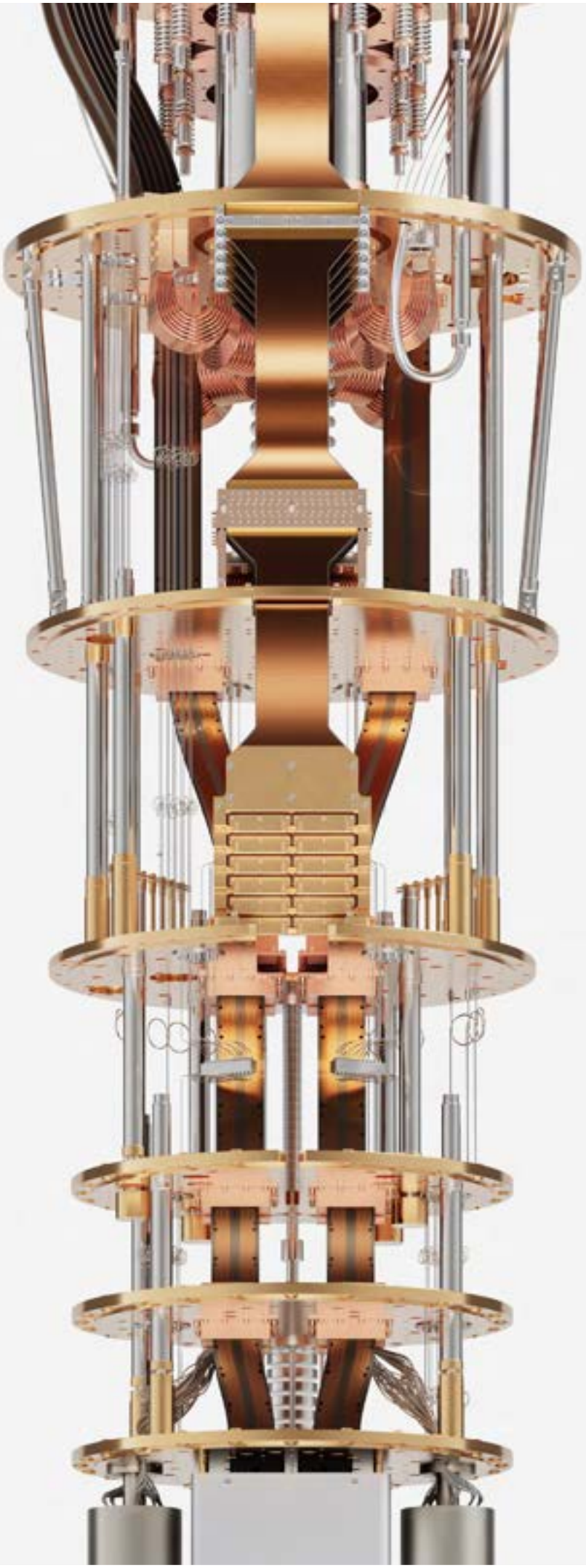
IBM **Institute for Business Value**

Journey to quantum advantage

Voices from the frontlines



IBM

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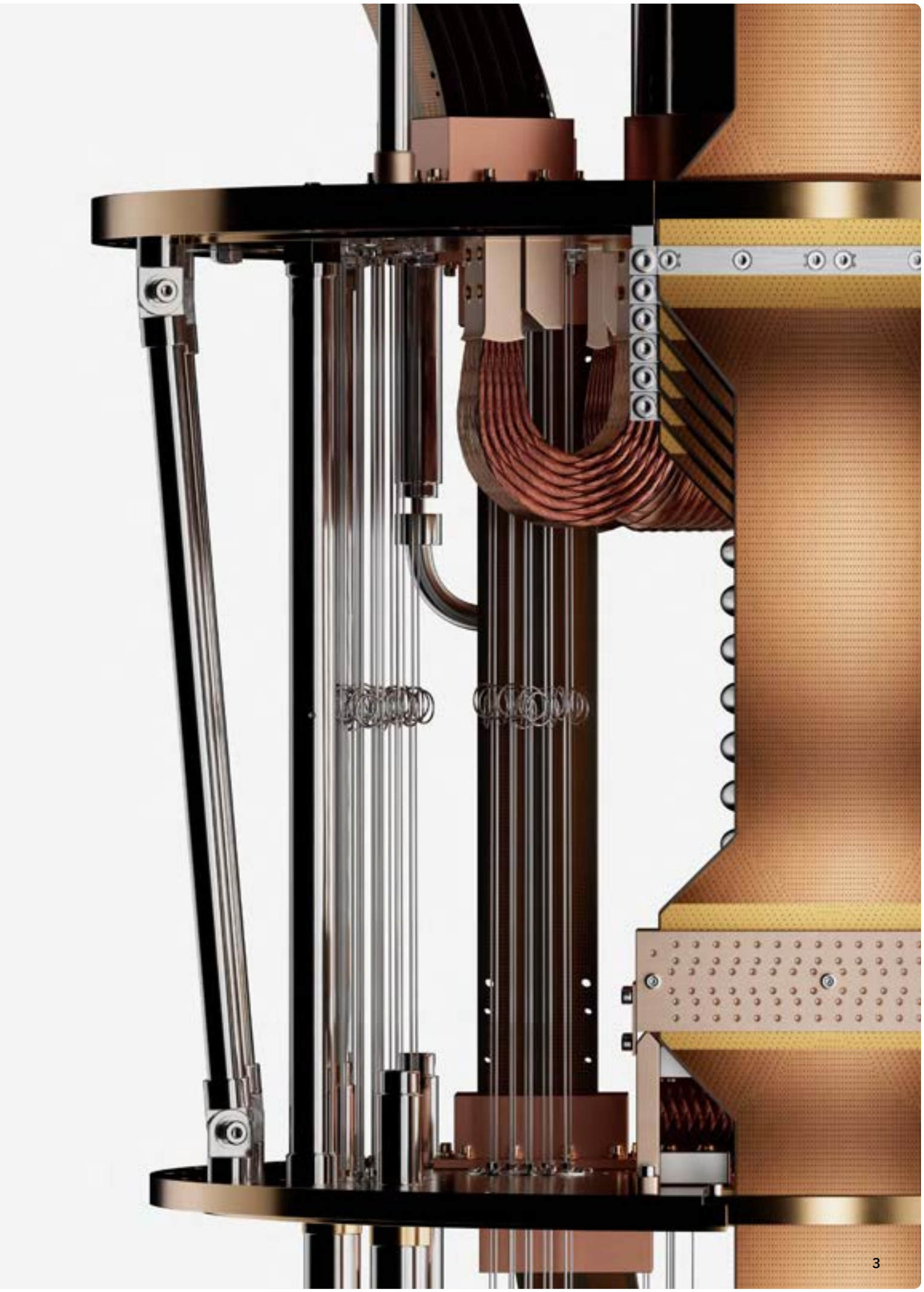


Leading the way

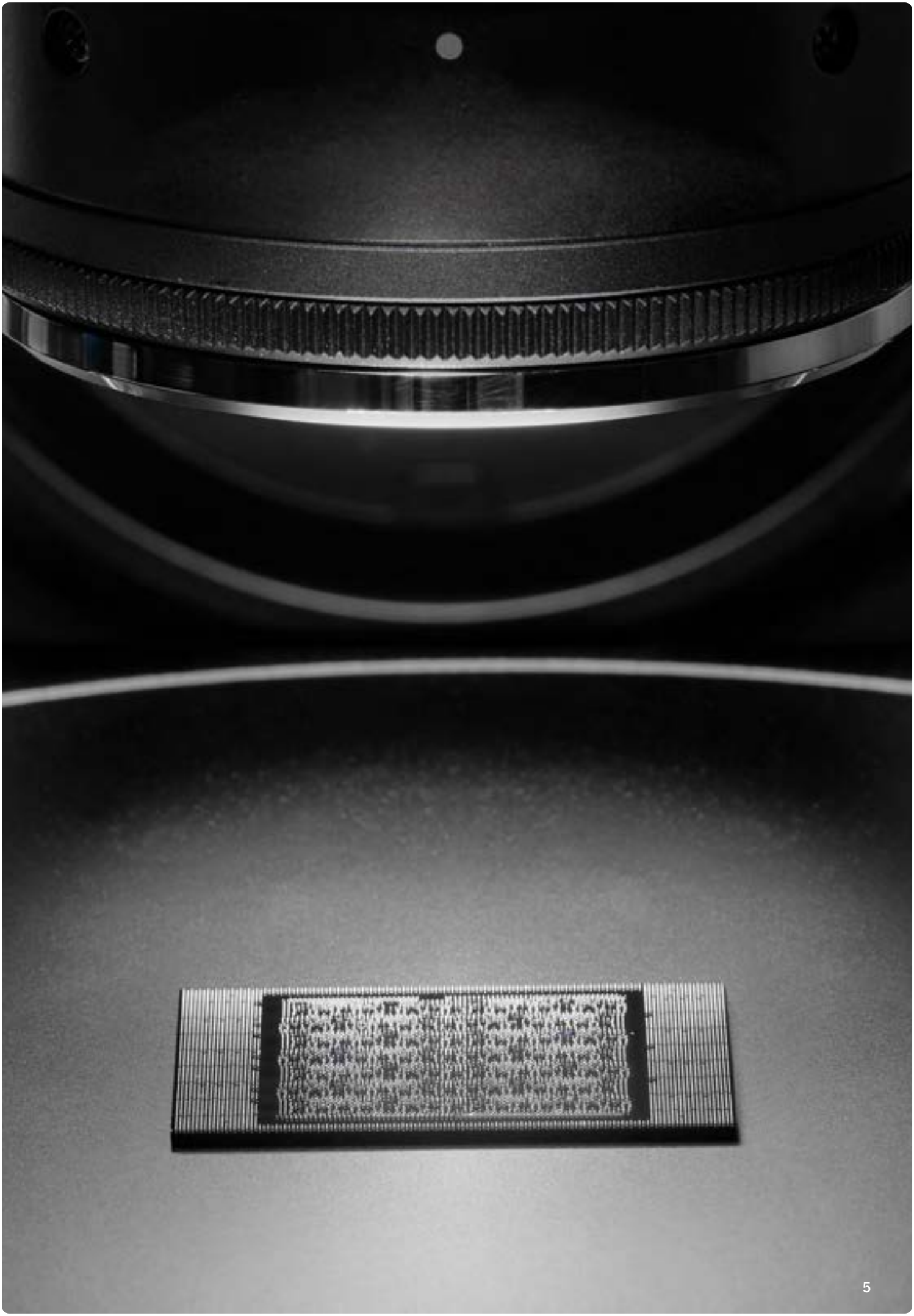
Quantum computing stands at a pivotal moment. The science has moved decisively beyond theory: organizations are far along the path to quantum advantage, when quantum computers can run a computation more accurately, cheaply, or efficiently than any classical method.

