energy.

<https://www.globenewswire.com/news-release/2021/11/04/2327618/0/en/Rigetti-Awarded-Department-of-Energy-Contract-to-Develop-Quantum-Simulation-for-Fusion-Energy.html>

Management of grid network

In 2021, German multinational energy company E.ON became the first utility company in Europe to handle decentralized energy systems with the help of quantum computing. This project is part of E.ON's efforts to speed up the use of digital technologies to improve the management of its grid network, prepare for future business opportunities, and to enhance customer services.

<https://www.smart-energy.com/digitalisation/e-on-to-manage-decentralised-energy-system-using-quantum-computing/>

Defense



Defense forces have historically been the most eager and early adopters of new technology to stay ahead of others. Quantum technology has the potential to drastically enhance military operations, from improving decision-making processes to strengthening cybersecurity measures. The advanced computational power of quantum computers allows for analyzing complex systems in near-real time and simulations that would otherwise be impossible with traditional computing methods.

1. Developing more secure communications systems

Quantum technology could be used to develop communication systems that are more secure and less vulnerable to hacking.

2. Improving radar and imaging systems

Quantum sensors could be used to improve radar and imaging systems, making them more sensitive and capable of detecting more diminutive and distant objects.

3. Enhancing navigation systems

Quantum technology could improve the accuracy and reliability of navigation systems, making it easier for military vehicles and equipment to operate in challenging environments.

4. Logistics and Supply Chain Optimization

Quantum computing can optimize logistics and supply chain management for the military, making it possible to plan routes, track resources and optimize distribution in real time by considering the factors relevant to the military.

For the overview of the defense industry, we stepped aside from quantum computing and shared use cases from adjacent areas, which are quantum sensing and quantum communication.



Navigation and timing information

Since 1978, the Australian Defense Force (A.D.F.) has heavily relied on the US Global Positioning System (G.P.S.). However, G.P.S. can be an easy target by the nation's rivals to restrict the system. The ADF and their partners have invested into the development of the Quantum Assured Position Navigation and Timing system, providing Australian troops with uninterrupted global navigation satellite systems (G.N.S.S.).

<https://www.dst.defence.gov.au/strategy/star-shots/quantum-assured-pnt>

Cyberthreats to the defense

The National Security Agency's (N.S.A.) Cybersecurity Directorate emphasized the need to develop new cryptographic systems to secure weapon systems from foreign adversaries in 2021. The threat of quantum computers to the cybersecurity of the defense industry is increasing. The N.S.A. warned that using quantum computers by adversaries could have a devastating impact on National Security Systems. The Quantum Computing Cybersecurity Preparedness Act was also recently signed into law by the White House, indicating the United States government's recognition of the severe issue of quantum security. The act aims to ensure the migration of government IT systems to post-quantum cryptography (P.Q.C.), which is resistant to attacks from quantum computers.

https://www.c4isrnet.com/thought-leadership/2023/01/20/pentagon-must-act-now-on-quantum-computing-or-be-eclipsed-by-rivals/?utm_source=substack&utm_medium=email

04

Is it time to **invest** in quantum computers?

Quantum computing is the new frontier in computational power, promising to revolutionize the way we solve problems and process information. With the ability to perform some calculations exponentially faster than traditional computers, quantum computers represent the first fundamental shift in computing since the emergence of computers in the 1940s. While investing in any emerging technology carries inherent risk, the potential rewards of quantum computing are too great to ignore. The ability to harness its potential could determine which companies come out on top. For companies seeking to stay ahead of the curve in terms of computational capabilities or cyber security, investment in quantum computing is a necessity.

1. Combat quantum-in-cyber risk

Quantum computing poses a current risk to data security with its ability to break cryptography algorithms protecting it. With information retaining its value for years to come, hackers could be motivated to intercept and store data in its encrypted form and decrypt it later when a big enough quantum computer appears. This area requires investment today to keep information secure.

2. Gain advantage from quantum computing usage

Quantum computing could be used to deliver solutions superior to classical ones. However, it requires developing large scale fault tolerant quantum computing and corresponding algorithms.

