BET on Quantum Computing

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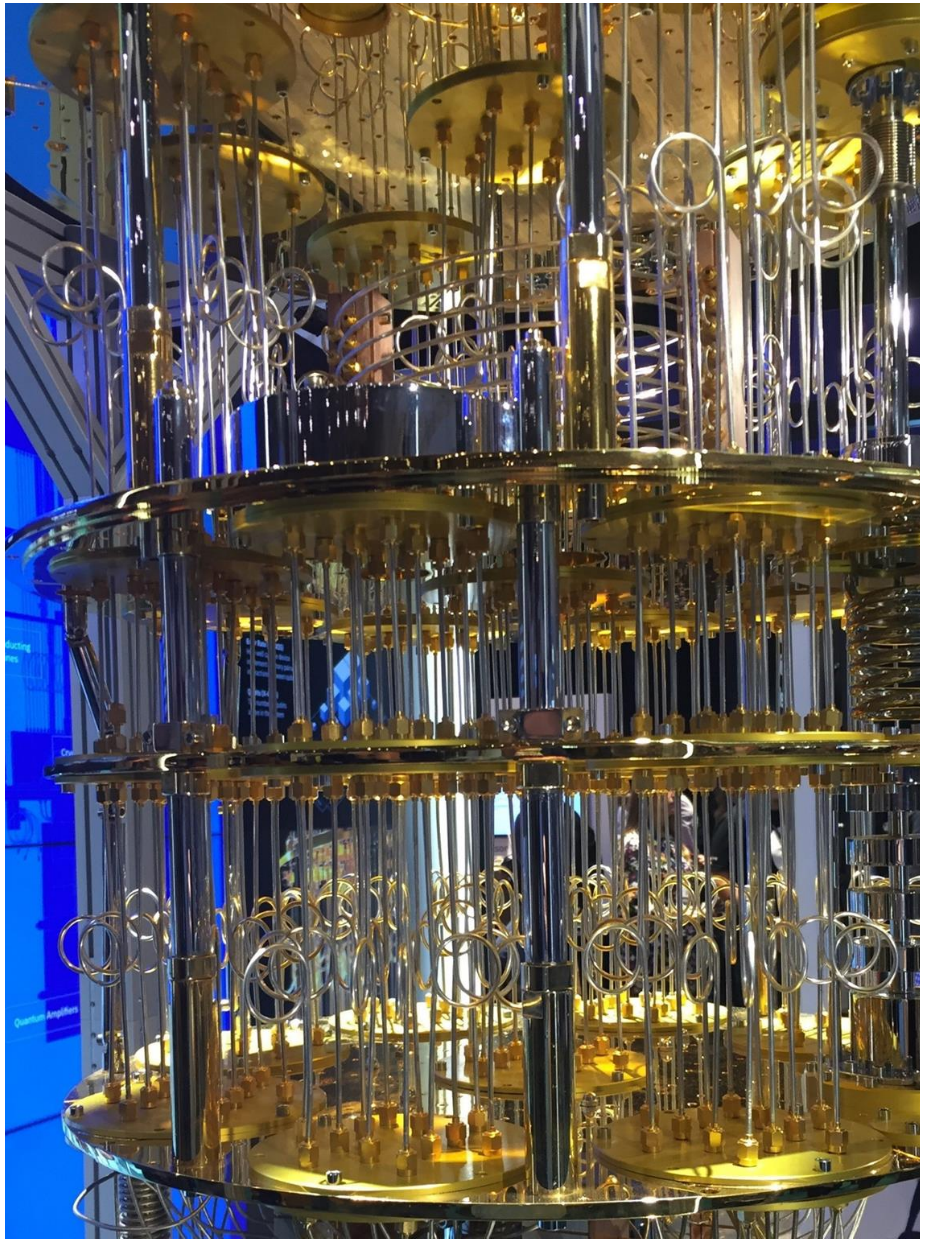

Participants in affected industries and functions already need to prepare for quantum computing (QC). Assess the status of your industry and the chances and risks of operation. Plan for long implementation times. The fast optimization time demands adaptation of business operations and probably a change in the business model. Allocate funds for R&D activities.