Journey to Quantum Advantage captures the momentum steadily building around the world. Based on interviews with leaders from across industries—aerospace, finance, life sciences, energy, government, education, and more—it collects real-world stories underscoring quantum's wide-ranging potential.

Complementing the IBM Institute for Business Value (IBM IBV)'s ongoing research on quantum readiness[1], this report celebrates the innovators and risk takers—those who seized frontier opportunities and are now advancing out front. Spurred by curiosity and visions of new capabilities, these leaders have overcome emergent complexities involving algorithms, hardware, and talent.

The organizations featured in this report didn't avoid obstacles; their leaders adapted to them. They shifted from isolated experiments to place strategic bets. They refined the meaning of quantum advantage. Convinced that partnerships power innovation, these organizations invested in ecosystems connecting industry, government, university researchers, and other stakeholders. Many of these ecosystems didn't exist a few years ago—a measure of growing maturity in the quantum space.

Taken together, these journeys illustrate what quantum readiness looks like. IBM IBV research finds quantum-ready organizations stand out not only for their technology. They seek accelerated innovation, solve intractable business problems, and future-proof their computing strategy. While the exact moment of quantum advantage will vary by use case and industry, these organizations all share something crucial in common: leaders who are building the future right now.



Origins



01



Every quantum journey begins with a realization: the moment when leaders recognize that the technology is not a scientific curiosity but a powerful opportunity. Despite uncertainty, organizations have pushed forward in pursuit of quantum advantage. In this section, we hear from leaders in different fields (aerospace, genomics, material sciences and financial services) with different views on advantage. The common thread: conviction. These leaders committed to quantum readiness before the path was clear.

Why quantum computing?

The top three reasons organizations invest[1]:

60% Solving intractable business problems

55% Future-proofing computing strategy

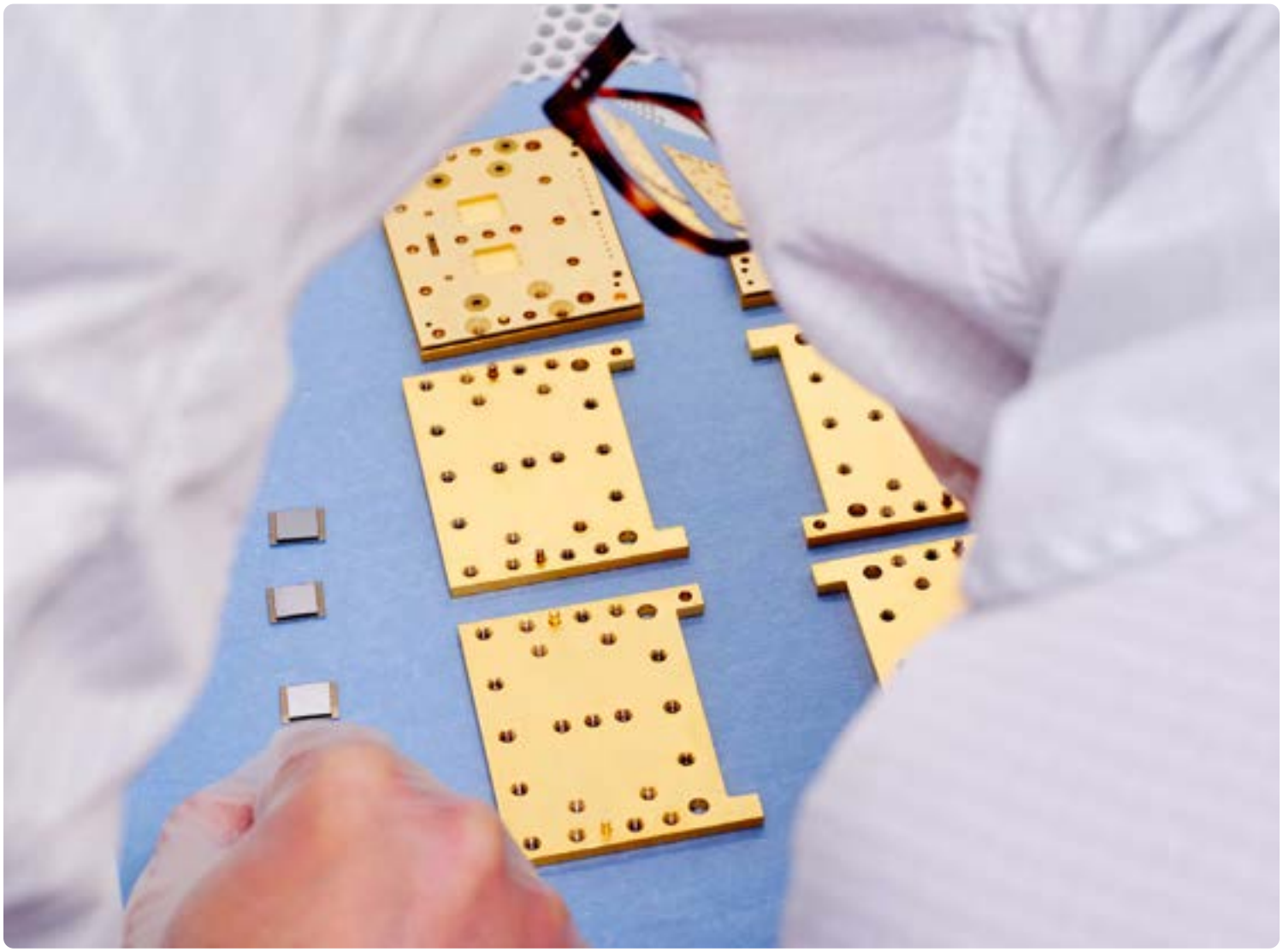
54% Accelerating innovation



Boeing

Ready for quantum take-off

Year quantum journey began	Industry
2020	Aerospace
Use case	
Materials chemistry	



In the aerospace industry, every design decision, every materials choice, every structural calculation carries weight. The industry may be the world's most regulated, safety-conscious sector. This focus has led Boeing down the path of modeling physical reality through advanced computation. Sharpening this capability sparked Boeing's interest in quantum computing.

From the outset, Boeing's quantum strategy has been shaped by a simple question: Should a particular computation be done differently than it is today? Finding the answer requires three things, says Dr. Jay Lowell, Principal Senior Technical Fellow at Boeing. First, knowing how quantum can be used. Second, benchmarking it realistically against current methods. And last, having a credible path to implementation within Boeing's operational environment.

For Dr. Lowell, quantum advantage doesn't stem from a technological milestone. Instead, he frames it as a business decision. "The only way to talk about quantum advantage is in the context of a particular, precise definition of an application or use case," Dr. Lowell says. "It should mark a transition point to a new way of doing something because of accuracy or speed, for example."

The approach reflects Boeing's broader computing philosophy. For more than a century, the company has relied on computation to design, test, and certify complex physical systems. That history makes Boeing's technology teams acutely aware of both the power and the limitations of new computing paradigms.

Rather than betting on a single application, Boeing has adopted a portfolio approach to quantum use cases. Quantum chemistry and materials science are key areas of focus, but they are not pursued in isolation. Each use case is evaluated as part of a broader landscape of computational needs. This strategy spreads risk and ensures that the organization remains adaptable as quantum technologies evolve.

Dr. Lowell emphasizes that for Boeing, the goals are clear and ordered by priority. "There are really only three kinds of business advantage that you can have," he says. "You can save lives, you can save time, or you can save money. And the order matters."

Early signals of quantum's value for Boeing involve expanded risk management capabilities. "Being able to assess something that you haven't been able to assess before is a way to uncover risks," Dr. Lowell says. The hope is that quantum computational power can strengthen safety and design confidence.

Boeing's approach is also shaped by regulatory reality. Every computation that informs an aircraft's design must be explainable, validated, and certifiable. That fuels caution toward opaque models. "We don't do anything if we can't understand how we would validate the results," Dr. Lowell says.

He sees quantum computing becoming indispensable, albeit not overnight. The moment of quantum advantage will arrive for Boeing when its business units demand quantum enabled capabilities repeatedly, requiring specific data that supports real products. At that point, quantum computing will no longer be experimental infrastructure but an operational necessity.

Dr. Lowell's advice:

"Understand exactly how the organization could benefit from quantum capabilities, both now and in the future."