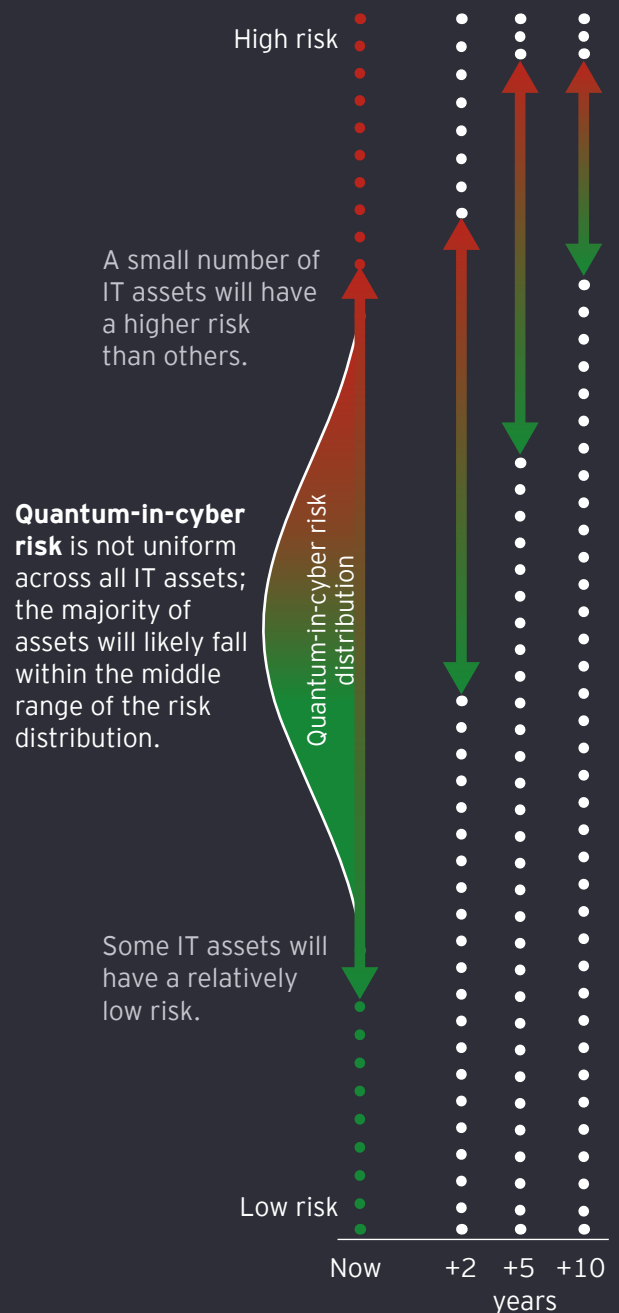
Quantum-in-cyber investment to protect your data

Quantum computing poses a current threat to organizations which needs to be remediated now. Remediation employs investment to quantify the risk, develop a plan to tackle the risk and implement a solution.

Currently, quantum-in-cyber risk is at the growth stage. With time, the number of vulnerable assets and the severity of the risk will grow. However, each organization is different. The following parameters could help to personalize a risk profile and decide on the investment horizon:

- Digital dependency
- Customer outflow
- Regulatory impact
- Fleet size
- Tech diversity
- Vendors
- APT with quantum
- Data retention
- Cyber maturity
- Quantum awareness

Considering these factors, organizations should prioritize developing a customized strategy to address their unique quantum-in-cyber risks. This includes assessing the organization's current risk level, setting a clear investment horizon, and incorporating quantum-resistant technologies and processes.



The field of quantum computing holds tremendous potential for reward, provided investment is made

Quantum computing is a rapidly growing field that has the potential to revolutionize the way we process information and solve complex problems. Given the potential benefits of quantum computing, it's no surprise that many organizations are investing heavily in research and development to drive this