Operationalization

Quantum computing represents a paradigm shift in computing. QC-optimized algorithms can solve some problems exponentially faster than classic algorithms. QC is poised to revolutionize data encryption, amplify decision making in complex scenarios, speed up R&D, refine financial models and redefine AI-driven insights. Its emergence could result in competitive realignments, the birth of novel markets, and redirection of strategic investments.

Strategic definition

Quantum computing is a type of nonclassical computing that operates on the quantum state of subatomic particles. These particles represent information as elements known as quantum bits (qubits). Qubits can be linked with other qubits, a property known as entanglement. Quantum algorithms manipulate linked qubits in their entangled state, a process that addresses problems with vast combinatorial complexity.

Technical definition

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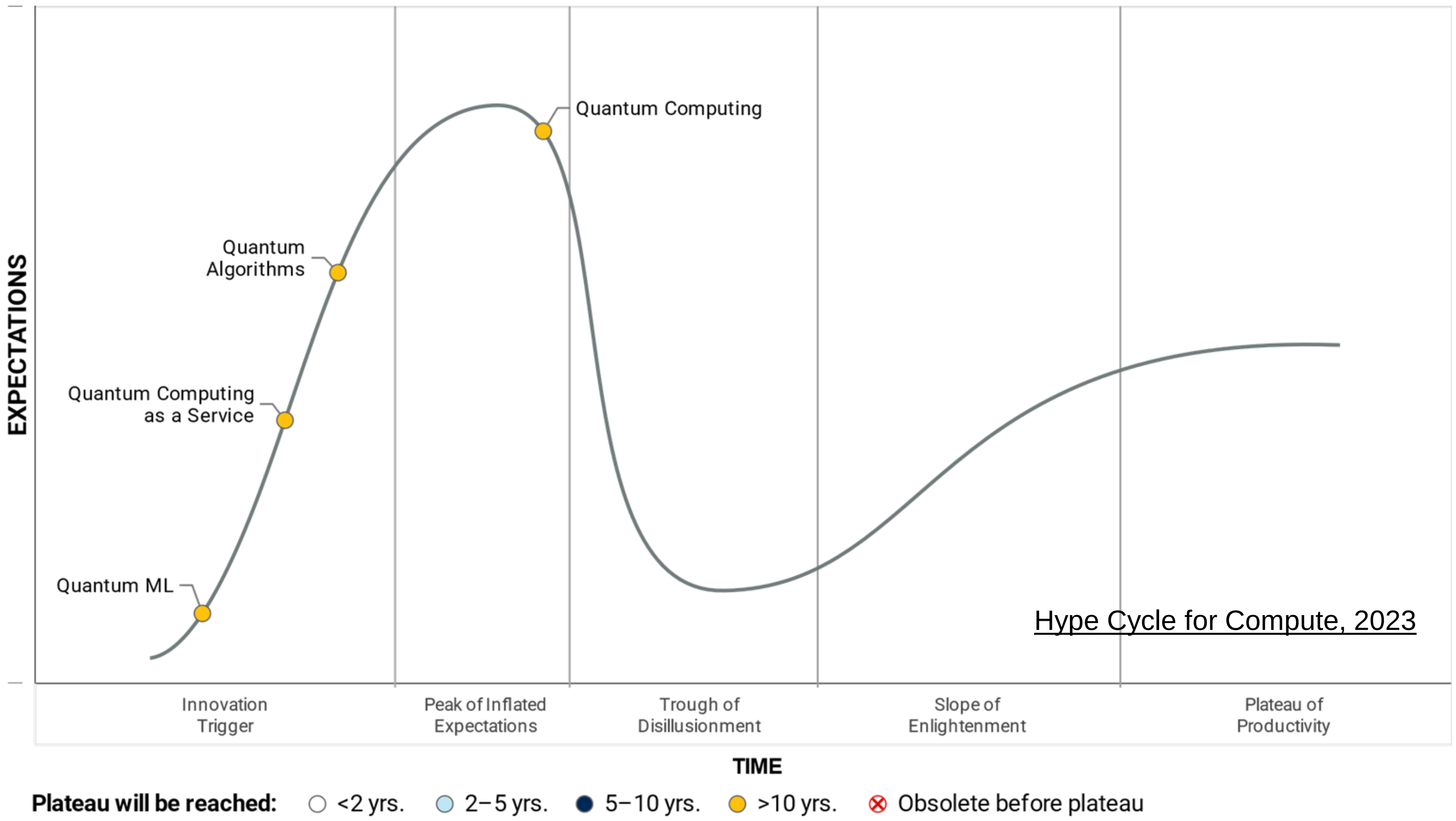
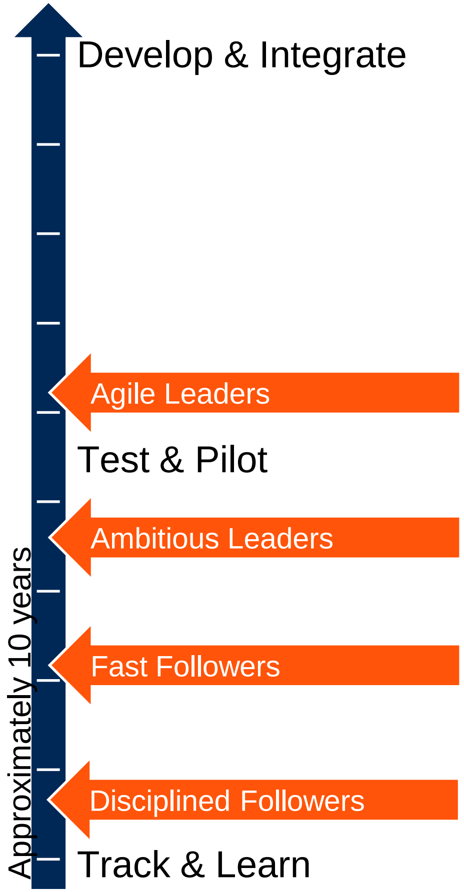
Hype Cycle for Quantum Computing



