

# Predicts 2021: Disruptive Potential During the Next Decade of Quantum Computing

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Initiatives: [Data Center Infrastructure](#); [CIO Leadership of Innovation](#), [Disruptive Trends and Emerging Practices](#)

Transformative innovation in quantum computing has driven the development of systems and opportunities for disruptive applications. Infrastructure and operations leaders will need to devise quantum initiatives to navigate and leverage evolving quantum computing capabilities during the next decade.

## Additional Perspectives

- [Summary Translation + Localization: Predicts 2021: Disruptive Potential During the Next Decade of Quantum Computing](#)  
(03 March 2021)
- [Invest Implications: Predicts 2021: Disruptive Potential During the Next Decade of Quantum Computing](#)  
(10 December 2020)

## Overview

### Key Findings

- Devising early quantum computing initiatives will create new QC champions who understand your enterprise context, developing the skills and capabilities required to navigate a rapidly evolving quantum ecosystem.
- Improvements in qubit fidelities must happen during the next five years; otherwise, the necessary next step of scaling to hundreds of thousands, or even millions, of error-correcting qubits to deliver the first gate model systems cannot begin.
- QC is beginning to transition out of the lab and into the digital economy, bringing with it emerging players, platforms, software, services and, of course, marketing hype.
- Organizations with even modest cryptographic use are beginning to appoint lead cryptographers to oversee not just crypto-agility, replacement and policy efforts, but to explore some of the other uses of the technology.

### Recommendations

I&O leaders devising QC initiatives should:

- Start a QC feasibility and opportunity study immediately. Determine whether there are opportunities in which QC could provide a competitive advantage or change the industry before you invest heavily in time, money and resources.
- Build a cross-enterprise QC working group to federate QC initiatives with cross-enterprise representation from the CTO, the CIO and core business functions.
- Select QC systems that optimally match the core set of applications relevant to their business context. Near-term opportunities comprise kernels, such as quantum optimization.
- Form a proof-of-concept budget and team for exploring new uses of postqualified experience technology.

## Strategic Planning Assumption(s)

By 2023, 50% of organizations with crypto-agility projects will create pilot programs to harvest business value from quantum-safe cryptography.

By 2025, nearly 40% of large enterprises will devise quantum initiatives to build management skills ahead of quantum computing (QC) opportunities.

By 2025, 25% of large enterprises will deliver evolutionary advantage over (non-quantum-enabled) peers through quantum-inspired initiatives.

By 2027, quantum annealers will become viable for 20% of optimization problems, driven by qubit technology advances foundational to enabling gate-model systems.

## Analysis

### What You Need to Know

QC continues to be more than a decade away (see [Quantum Computing Planning for Technology General Managers](#) and [Strategy Guide to Navigating The Quantum Computing Hype](#)). The potential business advantage of intermediate quantum technologies and quantum-inspired technologies is driving near-term investment and innovation in QC. As an indicator, Gartner inquiries on the topic of QC have increased by 28% since last year, (despite COVID-19) as infrastructure and operations (I&O) leaders develop strategies to navigate the hype around QC.

**Leverage near-term noisy intermediate scale quantum (NISQ) systems to develop skills and competency in your organizations, not for developing business outcomes. Delay major investments until you are able to validate the realistic potential for ROI for your enterprise context.**

The commercialization and success of NISQ system applications during the next five years is critical to continued adoption and long-term funding. Failure to provide quantum or quantum-simulated use cases that achieve business value, using shallow circuits, with demonstrable and repeatable results could lead to a quantum winter, in which investors stop investing until business value can be achieved. Expect to see an increasing number of use cases, as vendors position themselves for market leadership (see Figure 1). Review these use cases with a fair amount of skepticism. Determine whether the use case provides business value over classical methods and approaches.