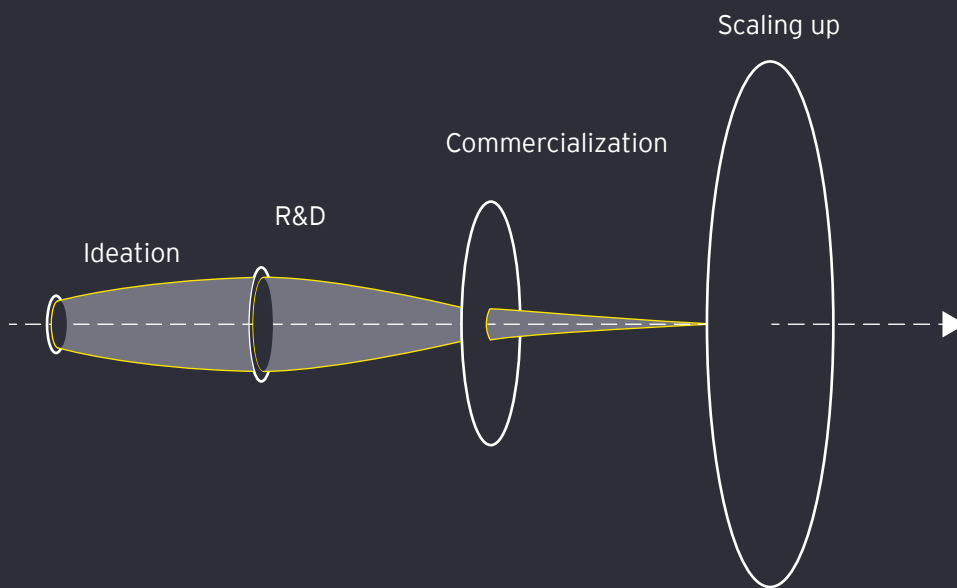
technological revolution. From tech giants like IBM and Microsoft to startups and academic institutions, many players are working to advance the field. Governments, too, are recognizing the importance of quantum computing and are investing in research and infrastructure to support the growth of this industry.



Australia, China, Japan, New Zealand, Singapore, South Korea, Taiwan

According to the Quantum Insider data, Dec 2022

Quantum computing is yet to enter the scaling up phase with some commercial opportunities today.



Investment into quantum computing today will not yield immediate return. The Emerging *Technology Investment Cycle* for quantum computing shows that the technology is consolidated on the left side with a lot of research in flight and a few commercialization opportunities. However, the transformative power of this technology is huge such that even today many commercial organizations are heavily investing in it.

1. **Ideation:** This is the early stage of the cycle, where new ideas and technologies are generated and evaluated for their potential value. Quantum computing has already advanced through and beyond this stage.
2. **Research and development:** At this stage, the focus is on developing and refining the technology through prototyping, testing, and experimentation. Quantum computing components are today at different stages of R&D, with some being commercialized.
3. **Commercialization:** In this stage, the technology is ready for market adoption. Not all quantum computing components and technology implementations are ready to be commercialized, but a few are already testing market segments.
4. **Scaling:** Once technology has been successfully commercialized, the focus shifts to scaling and growing the business. Quantum computing is not at the scaling stage yet, but the level of investment, benefit promised and attention may quickly change the picture.

05

What **steps** need to be taken today?

Solving a use case with a quantum computer is much more than just designing a quantum algorithm and running it on a quantum computer. Even more essential components are expertise in use cases, end-to-end solution delivery, commitment to innovation and deep technical knowledge. Such an approach could lead to the successful adoption of the new technology and competitive advantage. There are several steps that organizations can take today to nurture the internal environment and embrace quantum computing capabilities:

- ▶ **Be aware:** Raise awareness and educate yourself and your team about quantum computing.
- ▶ **Postquantum cyber:** Remediate quantum-in-cyber risk.
- ▶ **Engage:** Collaborate with other organizations and build partnerships with quantum computing companies.
- ▶ **Build:** Invest in quantum-related research and develop use cases.
- ▶ **Strategize:** Develop a quantum computing strategy.

Be aware ●●●●●

A growing number of global organizations have initiated programs in either quantum computing, quantum sensing or quantum security domains.

194

organizations across the globe



24

are headquartered in the Asia-Pacific region

According to the Quantum Insider data, Dec 2022

To prepare for a future of quantum computing, it is essential to understand what quantum computing is and how it works. This will help businesses and institutions better understand its potential impact and how it can be effectively used.

Maintaining a high level of awareness regarding specific concepts among employees can be challenging, but it ultimately proves to be rewarding in the long run. Driving up quantum computing awareness within organizations will ensure teams are better prepared to take advantage of this technology's opportunities and mitigate its risks.