"There are really only three kinds of business advantage that you can have. You can *save lives,* you can *save time,* or you can *save money.* And the order matters."

Dr. Jay Lowell
Principal Senior Technical Fellow, Boeing

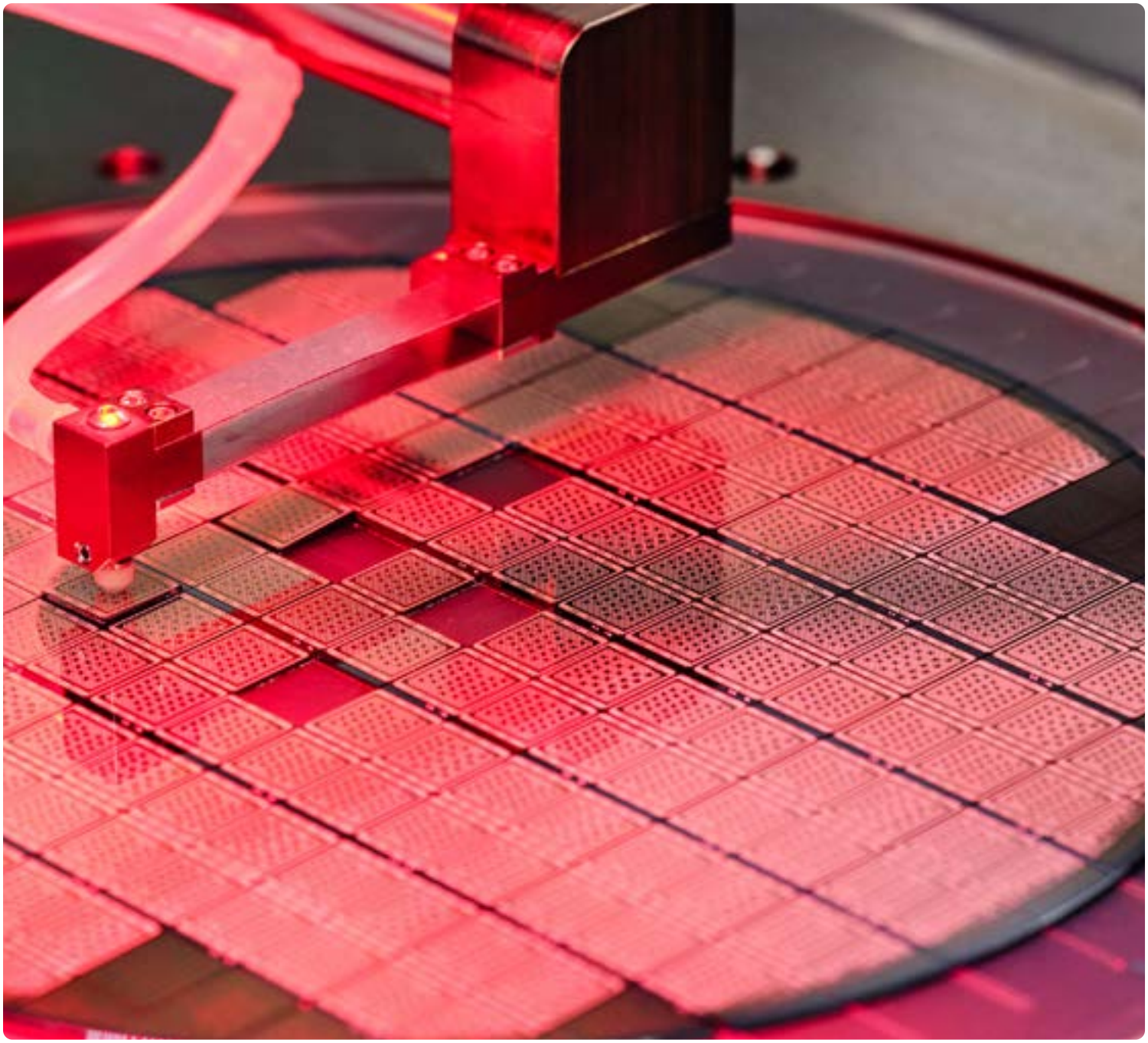


Qunova Computing

Building advantage at molecular scale

by CEO Kevin Rhee

Year quantum journey began 1997	**Industry** Chemicals, material science
Use cases Chemical and material design screening, drug discovery	



My journey into quantum computing began about 30 years ago. I first encountered the ideas behind quantum in the mid-1990s, when the field was still almost entirely theoretical. For many years, I followed its technical progress, academic debates, and the slow but steady maturation of the science. I had a strong intuition: this was not going to remain an academic curiosity forever. Quantum computing would eventually be widely commercialized.

Around 2010, I began to see signs that this technology was moving toward real-world relevance. That's when I decided to have my research group at Korea Advanced Institute of Science and Technology (KAIST) fully focus on quantum science and engineering. I had launched formal research programs there, working with students who were just beginning to explore quantum systems. I was fortunate to receive government support in 2018 to establish the AI Quantum Computing IT Research Center at KAIST.

While deeply engaged in academia, I also had my mind on the market and future applications for this technology. It became clear to me that the real opportunity would emerge when quantum computing could outperform supercomputers on meaningful industrial problems. I believed that window would open sometime between 2025 and 2028, so I founded Qunova Computing with venture backing in 2021 to ensure we'd be ready.

I started Qunova to deliver a real quantum advantage for industrial chemistry and materials science applications to bring significant positive impacts to businesses. In academia, quantum advantage is often defined as outperforming a classical algorithm in theory. In industry, the bar is much higher. A quantum solution must be more accurate, faster, or significantly better in terms of cost or energy consumption compared to other available computing options.

At Qunova, we focus on energy estimation problems in chemistry, where accuracy is everything. If a quantum or hybrid quantum classical approach can produce lower energy solutions than classical methods—or reach the same accuracy with dramatically fewer resources—that is real quantum advantage. This is not about abstract benchmarks. It's about practical, apples-to-apples comparisons.

Today Qunova's high-efficiency HI-VQE algorithm can estimate the ground state of molecular systems with quantum model accuracy in hours. Purely classical methods take days and cost thousands of dollars. And HI-VQE's accuracy scales beyond traditional approaches. The difference is transformative.

My vision for Qunova is to expand these capabilities to larger molecules, such as proteins, polymers, and DNA. The ultimate goal is to provide end-to-end quantum solutions for chemistry and drug design. We are on the right track.

I don't believe quantum will replace AI or high-performance classical computing, but it will sit above them. We'll turn to quantum to refine results, break accuracy barriers, and address the growing energy challenges posed by modern computing, unlocking a more energy-efficient path forward. For me, quantum computing has always been about one question: How can we improve upon the best tools we have today? Qunova exists to answer that question. We're almost there.

Dr. Rhee's advice:

"Innovate to break through the limits of today's supercomputing solutions."



“For me, quantum computing has always been about one question: can we do better than the best computing solutions we have today? We’re almost there.”

Dr. Kevin Rhee
CEO,
Qunova Computing

Wellcome Sanger Institute and Oxford University

Pushing genomics forward

Year quantum journey began	Industry
2023	Life sciences
Use cases	
Pangenome-guided sequence alignment, phylogeny, data encoding	

Some of the biggest challenges in genomics are computational. As the field's focus has expanded from single reference analyses toward pangenomics (population scale analyses), new computational challenges have begun to expose the limits of classical methods.

To learn whether quantum computing might offer a meaningful advantage, the Wellcome Sanger Institute and the University of Oxford launched the Quantum Pangenomics project. It was part of Quantum for Bio (Q4Bio), a global research challenge program focused on human health and funded by the non-profit Wellcome Leap.

"The goal is to understand where the boundary of classical–quantum advantage really is, and what minimum effort is required to do something genuinely novel with quantum computation," says Dr. Sergii Strelchuk, a project leader and Associate Professor of Computer Science at the University of Oxford.

Pangenomics is a very young sub-field, emerging in 2023. Unlike areas such as quantum chemistry, where decades of classical optimization dominate, pangenomics offers a rare opportunity to explore quantum approaches before a classical toolkit matures.

The Q4Bio program provided resources to pursue this opportunity. Funding coincided almost exactly with publication of the first draft human pangenome in 2023. That timing helped position the project (which the universities of Cambridge and Melbourne are also part of) at the leading edge of a new research frontier.



Quantum Pangenomics's structure embraces uncertainty by design. Early phases prioritized exploration and learning, including identifying areas where quantum approaches would not deliver near-term value. That process of elimination proved critical as the project team converged on a focused set of research directions. It began translating abstract ideas into executable circuits, simulations, and hardware optimizations.

The work paid off. In April 2026, the team announced a major milestone: the successful loading of the entire Hepatitis D viral genome onto a quantum computer (IBM's 156-qubit Heron processor).

"Encoding a whole genome onto a quantum computer is a world first and represents at least one order of magnitude improvement over any other efforts to represent DNA on quantum machines," said James McCafferty, Chief Information Officer of the Wellcome Sanger Institute.

Looking ahead, the Quantum Pangenomics team's approach to advantage will remain deliberately pragmatic, focusing on transparent, end-to-end pipelines that compare classical, quantum, and hybrid methods on real data. As Dr. Strelchuk puts it: "Institutions get value from quantum computing where you can evaluate the answers directly, not by promising better runtimes in theory."



Dr. Strelchuk's advice:

"Focus on people first. Find people with strong knowledge of mathematics, physics, and computer science, and then expose them to the quantum computing paradigm."