Figure 1: Quantum Technologies and Providers

## Quantum Technologies and Providers

■ Quantum as a Service (QaaS) Capability Available

Classical Systems		Quantum Systems							
Simulated Quantum Computing	Current			Emerging			Software and Consultants		
	Quantum Annealing Systems	Superconducting Gate Quantum Computing	Trapped Ion Quantum Computing	Photonic	Neutral Atom	Topological			
	IBM	D-Wave Systems	IBM	Honeywell	NTT	PASQAL		Microsoft	CQC
	Amazon		Rigetti	IonQ	Shanghai Jiao Tong University	Wuhan Institute of Physics and Chinese Academy of Science			1QBit
	Microsoft		Quantum Circuits Inc	Zurich Instruments	Xanadu				Q-CTRL
	Atos		Google	Harris Corp.	University of Science and Technology China	Atom Computing			Zapata Computing
	Quantum Inspired Computing		Alibaba, Chinese Academy of Sciences	Alpine Quantum Technologies					QC Ware
	Fujitsu Digital Annealer								Strangeworks
	Microsoft		Intel						Entropica Labs

Source: Gartner  
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QC ecosystems are developing well-ahead of quantum hardware. Algorithms and development environments are proliferating, creating the necessary software underpinnings and staff skills to leverage the hardware as it emerges.

QC is not a replacement for classical computing, and most known problems don't need quantum capabilities. For the set of problems in which QC is relevant, it can deliver a disruptive advantage.

New developments in QC are transforming the way I&O leaders can optimize their value streams to deliver value for near-term NISQ systems faster and more reliably. Five developments that affect your strategies include:

- **Evolution of noisy intermediate scale quantum systems:** Diverse vendors, with new approaches (photonic, superconducting gate, trapped ion and beyond) creating new opportunities.
- **Maturation of software development environments:** Stabilization of software development kits (SDKs), programming interfaces and integration with QC systems vendors enabling development of midterm enterprise roadmaps.
- **Standardization of delivery models:** Quantum computing as a service (QCaaS) is emerging as a standard delivery model across core QC systems vendors. Although traditional cloud service providers (CSPs) are attempting to create implementation-agnostic models, some end users might find deficiencies in capabilities.
- **QC hubs, peer networks and consulting solutions:** QC systems vendors (DWave, IBM and beyond) have curated peer and partnership solutions enabling enterprises to partner with vendors in exploiting the latest technologies.
- **Quantum-inspired solutions:** Several vendors are offering simulated and hardware accelerated environments to implement lessons from quantum initiatives primarily in annealing, in a classical context. Fujitsu, Microsoft, NEC, ATOS and beyond are a representative set of vendors.

**Don't wait. Start your quantum initiative now, if you're looking for the ability to opportunistically derive value from QC as it evolves.**

## Strategic Planning Assumptions

**Strategic Planning Assumption:** By 2025, 25% of large enterprises will deliver evolutionary advantage over (non-quantum-enabled) peers through quantum-inspired initiatives.

*Analysis by: Chirag Dekate*

### Key Findings:

QC is not a general-purpose computing paradigm and is only applicable for a narrow (yet to be fully quantified) pool of use cases. For core use cases, where QC can be applied, it will deliver capabilities that will be intractable in a classical computing paradigm.

- Devising early QC initiatives will create new QC champions who understand your enterprise context and the capabilities needed to navigate a rapidly evolving quantum ecosystem.
- Enterprises looking for QC applications for relevant problems will need to discover new algorithmic approaches and rearchitect applications in a quantum context.
- Enterprises that invest in discovering new algorithmic approaches for a quantum context are likely to discover new, innovative and potentially disruptive ways of solving the same problems in a classical context.
- Gartner clients that have started quantum initiatives have discovered new ways to solve the same problems in a classical context, driving immediate impact to core businesses.

### Market Implications:

Quantum computing market is nascent, with limited-scale quantum annealing and NISQ superconducting gate, ion-trap and early photonic systems dominating the landscape. Most enterprises have yet to devise quantum working groups or initiatives. As a result, they are unprepared to leverage capabilities aggressively as the ecosystem matures.

Early quantum pioneers (enterprises that have devised quantum initiatives) have successfully identified business use cases relevant to QC. Traditional vendors and cloud service providers are devising stacks that enable enterprise end users to leverage quantum-inspired classical technologies in the interim, as quantum technologies mature. Some end users have posited that rethinking their core business problems in classical context has enabled the potential for immediate impact in classical ecosystems.

## Recommendations:

I&O leaders devising QC initiatives should:

- Devise effective quantum competency initiatives by creating cross-enterprise QC working groups with representation from the CTO, lines of business (LOBs) and I&O teams. Include team members who have prior quantum physics background, and increase QC awareness using tutorials and training programs.
- Select business value relevant algorithms in collaboration with strategic partnerships with vendors.
- Use peer-expert networks or consulting companies for R&D expertise and for identifying business-relevant applications, algorithm templates and solution strategies.
- Leverage quantum partners to assist in algorithmic development and quantum consulting services.