When to start?



Quantum computing is a long-term strategy and investment.

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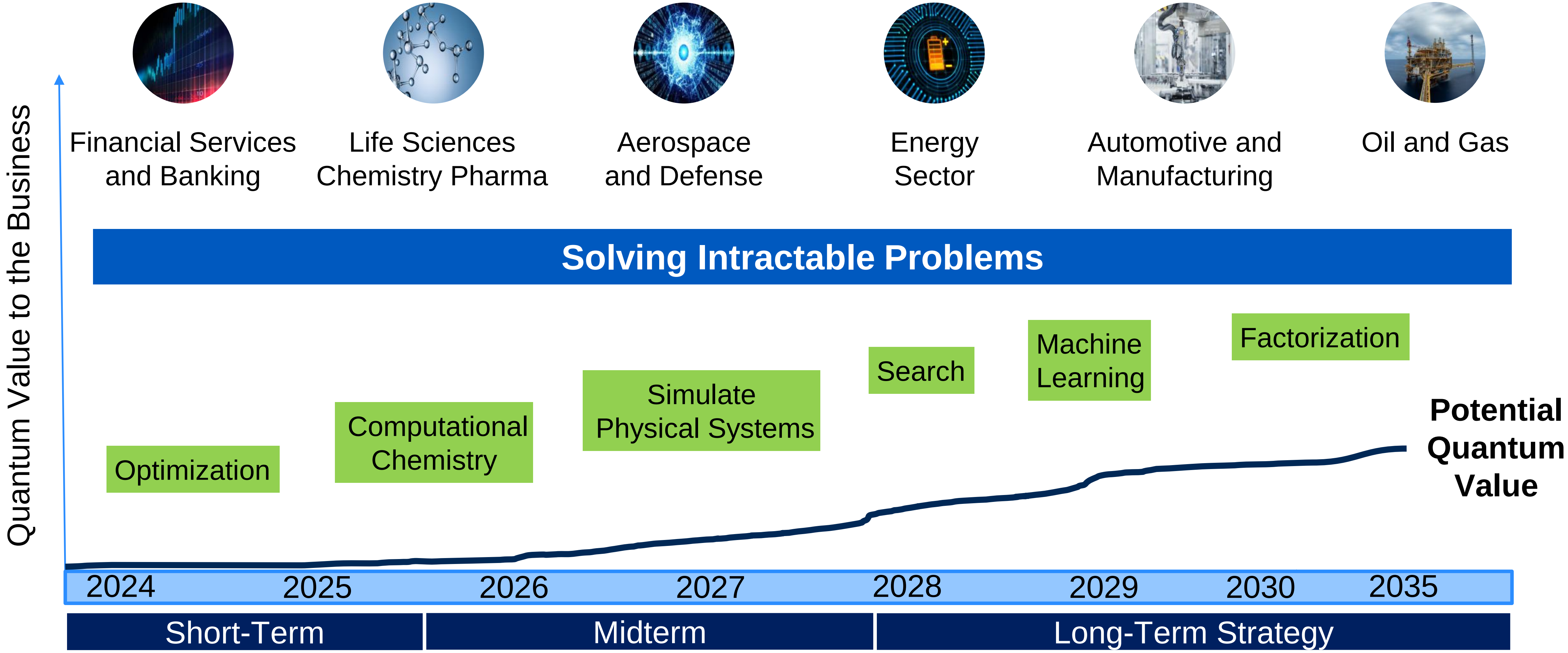
CIO Strategy Value Inflection Points



Gaining benefits of quantum computing depends on industries and problems to solve.