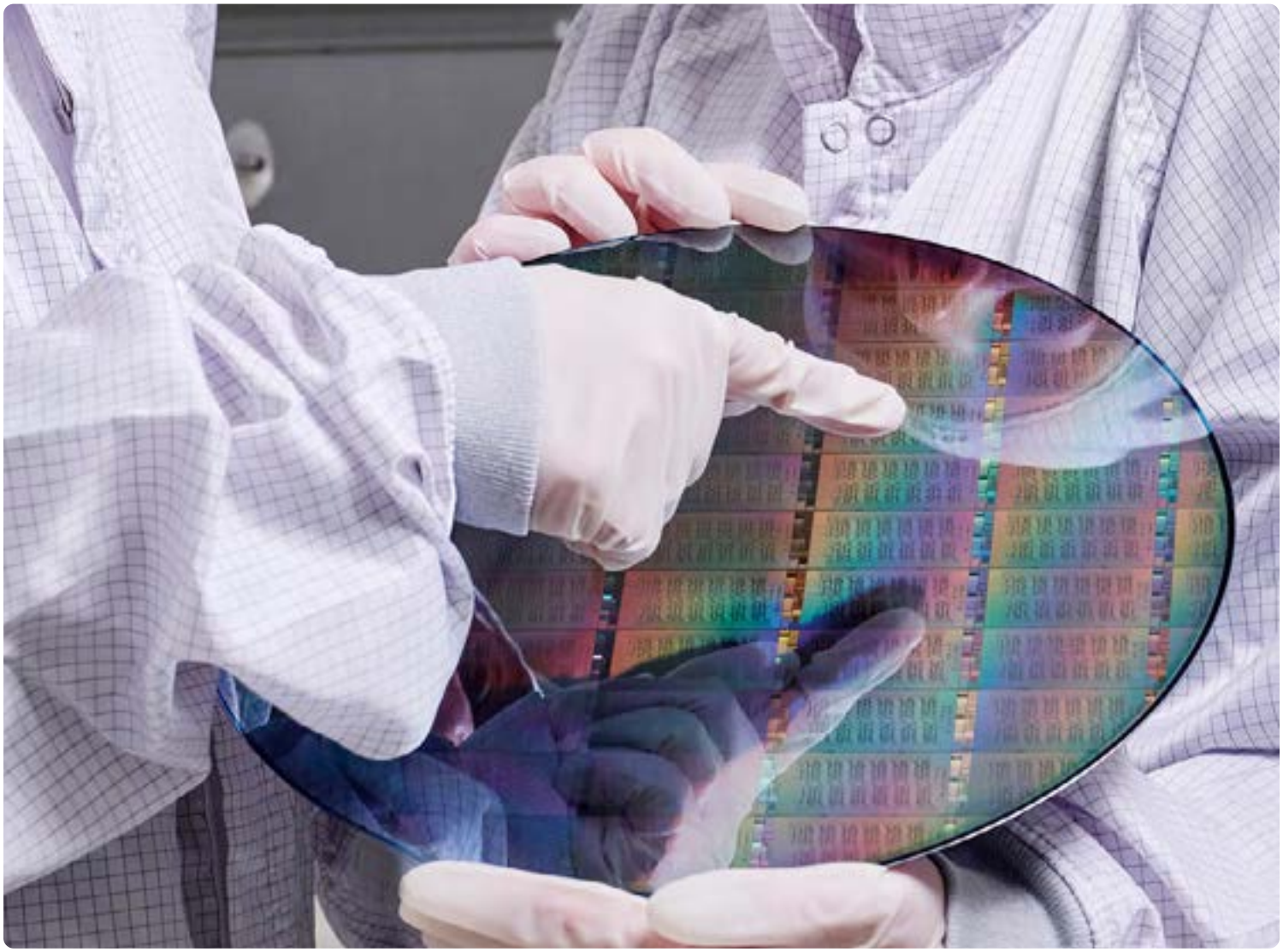
“The goal is to understand where the boundary of classical–quantum advantage really is.”

Dr. Sergii Strelchuk
Associate Professor of Computer Science,
University of Oxford

Vanguard

Investing for the long haul

Year quantum journey began	Industry
2022	Financial services
Use cases	
Portfolio optimization, risk modeling	



The finance sector has no shortage of complex mathematical problems. Bimal Mehta, who leads Vanguard's quantum computing research team as Chief Research Scientist for Emerging Technologies, shares how the investment management firm has brought practical value into focus through experimentation.

What sparked Vanguard's quantum journey?

It was the desire to stay ahead of emerging technologies that could eventually help solve problems we can't easily solve today. We wanted to understand whether quantum computing—combined with classical methods like machine learning—could help us approach very complex mathematical problems differently. Our initial intent was to understand the fundamentals. We didn't want to wait until the technology fully matures, and then try to catch up.

How did the business move into active experimentation?

After we realized we didn't have a quantum-ready workforce, we looked for industry partners to guide us. At the same time, we knew this couldn't just be a technology experiment. We needed business buy-in. So we took what we had learned about quantum—both what it could do and what it couldn't do—and brought that to the business.

We were very clear in setting expectations. This wasn't about running quantum in production today. It was about being ready if and when the technology reaches the point where it can deliver real advantage. That framing helped us secure sponsorship and funding.

Which use cases has Vanguard explored?

There have been three use cases. Anti-money laundering, where we looked at hybrid quantum-machine learning approaches to pattern detection. Another was risk modeling, particularly quantum Monte Carlo simulations.

But the most promising use case was portfolio optimization, especially in fixed income. Bond portfolio optimization is extremely complex. You have to group thousands of bonds into baskets while accounting for many constraints—yield, maturity, coupon rate, and more. Today, we use classical solvers that give near optimal solutions. Finding a truly optimal one can take an impractical amount of time.

The opportunity with quantum isn't necessarily speed, however. The real promise is narrowing the search space so you can reach a better solution within the same time window. In our experiments, even with a limited number of qubits, we were able to get very close to an ideal solution. That showed us the approach works theoretically.

What are your team's key learnings thus far?

How to map real financial problems to quantum formulations, how to define constraints, and how to run them in a hybrid environment. Just as important, we built internal knowledge and confidence. If tomorrow we had access to significantly higher qubit counts, we would know exactly how to scale what we've already done.

How does Vanguard think about quantum advantage?

For us, quantum advantage only matters if it's usable. A demonstration of advantage in physics or chemistry is impressive, but the real question is whether it helps us solve problems that matter to our clients. If advantage allows us to deliver better portfolio outcomes, better risk management, or a better client experience, then it's meaningful. Otherwise, it's just a technology milestone.

What excites you most as you look to the future?

We're seeing a genuine paradigm shift in technology. Quantum computing is becoming part of that shift, alongside AI and high performance computing.

Bimal Mehta's advice:

"Start small and get buy-in from the business by focusing on problems in your organization that cannot be solved today. And don't go it alone: identify a partner that can help you on the journey."

“If advantage allows us to deliver better portfolio outcomes... or a better client experience, then it’s meaningful. Otherwise, it’s just a technology milestone.”



Bimal Mehta
Chief Research Scientist for Emerging Technologies, Vanguard

Strategic bets



02



Quantum journeys rarely follow a straight line, but all are guided by strategy. Across industries, leaders define long-term goals and make disciplined choices to achieve them. Some organizations focus on a few high-potential use cases, while others prioritize steady progress through broader exploration. Staying the course requires flexibility. Early optimism can be tested in the face of unclear return on investment or technical challenges. But what unites all organizations moving toward quantum advantage is strategic vision: the pursuit of innovation where it matters most, and a willingness to align capabilities and teams in pursuit of solving real-world problems.

Top 3 barriers to adoption[1]

61% Inadequate quantum skills

56% Immature quantum technology

46% Unclear timelines of use cases

E.ON

Powering innovation

Year quantum journey began	Industry
2019	Energy

Use cases

Optimization, quantum machine learning, scenario modeling



When E.ON began its quantum journey, excitement was high across the company. Early proofs of concepts suggested that quantum techniques could reshape key elements of Europe's energy systems, from grid balancing to forecasting renewables.

As Dr. Giorgio Cortiana points out, however, pursuing quantum advantage is not straightforward.

"Starting the quantum journey is relatively easy given the technology's disruptive potential," says Dr. Cortiana, Head of Quantum Computing at Germany-based E.ON, one of Europe's largest energy companies. "The real difficulty is clarifying when and how quantum's benefits will be realized."

The company's initial wave of exploratory pilots confirmed the underlying promise of quantum methods but also exposed their limitations: shallow circuits, limited qubit capacity, and hardware unable to outperform well-established classical methods. While the promise was real, hardware performance was not quite there yet.

"Leading-edge innovation demands *consistency* and *endurance.* Success typically comes from long-term commitment that allows capabilities, understanding, and opportunity to mature together."



Dr. Giorgio Cortiana
Head of Quantum Computing,
E.ON

As experimentation moved toward more realistic, industrial problem formulations, the gap between available hardware and true advantage became increasingly clear. Error rates compounded. Circuit depth exceeded coherence windows and resource estimates for large-scale deployment escalated rapidly.

Business leaders understandably look for clarity on timelines and return, while technical teams operate at the frontier of what existing machines could support. The tension between research uncertainty and business expectations is not an anomaly, but a defining feature of applied research.

The resulting pressure led to a critical inflection point. E.ON recalibrated its internal roadmap to reflect the broader trajectory of quantum hardware development. With fault-tolerant quantum machines not expected before 2029, Dr. Cortiana and his team, together with E.ON's management, adjusted company expectations and reframed success accordingly. The search for near-term advantage—by means of increasingly hybrid algorithms and workflows—complemented long-term capability building.