A high level of awareness facilitates the outsourcing of idea generation to experts in their respective fields, broadening the range of potential solutions. Simultaneously, it enables the identification of potential business risks at a stage where the remediation process can be carried out smoothly and painlessly. This ensures businesses stay ahead of the curve and remain competitive in an increasingly technological world.

Steps for building awareness

1

Set up quantum explanatory sessions for C-suite members

3

Partner with universities to offer courses on quantum technologies for employees

2

Attend public events and conferences

4

Provide access to the dedicated quantum technology learning courses

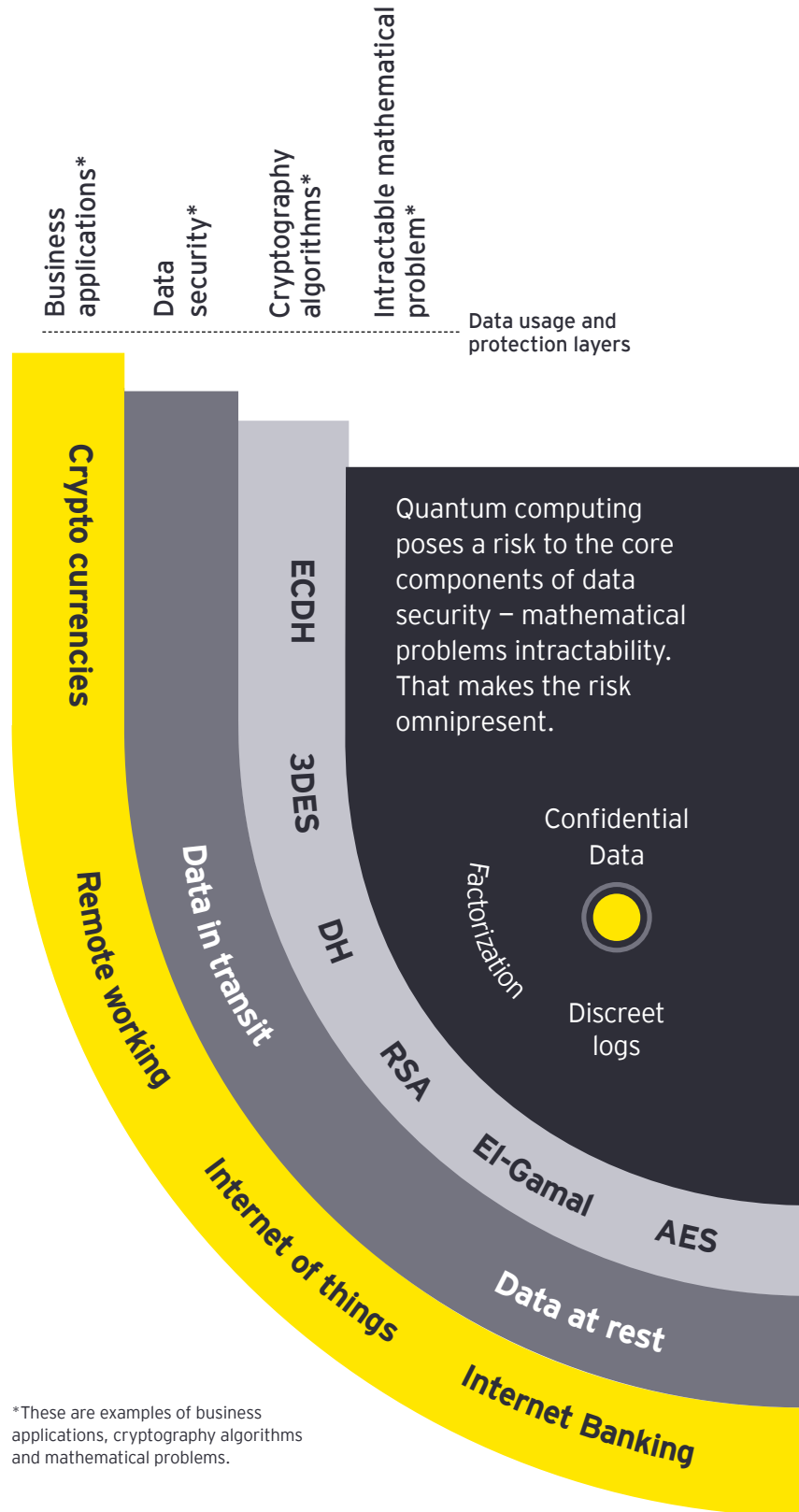
Postquantum cyber

Quantum computing poses a significant risk to data security, as it can break many encryption algorithms currently in use to safeguard sensitive information. This is because quantum computers can quickly solve complex mathematical problems that ensure cryptographic security. Existing cryptography algorithms were not designed to withstand an adversary with access to a quantum computer.

Even though quantum computers are not big enough today to break encryption keys used in production, the risk is still current. Data keeps value over time. A file created today with a shelf life of seven years should be protected over seven years. Once data shelf life intersects with the horizon of building a large-scale quantum computer, a file needs quantum-resistant protection.

Overall, the risk that quantum computing poses to data security and cryptography is a significant concern. It will be necessary for organizations to carefully consider this risk and take steps to protect their sensitive information.

As quantum computing technology advances, organizations must stay informed and prepared to adapt their security measures accordingly. Transitioning to postquantum cryptographic algorithms is crucial and may take years to complete. By maintaining a proactive approach, organizations can safeguard their sensitive information against potential quantum threats and ensure long-term data security.





Postquantum cyber

Actions to achieve post-quantum security

- 1 Develop a post-quantum implementation strategy
- 2 Create an enterprise wide timeline for a quantum safe cryptography transition
- 3 Review data disposition requirements and enforce adherence to those requirements
- 4 Update existing cryptographic policies to reflect postquantum cryptography requirements