## Related Research:

- [Cool Vendors in Quantum Computing](#)
- [Strategy Guide to Navigating the Quantum Computing Hype](#)

Analysis by: *Martin Reynolds*

## Key Findings:

- Quantum annealers are akin to analog computers, almost instantaneously solving certain classes of optimization problems. These solutions take the form of likely minima or maxima in a complex portfolio. For example, picking the optimum set of 30 financial instruments from a field of 100, the optimum loading and routing order for a delivery truck, shaping a molecule to create a new pharmaceutical.
- Today's annealers rapidly solve optimization problems, as long as they fit within the bounds of the relatively poor qubits that we have today. These qubits are noisy, which limits both the size of the problem and the quality of the result.



- Most research initiatives focus on gate-model systems, akin to a programmable computer, because these systems follow procedural steps. These systems also suffer from noisy qubits, but face a greater challenge: Today's qubits are too noisy to create error-corrected systems. Practitioners cite a 10x improvement in noise as being essential to scale qubits to build a gate-model system
- We believe that this breakthrough must happen during the next five years. Otherwise, the necessary next step of scaling to hundreds of thousands, or even millions, of error-correcting qubits to deliver the first gate model systems cannot start.
- Once this breakthrough occurs, the materials and processes will also improve quantum annealers to the point at which they will become competitive against traditional optimization systems.

## Market Implications:

Quantum annealers are relatively easy to understand and implement in an optimization problem. However, current systems struggle to deliver a business advantage, because they cannot handle the scale of many business problems. Although extremely fast on problems within their scope, their exponential slowdown drives them to impracticality for larger problems. When 10x better qubits arrive, we believe that — because both resolution and scale of an entangled group will grow — quantum annealers will beat any conventional solution. Therefore, quantum annealing will become a key tool for any organization facing complex optimization problems.

## Recommendations:

As with all quantum solutions, early identification of opportunities and building some quantum expertise well ahead of time is critical. I&O leaders devising QC initiatives should start today by:

- Identifying high-value optimization problems in their organizations
- Determining whether quantum optimization will confer a business advantage
- Conducting exploratory projects that improve the understanding of quantum annealing and computing solutions

## Related Research:

- [Strategy Guide to Navigating the Quantum Computing Hype](#)
- [Quantum Computing Planning for Technology General Managers](#)
- [Better Safe Than Sorry: Preparing for Crypto-Agility](#)

Analysis by: *Matthew Brisse*

## Key Findings:

- QC is beginning to transition out of the lab and into the digital economy, bringing with it emerging players, platforms, software, services and, of course, marketing hype.
- Sixty-four percent of large enterprise organizations do not believe they have the skills necessary to implement and deliver business results from quantum computing. Only 6% of organizations feel that they have the good to excellent skills necessary to implement and deliver a quantum solution.
- There is a ground swell of technical professionals deciding to learn QC through community networks, free access to quantum systems, training and virtual events.
- The first quantum use cases are starting to emerge with much fanfare, but with yet-to-be-determined business value over classical approaches.

## Market Implications:

QC has the potential to be very disruptive, with the potential for high rewards that are unlikely in a three- to five-year time horizon. Enterprises face a stark choice: Wait for QC to mature or start quantum initiatives today. For some organizations waiting or ignoring QC might place intellectual property (IP) and patent portfolios at risk. Early adopters of QC will have the competitive advantage by patenting quantum and quantum-inspired innovations within their specific domains.

The real race for quantum supremacy is for the quantum developer. Vendors are increasing their investments in quantum development and support ecosystems to attract talent and showcase their capabilities. A number of organizations have shared with Gartner that it will be easier for quantum physicists to learn their businesses, than for someone from inside to learn quantum physics. Although that may be true today, it won't always be the case. Quantum software development platforms and SDK environments are rapidly evolving. Many QC providers offer free access to systems often complemented with rich quantum libraries and developer ecosystems. Consulting services in QC often provide vendor-agnostic development environments and vertically aligned partnerships.

Enterprises seeking to hire quantum experts from academia will find more relatively inexpensive talent today than five to 10 years from now when they will be in greater demand. This pattern follows along the same path that artificial intelligence (AI) did five to 10 years ago.