E.ON's journey has tested assumptions. But it has also reinforced the company's conviction that quantum technologies will ultimately matter—albeit on a longer and less predictable timeline than initially hoped for.

"After the initial excitement, people start asking, 'Should we wait a couple of years?'" Dr. Cortiana says. "That hesitation is natural. But what you build early only delivers value if you continue to evolve it over time. Leading-edge innovation demands consistency and endurance. Success typically comes not from isolated ideas, but from long-term commitment that allows capabilities, understanding, and opportunity to mature together."

Dr. Cortiana's advice:

"Be clear about which part of the business quantum could provide an edge. If it's a small portion, consider concentrating on a specific use case."

Yonsei University

Accelerating medical breakthroughs

Year quantum journey began 2024	**Industry** Higher education, medicine
Use case Drug discovery	



At South Korea's Yonsei University, medical research and quantum computing go hand in hand. Dr. Jae-Ho Cheong—a professor in the school's College of Medicine and Department of Quantum Information Science, and Director of the Yonsei Quantum Initiative—explains the university's strategic bets.

Why did Yonsei decide to launch its quantum initiative?

We believe a core part of the school's mission is to address difficult problems humanity is now faced with—an energy crisis, climate change, and especially global health burdens. A few years ago, university leaders were thinking carefully about how to fulfill that mission in the coming decade. They identified quantum as a crucial future-enabling technology, because current computational capabilities are not enough.

In the medical research space, current innovation and drug discovery practices struggle with speed and complexity. Progress is too slow and development is too costly. We believe advanced technologies—both AI and quantum computing—can fundamentally accelerate progress.

How do your areas of expertise—surgery, oncology, and technology—shape your quantum work?

I developed a gene based predictive test for cancer years ago, but I realized that prediction alone is not enough. We need more efficient, more accessible cancer therapies. When you look closely, many cancer types, especially clinically intractable subtypes, trace back to how energy is handled in mitochondria—specifically, electron transfer systems. That is a fundamentally quantum mechanical process. To truly understand and simulate it, classical computers are not sufficient. Quantum computers are much more natural tools to address this problem.

Yonsei is unique in having an on-site quantum computer. How does that influence your computing strategy?

We recognize the importance of hybrid quantum-classical workflows, which are essential for solving real-world medical problems. Our Eagle system is connected to Fugaku, the supercomputer at the RIKEN Center for Computational Science in Kobe, Japan. The physical distance is 800 kilometers [497 miles] but the latency period is just 20 milliseconds.

This quantum-centric high performance computing platform has led us to valuable cross-disciplinary collaborations with RIKEN scientists—chemists and physicists who rarely engage in life sciences research collaborations. Currently, Yonsei and RIKEN researchers as a team tackle one of the most formidable challenges in quantum chemistry: determining the electronic structure of Fe-S clusters in mitochondria with unprecedented accuracy

What does quantum advantage mean to you and your team, in practical terms?

From an end user perspective, quantum advantage does not need to be dramatic to be meaningful. The drug discovery process typically takes about 15 years. If quantum computing helps us reduce that time by, say, 10% or 20%, that changes lives. But quantum computing can also enable new methods that are impossible with classical computing. For example, we could potentially see better classification of cancer patients into more homogenous clinical sub-segments for better treatment matching.

Beyond research, how is Yonsei building long term quantum capabilities?

We made two big strategic decisions to lead the field in South Korea and the Pacific region. First, we launched a graduate degree program in quantum information science. We now have 20 Ph.D. students. Second, we decided to hire more faculty members capable of doing quantum research and education.

After we purchased and began operating our quantum computer, the question naturally arose: How could we nurture the next-generation workforce? We're now answering that question in our research facilities.

Dr. Cheong's advice:

"Start by asking the right questions to clearly define the problem you intend to solve."

“The drug discovery process typically takes about 15 years. If quantum computing helps us reduce that time by, say, 10% or 20%, *that changes lives.*”



Dr. Jae-Ho Cheong
Director of the Yonsei Quantum Initiative,
Yonsei University

Bosch

Taking the harder path

Year quantum journey began	Industry
2017	Automotive

Use cases

Materials simulation for e-drives, fuel cells, electrolyzers, and advanced sensors



Global engineering and technology company Bosch has had more success than most in hitting quantum computing milestones. The company successfully developed quantum algorithms and established a materials simulation workflow that, at the time, utilized the largest number of qubits applied to a real-world solid-state materials problem.

“At the beginning of our journey, we achieved significant progress,” says Dr. Thomas Eckl, Chief Expert at Bosch. He points to demonstrations on early, noisy quantum devices as a major technical milestone.

That momentum, however, met a familiar industry-wide obstacle: scaling. As Bosch attempted to move from proof of concept to larger, more realistic problem sizes, the limitations hit. Noise levels remained too high and qubit connectivity too limited. Results increasingly fell short of expectations.

This set the stage for a choice. Bosch could continue pushing the early, noisy applications it had success with, or pivot to preparing for a fault tolerant future without having hardware available today. The company chose the harder path: moving beyond early wins toward a new roadmap. Its quantum program is now centered on developing robust scalable algorithms for the fault-tolerant regime, with a focus on resource estimation, workflow integration, and understanding algorithmic performance on real quantum hardware.

The adjustment has been more than technical. Internally, Bosch has had to manage expectations and sustain long term commitment amid rising economic pressures and scrutiny of quantum investments. “We began with enthusiasm and a broad vision,” Dr. Eckl says. “Now the focus has shifted to measurable outcomes: where will quantum deliver real value, and when will the ROI materialize?”

To sustain momentum, Bosch has increasingly focused on use cases with shorter feedback cycles and clearer near-term impact. While materials simulation remains a central long-term strategic investment, the company has broadened its efforts toward engineering applications such as optimization and partial differential equation solvers, where advances could accelerate design iterations and deliver business value faster. Demonstrating measurable progress on real-world problems step by step, Dr. Eckl argues, is critical for maintaining organizational engagement and long-term readiness.

“If we can demonstrate usefulness for relevant applications,” he says, “that builds confidence that quantum will ultimately solve problems we can’t address today.”



Dr. Eckl’s advice:

“Identify the computational bottlenecks limiting your organization’s ability to solve critical problems. Then evaluate whether existing or emerging quantum algorithms could overcome those limitations.”

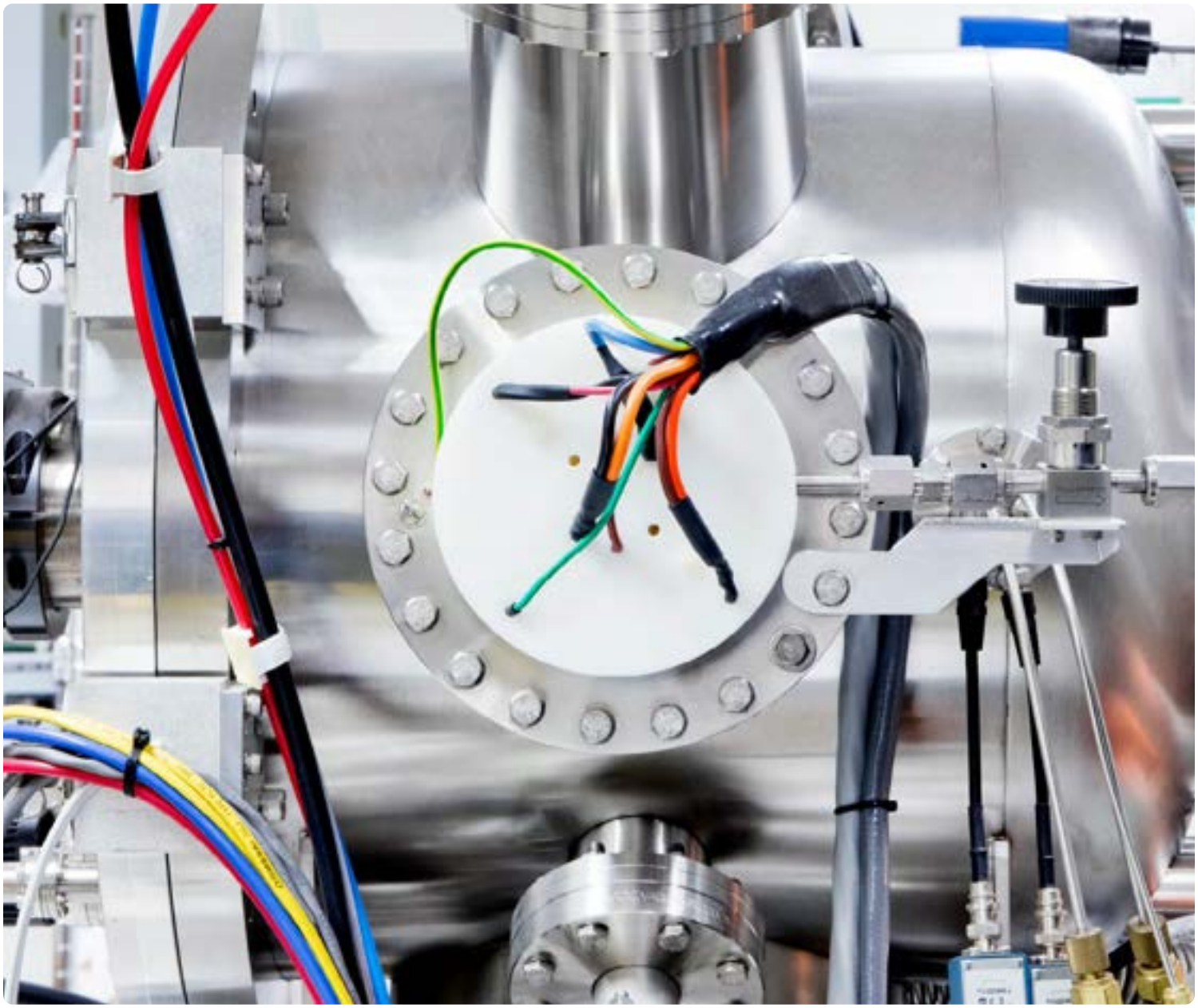
“We began with enthusiasm and a broad vision. Now the focus has shifted to measurable outcomes: where will quantum deliver real value, and when will the ROI materialize?”