- 5 Incorporate the cryptographic agility concept into IT architecture concepts
- 6 Update an inventory management system to account for cryptography assets and modules
- 7 Update security requirements that govern vendor relationships and agreement templates
- 8 Identify third party contracts which need to be updated to include postquantum support
- 9 Build internal competence for a smooth transition
- 10 Run a quantum-in-cyber pilot assessment

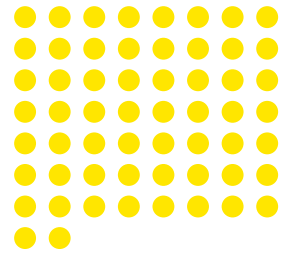
Engage

In the world of quantum computing, staying on top of the latest developments is essential for any organization looking to remain competitive. However, with the field rapidly evolving, it can be challenging to keep up. That's why collaboration is key. By partnering with other organizations and sharing knowledge, companies can stay ahead of the curve in quantum computing. Collaboration helps organizations stay informed on the latest advancements and also gain access to valuable quantum computing resources.

The Asia-Pacific (APAC) is fast becoming a hub for quantum computing innovation, thanks to its rich talent pool and strong government and university support. With 51 research centers located throughout the region and covering a diverse range of topics, opportunities to find the right quantum computing partner today are multiplying. But it's not just about research and development; commercialization is key to building a thriving quantum industry. The Asia-Pacific region has at least three consortia where industry and academia come together to explore the best ways to proceed. By bridging the gap between research and commercialization, the Asia-Pacific region is setting the stage for a thriving quantum computing future.

51

research centers in the Asia-Pacific region



3

consortia in the Asia-Pacific region



According to the Quantum Insider data, Dec 2022

Steps to connect with the quantum community

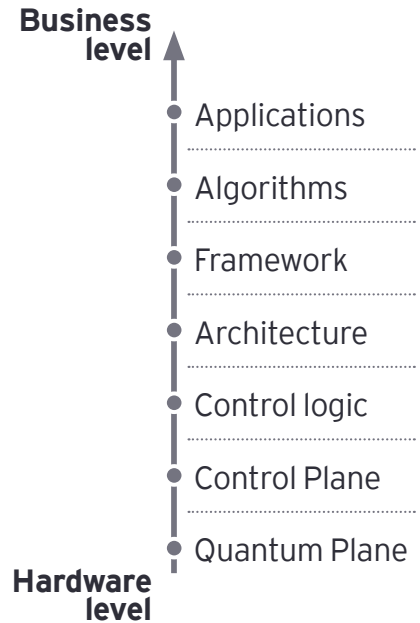
- 1 Foundations – access to hardware
- 2 Join consortia relevant to your industry – Australian Quantum Alliance, Q-STAR or QIIC.
- 3 Become part of the Quantum Company network and contribute
- 4 Join university research program
- 5 Consider investment into other quantum computing companies
- 6 Set up an internal leading group to accumulate knowledge and coordinate engagement

Build

For parties interested in using quantum computing, investing in research and development is essential to explore the technology's potential applications.