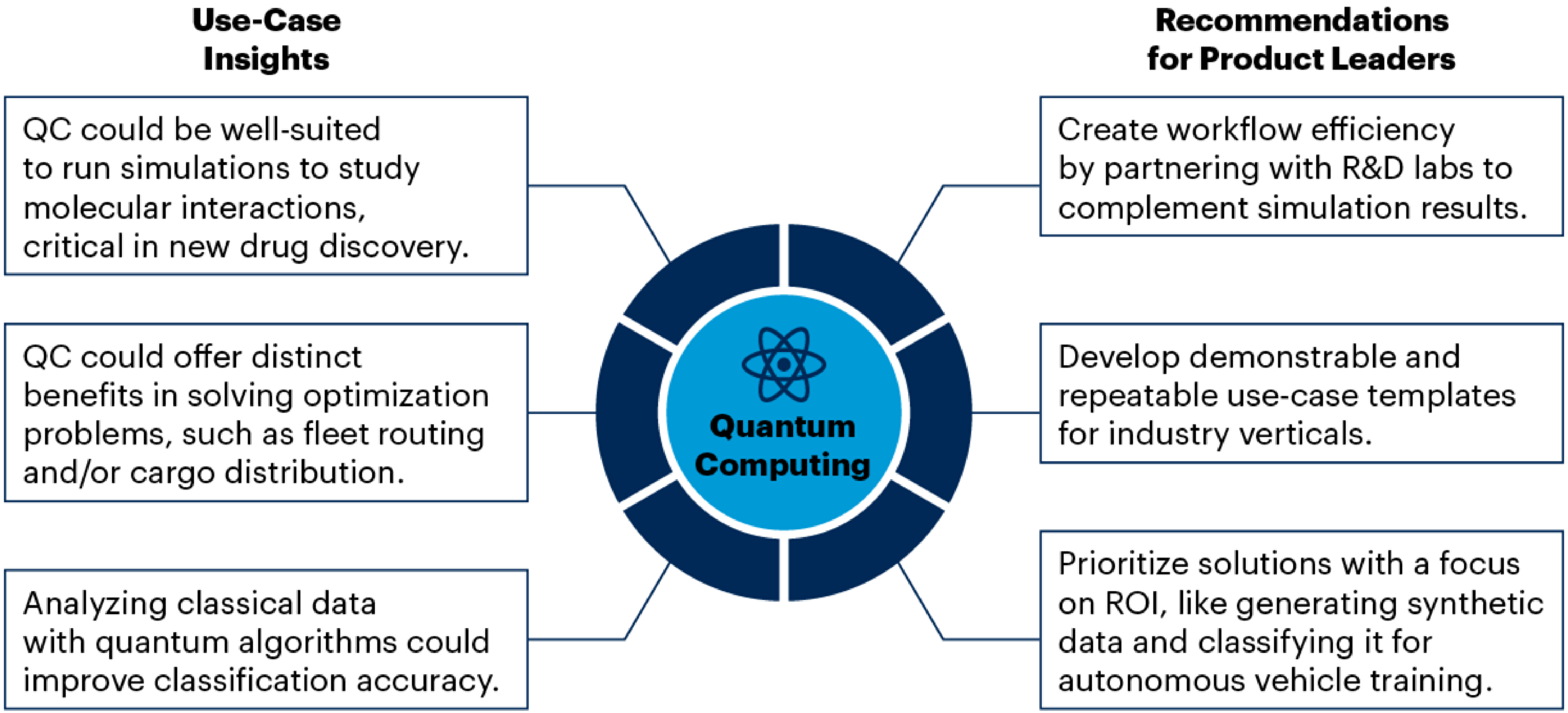
Strategic Planning Assumptions

- Post-quantum cryptography risk assessment will be the top issue that businesses will look for advice on.
- By 2025, postquantum encryption algorithms will see more use for their secondary properties, like privacy enhanced computation, than they will as replacements for existing cryptography.
- By 2025, nearly 40% of large enterprises with mature quantum computing initiatives could deliver advantages over peers, with NISQ-inspired solutions.
- Over 50% of large enterprises will have quantum initiatives to build skills in preparation commercially QC systems.
- By 2027, more than 60% of the startups in the quantum computing space will go out of business because they did not focus on business advantage for clients.
- By 2029, advances in quantum computing will make conventional asymmetric cryptography unsafe to use.
- Quantum computing as a service (QCaaS) will be the predominant delivery platform for over 75% of enterprises.

2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034

Organizations cannot afford to wait too long, before they assess quantum impacts.

Use Case Insights on Quantum Computing



Source: Gartner

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Cases with a clear focus on ROI should be prioritized to demonstrate value.

Case Studies in Quantum Computing

Boeing seeks new ways to engineer strong, lightweight materials, solving the ply composite problem: finding an optimal way to stack layers of materials. Together with IBM, the team ran a record 40 binary variable optimization algorithm, increasing efficiency in solving the problem radically, even against an early QC prototype.

Würth — a tools, fastener and chemicals company with investments in industrial IoT — partnered with Crypto Quantic to secure their electronics and wireless modules, enabling automatic and secure connections of thousands of sensor nodes to local and cloud-based servers with post-quantum cryptography.

Early cases clearly show possible benefits of quantum computing

Case Studies in Quantum Computing

České dráhy – national railway service of the Czech Republique – partnered with Toshiba to secure 46 km of fibre optic cables. The test installation successfully proved that the quantum-secured infra-structure can be operated in proximity to heavy railway traffic, enabling QC for thousands of kilometers of trackside fibre communication links.