Dr. Thomas Eckl
Chief Expert,
Bosch

Chicago State University

Closing skills gaps

Year quantum journey began	Industry
2018	Higher education



Chicago State University (CSU) views quantum as both a platform for innovation and an engine of workforce development. As the city's growing quantum ecosystem—which encompasses research universities, national labs, industry partners, Chicago Public Schools and others—gains steam, CSU President Zaldwaynaka "Z" Scott explains how her school is creating accessible pathways from classrooms to careers.

How did Chicago State University become a force in the city's quantum ecosystem?

For nearly a decade, our scientists have been exploring quantum and how it integrates with other research areas. As the state of Illinois began to build a stronger tech ecosystem—especially around quantum and microelectronics—we saw a clear alignment with Chicago State's interests and mission. What really sharpened the strategy was recognizing the need for skilled workers in this emerging field. We started to look at how CSU could be a catalyst for inclusive innovation, given our location less than five miles from the planned Illinois Quantum Microelectronics Park (IQMP) on Chicago's South Side and our status as the only federally designated four-year Predominantly Black Institution in Illinois.

How does CSU's quantum strategy support skills development?

Our goal isn't just to do advanced science. It's to make sure communities understand the opportunity and are able to participate in it.

"When you coordinate intentionally—across institutions, sectors, and neighborhoods—*you can grow both science and communities together.*"



President Zaldwaynaka Scott
President,
Chicago State University

Closing skills gaps requires intentional planning from the start. That means designing educational pathways that span elementary through high school, certificates, undergraduate study and master's degree programs, and research experiences. We're looking at it all as a way for us to engage.

What does that approach look like in practice?

We've partnered with the University of Chicago on quantum summer camps for high school students. We've brought Chicago Public Schools science teachers to our campus to give them training, tools, and materials to teach quantum concepts in their high-school classrooms. We offer entry-level microelectronics courses on our campus with the goal of preparing students for entry level jobs and real economic opportunity. That's just a few examples.

How is CSU balancing near term job readiness with long term quantum futures?

We've been very proactive. We are the first in Illinois to offer Illinois Board of Higher Education-certified quantum minor and quantum certificate programs so students can supplement their majors with relevant skills. We already have hundreds of students interested, and our first certificate graduates are entering the workforce now and making an impact. For instance, one graduate will begin a joint research project with Harvard and another will begin a research position at Pfizer. There is of course no way to offer students complete knowledge in such a fast-changing space. We try to give students a strong foundation to take into jobs, where they can continue to grow and keep up depending on the field they enter.

How is the university supporting longer-term research and collaborations that push quantum forward?

We established the CSU Quantum Education, Science & Technology Center so this work has a permanent institutional home. We've built a cross disciplinary team at the center, because we know quantum won't live only in STEM, it will touch many disciplines. We hope this center helps to grow our collaborative relationship with Argonne National Laboratory. We're also a major educational partner in IQMP, a 128-acre research hub that will bring national labs, universities, government, and businesses together.

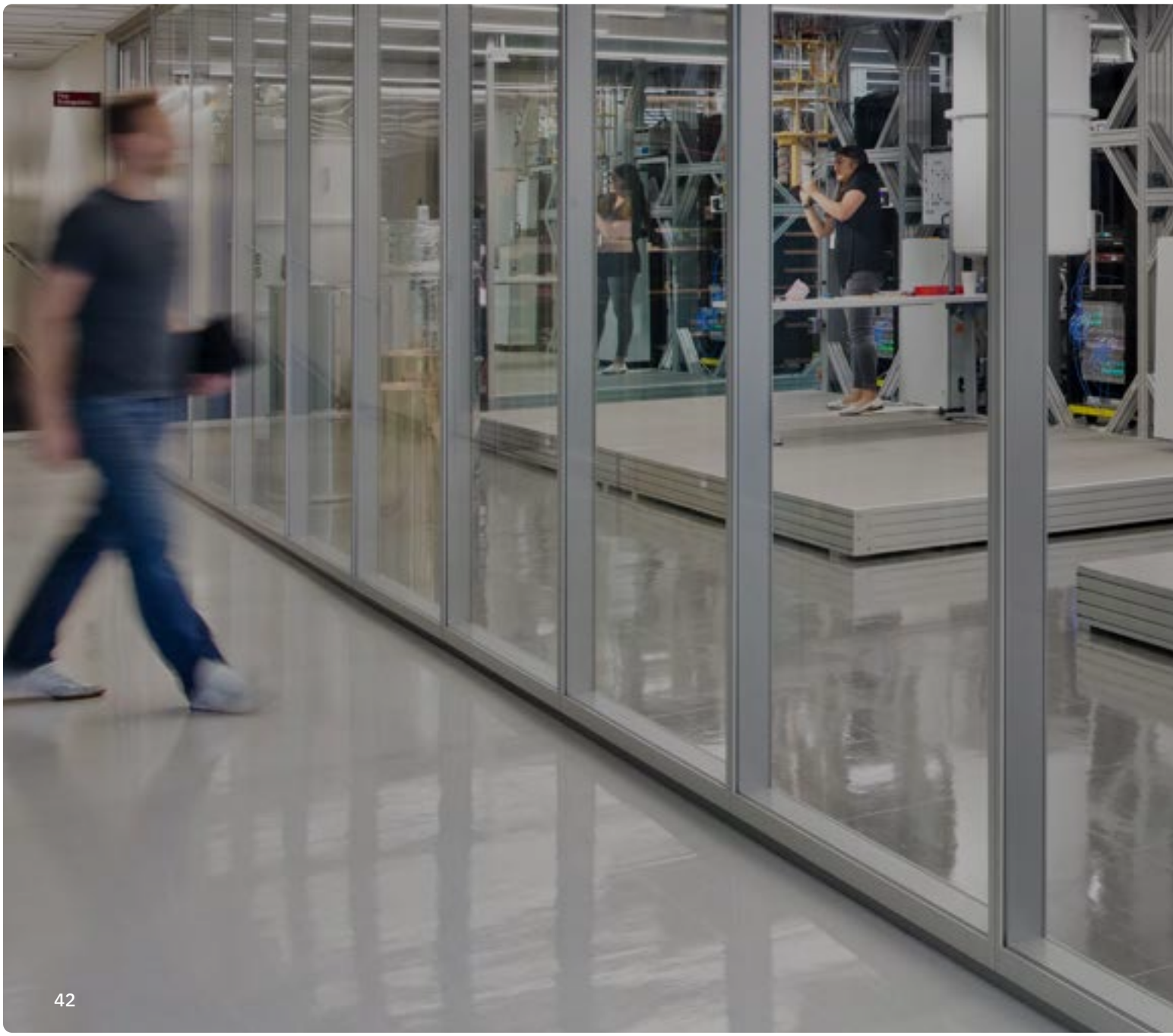
What does success look like 10 years from now?

Success is graduating students with quantum credentials that prepare them to work in that space. It's having upgraded laboratories where students are learning alongside experienced researchers to get the campus experience they deserve. It's seeing community members confident they aren't locked out of opportunity. And it's proving that when you coordinate intentionally—across institutions, sectors, and neighborhoods—you can grow both science and communities together.

President Scott's advice:

"Be intentional about who should be at the table. Make sure that your invitation list has a broad section of the community present."

Ecosystems in action



03



Quantum progress depends on ecosystems: networks that connect industry, government, academia, hardware providers, and research institutions. In this section we hear from leaders building partnerships that foster collaboration and innovation. Their stories illustrate that quantum readiness grows where ecosystems flourish and resources align.