Quantum computing is not a plug and play technology. Incorporating it into existing infrastructure and processes is a long term and complicated enactment. It could take years for an organization to progress on this path. Further development of the technology will raise demand for talent, where hiring and training quantum staff may be complicated.

For these reasons, companies must begin planning for quantum technology now to be competitive in the future. The quantum computing stack has multiple layers. An organization should aim to choose those where it wants to lead and build competency in it and connections around it.



Procedures to uncover potential advantages

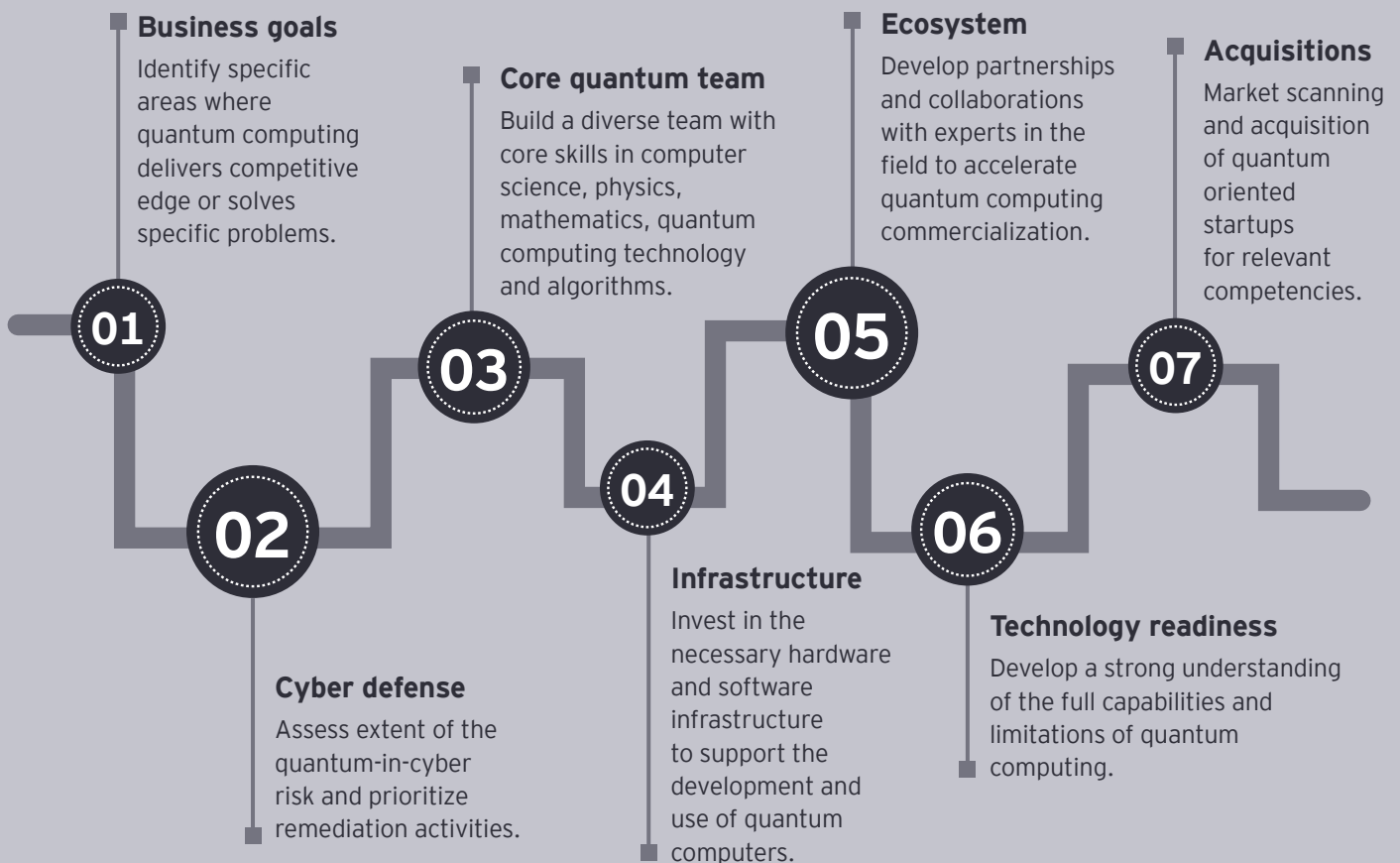
- 1 Translate quantum technology benefits into business terms through identification of quantum computing use cases modeling
- 2 Explore industry tools to qualify tasks that could benefit from quantum computing
- 3 Develop proof of concept for selected use cases
- 4 Develop and secure intellectual property in areas that most benefit your business
- 5 Prepare internal quantum knowledge, documents and processes to transition to a postquantum world
- 6 Run a hackathon or a case development challenge