BMW and AIRBUS have been researching fuel cell efficiency to address sustainable mobility. The two companies partnered with Quantinuum and built a quantum-classical hybrid workflow to compute the oxygen reduction reaction (ORR) on platinum-based catalysts for fuel cell improvement, paving the way for next-generation car and aviation cells.

Early cases clearly show possible benefits of quantum computing

Strategic Insights on Quantum Computing

QC exposes corporates to risk today. Harvest now, decrypt later (HNDL) attacks are already an actual threat.

Even if you are not operating quantum cases today, immediate security action is required, such as the use of quantum safe cryptography.

There is no commercially viable business use case for QC so far, but, as the technology matures, combinatorial optimization, cryptography, quantum chemistry/materials science and machine learning will be key areas for implementation.

While the disruptive impact of QC is more than a decade away, product leaders must start planning to engage with QC developments in the next six to eight years. This will be necessary to be prepared to intercept the technology when, and if, it becomes commercially viable.

Public funding	Private investments
Governments are investing > $22 billion globally	2019 to 6/2022 $2.3 billion has been invested in QC startups
China will be investing > $10 billion	Hardware investments in Americas take the lion's share, with >$1.2 billion

The game-changing potential of the technology is already recognized by markets and governments.

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Critical Insights for Product Leaders on Quantum Computing

Critical Insights

- QC systems won't replace classical computing systems.
- Qubit stability and systems issues are still major obstacles in scaling these systems.
- There are no established business use cases for QC systems.

Quantum Computing

Impacts on Product Leaders

- Develop in-house expertise for quantum-classical hybrid solutions.
- Leverage QCaaS to gain early exposure to QC tech.
- Prioritize solving optimization problems with annealers to gain early experience.

Source: Gartner
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Activity Decision on Quantum Computing for Product Leaders

Start

- Developing use-case templates tied to near-term business advantage.
- Positioning your company to receive govt. funding.

Stop

- Overinvesting in hiring and building large teams.
- Developing products/services in isolation and instead leverage ecosystems.

Sustain

- Product/service development tailored for QCaaS.
- Integration of their product/services in hybrid workflow to connect QC to classical systems.

Source: Gartner
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You must prepare to integrate QC into your IT tools, both in terms of talent and infrastructure.

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Quantum Access Across Multiple Quantum Technologies

Amazon | Microsoft | Google | IBM

Quantum Software and Services

1QBit, Accenture, Booz Allen Hamilton, Capgemini, BEIT, Strangeworks, Classiq, Deloitte, Entropioca Labs, EY, ExaQ.ai, Horizon Quantum Computing, Jij, KPMG, Mphasis, HQS Quantum Simulations, Terra Quantum, Multiverse, ProteinQure, Protiviti, QCWare, JoS Quantum, Qsimulate, Qu & Co, Quanvia, Qubit Engineering, Ketita Labs, QunaSys, Odyssey Therapeutics, RiverLane, SolidStateAI, Phasecraft, StrangeWorks, Zapata Computing, Toshiba, aQuantum, Semicyber, NTT Data, Quemix, Quantum Research International, QSimulate, Solid State AI, Reply, qBraid Lab, agnostiq, A* Quantum, BosonQ PSI, Q-CTRL, Entropica Labs, Horizon Quantum Computing, Kuano, PolarisQb, Quantastica, Quantum Benchmark, QuantrilOx, Qubit Pharmaceuticals, SandboxAQ, Quantum South

Classical

Simulating Quantum Computing

- Amazon
- Atos
- Google
- IBM
- Microsoft
- NVIDIA GPU

Emulating Quantum Computing

- Fujitsu Digital Annealer
- Microsoft (FPGAs)