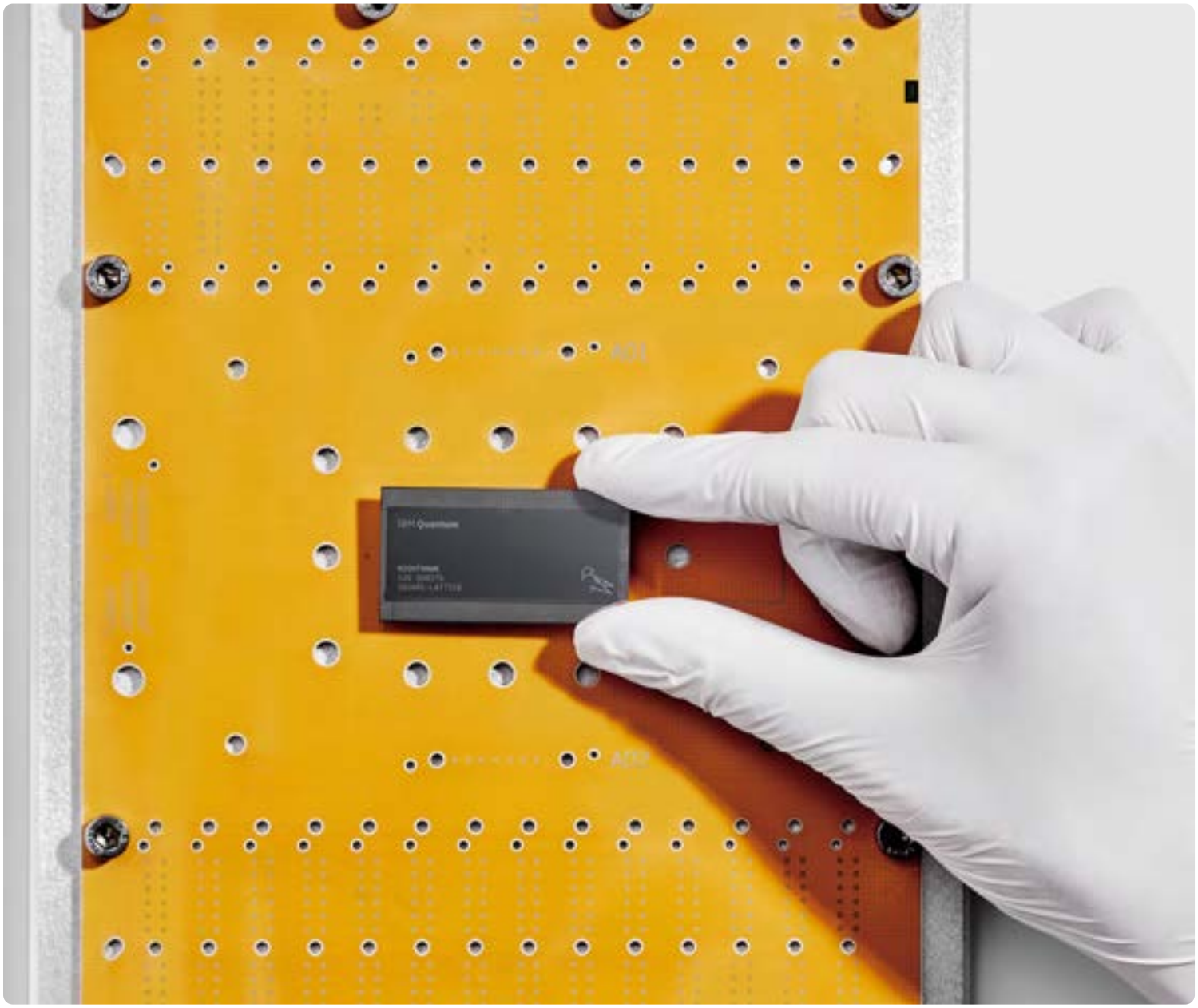
1 in 2

quantum-ready organizations participate in one or more ecosystems.[1]

Volkswagen

Driving toward readiness

Year quantum journey began	Industry
2023	Automotive
Use case	
Materials exploration	



An ecosystem mindset is deeply embedded in how Volkswagen approaches innovation. The company's innovation organization has a global footprint: digital and AI in California, a vibrant startup network in Israel, rapid experimentation in China, and the full group ecosystem in its German headquarters.

For Dr. Nikolai Ardey, Executive Director of Volkswagen Group Innovation, the path toward quantum advantage depends on companies, researchers, startups, and technology partners learning and advancing together. "No single company has all the answers," Dr. Ardey says.

"Partnerships are how we explore use cases, build capability, and prepare the organization for what comes next."

Volkswagen's quantum team focuses on areas where quantum methods could eventually outperform classical computing—material science, optimization, traffic simulation, fluid dynamics—targeting hybrid quantum-classical architectures. Exchanges with quantum platform providers help Volkswagen build skills, test assumptions, and ground its roadmap in real system capabilities. The company also maintains strong ties with universities and research institutes.

“No single company has all the answers yet. Partnerships are how we explore use cases, build capability, and prepare the organization for what comes next.”

Dr. Nikolai Ardey
Executive Director,
Volkswagen Group Innovation



“Academic collaboration is a key part of making quantum mature,” Dr. Ardey says. “Universities and research institutes help advance the fundamentals, while industry brings real problems that push the technology toward practical relevance. So we maintain our academic network, while also investing in and collaborating with startups.”

Volkswagen also participates in forums where automotive leaders align on shared challenges and coordinate on quantum topics. “Even among competitors, there are pre-competitive topics where collaboration makes sense and accelerates overall readiness,” Dr. Ardey says.

Ultimately, Volkswagen views quantum computing as a long-term capability that must be nurtured. Building internal expertise, shaping realistic expectations, and preparing the organization all require sustained engagement with external partners. Those who invest early in ecosystems—across technology, academia, industry, and government—will be best positioned to capture new value.

“Readiness comes from collaboration,” Dr. Ardey says. “We’re learning with others who are on the same journey.”

Dr. Ardey’s advice:

“Ensure your organization builds or accesses the specialized expertise needed for early quantum projects, while planning for broader adoption as the technology becomes more accessible.”

Basque Quantum (BasQ)

Forging long-term impact

Year quantum journey began	Industry
2016	Government
Use cases	
Financial services optimization, biomedical	



The Basque Country may be one of Spain's smaller regions, but its quantum profile looms large. Over the last 10 years, the Basque Government has built a cross-sector ecosystem with the goal of positioning the autonomous region as a global quantum player. Basque Country Vice-Minister of Science and Innovation Dr. Adolfo Morais and Basque Quantum (BasQ) Scientific Director Dr. Francisco Javier Aizpurua explain why and how.

How did the Basque Country land on quantum computing as a strategic priority?

Vice-Minister Adolfo Morais: The Basque Country is small in size and population, a reality that forces strategic choices. Around 10 years ago, the government launched a long term flagship research and impact program designed to identify areas that would truly matter for the future of the region. Quantum science and technology was one of those areas, and our interest in it evolved into a strategic initiative for quantum, called BasQ. The ambition was to concentrate resources, talent, and policy, and link them to impact. We also wanted autonomy: access to advanced technology, the ability to develop our own workforce, and a mature ecosystem rather than isolated projects.

Once the government made the deliberate decision to explore the impacts of quantum science on industry and society, quantum computing emerged as a capability with the potential to transform multiple sectors.

Dr. Javier Aizpurua: And there was an important parallel evolution. On one hand, policymakers began supporting a focused strategy around quantum technologies. On the other hand, researchers and technologists deepened their work aligned to that vision.

Which sectors and organizations are part of the BasQ ecosystem?

Dr. Aizpurua: It's a collaborative ecosystem that includes universities, public research centers, applied mathematics institutes, startups, established industrial companies, and public sector organizations. We see strong engagement from sectors such as banking, advanced manufacturing, energy, and biomedical research. The key has been alignment: administration, science, and industry moving together rather than in isolation.

Vice-Minister Morais: From the start, collaboration between public and private actors was essential. This shared vision has allowed the ecosystem to grow coherently rather than fragment.

Has BasQ's goal and scope evolved over time?

Dr. Aizpurua: The core ambition has remained the same: to become an international reference in quantum technologies, particularly quantum computing. What has evolved is focus. Initially, the vision was broad and exploratory. Today, we are much more precise about where we can achieve excellence. At the same time, the scope has expanded—we are working across more challenges, more algorithms, and more applications. But always with a sharper definition of where we can truly lead.

Which research areas and use cases have emerged?

Dr. Aizpurua: On the scientific side, there is strong activity in electronic structure calculations, partial differencial equations solving, and high energy physics, especially the simulation of gauge fields. On the applied side, we see promising work in optimization—particularly in financial services—as well as biomedical research and accelerated AI. The spectrum runs from fundamental science to highly practical optimization problems.

What lessons does the Basque Country's journey offer to other regions considering similar investments?

Vice-Minister Morais: A shared, long term vision is essential. Administration, researchers, and industry must advance together with a clear understanding of strengths and limitations. Quantum is a major bet. Public investment must be justified by long term value. For us, that alignment has been the foundation of the ecosystem's success.

Vice-Minister Morais' advice:

"Have a common vision encompassing policymakers, researchers, and industry, and be clear about your strengths and weaknesses."

“From the start, collaboration between public and private actors was essential.”



Dr. Adolfo Morais
Vice-Minister of Science and Innovation,
Basque Country

“The key has been alignment: administration, science, and industry moving together rather than in isolation.”