Organizations should view QC as a critical capability that is maturing at a rapid pace, much as AI did five to 10 years ago, perhaps even as long as 15 years ago. Finding the right tool for the job not only means developing the best quantum or quantum-simulated algorithm for your problem, but mapping that problem/algorithm on the best quantum system available in the market, which provides the fastest and most accurate, repeated results.

## **Recommendations:**

I&O leaders devising QC initiatives should:

- Resist the urge to become enamored with QC. Think of QC much as you would AI or machine learning (ML) three to five years ago. For most organizations, QC should be thought of as a tool to bring competitive value to the organization.
- Start a QC feasibility and opportunity study today. Determine whether there are opportunities in which QC could provide you with a competitive advantage or change your industry before you invest heavily in time, money and resources.
- Build a quantum strategy that is heavy on quantum education, training, development and process platform selection, domain specific algorithmic development, classical-quantum hybrid architectural designs and application development.
- Build a quantum working group or a center of excellence to identify candidate problems suitable for QC. The team must include CTO business leaders and experts with QC/quantum physics backgrounds from inside your company.

## Related Research:

- [Strategy Guide to Navigating the Quantum Computing Hype](#)
- [Quantum Computing Planning for Technology General Managers](#)
- [Better Safe Than Sorry: Preparing for Crypto-Agility](#)

**Analysis by:** *Mark Horvath*

## Key Findings:

With the upcoming migration of many cryptographic and digital signature algorithms to quantum-safe replacements, there is an opportunity to replace existing crypto, and to significantly upgrade its business utility. Many post-quantum systems have properties beyond just encryption, some of which represent new business and data analytics opportunities.

- The NIST Post-Quantum Algorithm Contest is entering the final rounds, and it's clear from the shortlist of candidates that most of them have utility beyond just drop-in replacement for RSA or ECC.
- Organizations with even modest cryptographic use are beginning to appoint lead cryptographers to oversee not just crypto-agility, replacement and policy efforts, but to explore some of the other uses of the technology.
- Gartner inquiry on homomorphic algorithms (lattice) as a multiparty computing technology has increased 40% during the past two years, showing significant interest in commercial applications.
- Verticals such as financial services and healthcare have a need for crypto-agility programs and data and operational models that make post quantum encryption (PQE) an attractive upgrade path. Companies such as Duality, Inpher, Enveil and IBM have found clients for their PQE-based products in scenarios ranging from confidential computing and differential privacy to IP protection.

## Market Implications:

Quantum-safe algorithms are useful replacements for existing RSA, Elliptic Curve and other asymmetric algorithms, and are starting to appear in production-ready products. New quantum-safe digital signature algorithms such as Falcon have properties that make them useful in a variety of financial services, blockchain and micropayments schemes. Although led by crypto-agility efforts, many organizations (e.g., ISARA and IBM) are also doing significant work beyond just cataloging and replacement planning.

## Recommendations:

I&O leaders devising QC initiatives should:

- Appoint a qualified lead for crypto-agility efforts. This person should eventually be responsible for cryptographic policy and be familiar with quantum-safe alternatives.
- Form a proof-of-concept budget and team for exploring new uses of post-quantum-encryption technology.
- Experiment with real-world business use cases, e.g., MultiParty Computing
- Set realistic business goals. While CA is a necessary precaution over the next few years, the impact to the business, both negative and positive, should be monitored.

## Related Research:

- [Better Safe Than Sorry: Preparing for Crypto-Agility](#)
- [Venture Capital Growth Insights: Post-Quantum Cryptography](#)
- [Emerging Technology Analysis: Act Now on Quantum-Safe Encryption or Risk Losing Deals](#)

## A Look Back

*In response to your requests, we are taking a look back at some key predictions from previous years. We have intentionally selected predictions from opposite ends of the scale – one where we were wholly or largely on target, as well as one we missed.*

This topic area is too new to have on-target or missed predictions.

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## Recommended by the Authors

Some documents may not be available as part of your current Gartner subscription.

[Cool Vendors in Quantum Computing](#)

[Strategy Guide to Navigating the Quantum Computing Hype](#)

[Quantum Computing Planning for Technology General Managers](#)

[Better Safe Than Sorry: Preparing for Crypto-Agility](#)

[2020 Strategic Roadmap for Compute Infrastructure](#)

[Venture Capital Growth Insights: Post-Quantum Cryptography](#)

[Emerging Technology Analysis: Act Now on Quantum-Safe Encryption or Risk Losing Deals](#)

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