Strategize

To fully take advantage of the potential benefits of quantum computing, it is crucial to develop a clear strategy for how you will use the technology in your business or organization. A quantum

computing strategy can vary depending on an organization's specific goals and needs. In general, a successful quantum computing strategy should involve a combination of several key elements.

Elements of a successful strategy



Quantum Dictionary

Quantum technology refers to a set of cutting-edge technologies that use the principles of quantum mechanics to execute a useful operation. Quantum technology includes quantum optics, quantum computing, quantum cryptography, quantum sensing, quantum communication, quantum metrology and other areas.

Quantum computing is a branch of quantum technology that focuses on performing computations using unique properties of quantum bits (qubits). Quantum computing introduces a more general computational model compared to a classical model, capable of performing tasks that classical computers cannot.

Quantum sensing is a branch of quantum technology that focuses on detecting changes in physical quantities, such as magnetic fields, electric fields, temperature, and pressure, with high precision and accuracy. Quantum sensing relies on the interaction between quantum systems, such as atoms, which makes them much more sensitive and precise than classical sensors.

Classical bit is the basic unit of information in classical computing. It can have one of two values: 0 or 1. These values can be combined to represent larger numbers, letters, or other symbols, and are used to store and process information in computers. A bit can be thought of as a switch that is either off (0) or on (1).

Quantum bit (Qubit) is a unit of information that takes advantage of the unique properties of quantum mechanics. In contrast to a classical bit, which can only be in the state of 0 or 1, qubits can exist in multiple states at the same time in a so-called superposition of states and can become entangled with other qubits.

Superposition is a concept in quantum mechanics which states that a particle can exist in multiple states at the same time, until observed.

Entanglement is a phenomenon in quantum mechanics where two particles can become connected in such a way that the state of one particle is dependent on the state of the other, even when separated by large distances. It is like having two coins that always land on the same side, no matter how far apart they are from each other. This connection or correlation between particles is instantaneous and cannot be explained by classical physics.

Phase kickback is a phenomenon in quantum mechanics where a change in the phase (or angle) of one qubit can cause a change in the phase of another entangled qubit. This effect is used in certain quantum computing algorithms to perform calculations more efficiently. Simply put, it's a way of influencing the state of one qubit by changing another entangled qubit, allowing for more precise control of quantum systems.

Superposition, entanglement and phase kickback are differentiators of quantum computing. These concepts underpin the computational advantage of quantum computers.

Contacts



Aaron Perryman
EY Asia-Pacific
Financial Services Consulting
and Digital Leader
Aaron.Perryman@sg.ey.com



Mike Orman
EY Asia-Pacific
Financial Services Technology
Consulting Leader
mike.orman@au.ey.com



Lukas Bower
EY Oceania
Financial Services Digital & Emerging
Technology Leader
lukas.bower@au.ey.com



Alexey Bocharnikov
EY Asia-Pacific
Quantum Technology leader
alexey.bocharnikov@au.ey.com

Author

Alexey Bocharnikov

Contributors

Shivika Handa, Kelvin Lee, Will Duckworth, Harvey Lewis

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