Quantum Annealing Systems

- D Wave
- NEC [a]
- Qilimanjaro

Quantum Systems, Software and Services

Superconducting Gate Quantum Computing

- Alibaba / CAS [a]
- Amazon [a]
- Atlantic Quantum [a]
- Dwave [a]
- Google
- IQM
- Oxford Quantum Circuits
- Qilimanjaro [a]
- Rigetti Computing
- Alice & Bob [a]
- Anyon Systems
- Baidu
- Fujitsu
- IBM
- Nord Quantique [a]
- QCI [a]
- Tsinghua University [a]
- Blexímo [a]

Trapped Ion Quantum Computing

- Alpine Quantum Technologies
- eleQtron [a]
- Infineon Technologies
- IonQ
- Oxford Ionics [a]
- Quantinuum (Honeywell CQC)
- Tsinghua University [a]
- Universal Quantum
- Baidu and CAS

Photonic Quantum Computing

- Chinese Academy of Science (CAS) (Hefei National Laboratory [HFNL]) [a]
- ORCA Computing [a]
- Photonic Inc [a]
- PsiQuantum [a]
- Quandela
- QuiX Quantum [a]
- Sparrow Quantum [a]
- Toshiba [a]
- Xanadu
- Quantum Source [a]
- TuringQ [a]

Cold / Neutral / Helium Atom

- Atom Computing [a]
- Infleqtion
- EeroQ [a]
- Pasqal (Qu&Co)
- planqc [a]
- QuEra
- Wuhan Institute of Physics and Mathematics (WIPM) of CAS [a]

Spin / Quantum Dot

- Archer Materials Limited [a]
- C12 Quantum Electronics [a]
- Diraq [a]
- Equal1 Laboratories [a]
- Infineon [a]
- Intel
- Origin Quantum Computing
- Photonic Inc [a]
- Quantum Motion Technologies [a]
- QuTech [a]
- Silicon Quantum Computing [a]

NV Diamond / NMR

- Diatope [a]
- Element Six [a]
- Nvision [a]
- Quantum Brilliance
- Quantum Diamond Tech [a]
- QuTech [a]
- SpinQ Technology
- CIQ Tek
- Tsinghua University [a]

Topological

- Microsoft [a]
- QuTech [a]

Quantum Computing as a Service (QCaaS) Capability Available

[a] Prototype/Emergent Quantum Computing Capability

Quantum Computing is a crowded market space already.

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Appendix

Quantum Computing Glossary

Qubits

Basic units of quantum information, representing more complex states than binary bits.

Coherence

The time qubits maintain their quantum states, crucial for quantum computing.

Entanglement

A quantum link between particles, where the state of one affects the other.

Superposition

A quantum state where a qubit can be in multiple states (0-1) simultaneously.

Quantum Supremacy

When a quantum computer solves a problem beyond the reach of classical computers.

Quantum-Safe Encryption

Methods resistant to quantum computer-based attack, e.g., harvest now decrypt later.

Gate Model Systems

Quantum computers using gates to manipulate qubit states, like logic operations.

Quantum Annealer Systems

A type of quantum computer for solving optimization problems, like the travelling salesman.

Digital Annealer Systems

A classical computing system designed to solve complex optimization problems rapidly.

Recommended Gartner Research

- **Emerging Tech: Research Roundup of Quantum Computing Uses and Challenges** Gaurav Gupta, Alan Priestley, Menglin Cao, Sridhar Srinivasan
- **Emerging Tech: Critical Insights on Quantum Computing** Gaurav Gupta, Alan Priestley, Menglin Cao, Sridhar Srinivasan
- **Emerging Tech: Emergence Cycle for Quantum Computing** Alan Priestley
- **Emerging Tech: Top Use Cases for Quantum Computing** Gaurav Gupta, Menglin Cao, Sridhar Srinivasan, Alan Priestley
- **Infographic: How Use Cases Are Developed and Executed on a Quantum Computer** Matthew Brisse, Taylor Satterfield, Chirag Dekate, Mark Horvath
- **Emerging Tech: How to Make Money From Quantum Computing** Gaurav Gupta, Menglin Cao, Alan Priestley, Sridhar Srinivasan

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