Dr. Javier Aizpurua
Scientific Director,
Basque Quantum

Tokyo Electron Limited (TEL)

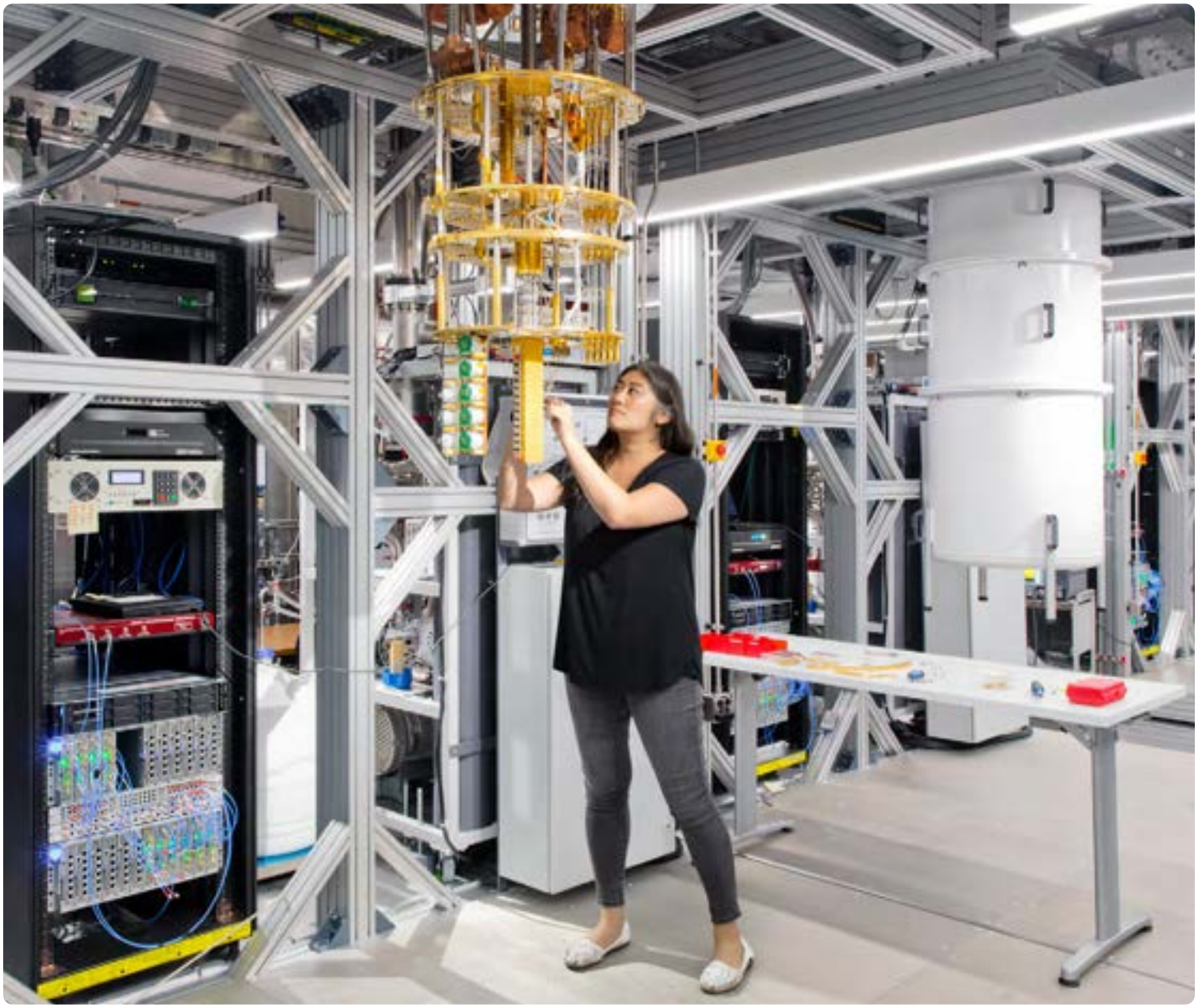
Assembling expert teams

(by Dr. Akihisa Sekiguchi)

Year quantum journey began	Industry
2018	Electronics

Use cases

Equipment configuration and semiconductor process optimization, nanometer scale and macroscopic scale fluid simulations



We first began exploring quantum computing at Tokyo Electron Limited (TEL) more than five years ago. Quantum was a technology worth learning about, but not yet ready for structured investment. That changed when we realized that meaningful progress would require education, shared learning, and long-term partnerships rather than isolated experiments.

With partners like Q-STAR [Japan-based Quantum Strategic industry Alliance for Revolution], we refined expectations, conducted joint application research, and identified real problems that classical systems struggle to solve. One of the most important lessons was the power of diverse expertise versus narrow specialization. Success requires teams that combine deep domain knowledge, from data science to classical computing to quantum implementation. No single organization naturally possesses all of them.

We were able to assemble multidisciplinary teams to work through real semiconductor challenges. Semiconductor manufacturing is inherently complex—it spans materials science, process physics, optimization, and data. We needed access to talent that would be difficult to secure independently.

Partnerships also matter because uncertainty is high. Hardware architectures are evolving, timelines are shifting, and benchmarks continue to change. By navigating that uncertainty with partners, you learn more, faster. Sharing insights about mistakes and iterating together makes that cycle more effective and more efficient.

Looking ahead, I firmly believe that quantum computing will only reach its potential through ecosystems of like-minded organizations. No single entity can address the technical, ethical, security, and societal implications alone. International collaboration, shared industry guidelines, and coordinated education efforts will all be necessary.

For TEL, quantum fits naturally with how we deliver value: faster innovation, better technology, and deeper insight into the physics and processes our customers care about. Building partnerships has allowed us to move closer to that vision. As quantum advantage emerges, it will belong not to isolated pioneers, but to those who invested in building ecosystems that power collaboration and innovation.

Dr. Sekiguchi's advice for beginning the quantum journey:

"Remember to pack domain experts, data scientists, HPC simulation algorithm experts, and quantum hardware and software specialists in your suitcase."



“Quantum advantage will belong not to isolated pioneers, but to those who invested in building ecosystems that power collaboration and innovation.”

Dr. Akihisa Sekiguchi
Senior VP and GM of US R&D, Fellow,
Tokyo Electron Limited (TEL)

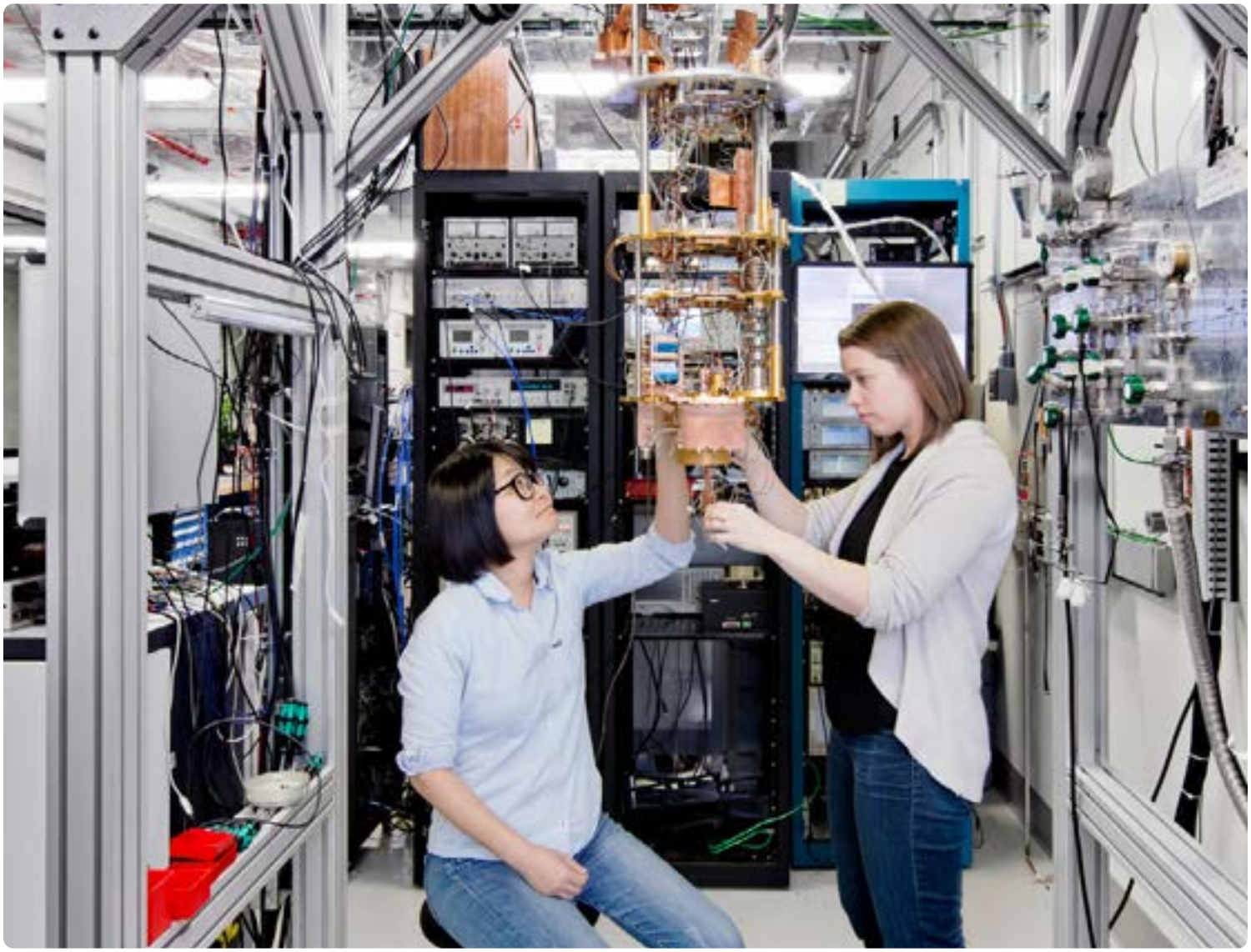
Republic of Singapore

Creating a quantum hub

Year quantum journey began	Industry
1998	Government

Use cases

Grid and investment portfolio optimization, solar panel and data center predictive maintenance, secure communications, logistics and supply chain optimization



Singapore is committed to cultivating a thriving quantum ecosystem that brings government, academic, and private-sector organizations together to build readiness. Sustained government funding has helped establish flagship institutions such as the Centre for Quantum Technologies—hosted by the National University of Singapore—which has produced highly-cited research and multiple industry spin offs.

"We have invested steadily over two decades," says Choy Yong Cong, Director of International Affairs and Quantum Policy and Strategy at Singapore's Ministry of Digital Development and Information. "This has positioned us well to capture the current trajectory of quantum tech development and seize opportunities."

The latest phase of Singapore's journey is the National Quantum Strategy, launched to strengthen capabilities across research, engineering, talent, translation, and partnerships. Its implementation is led by the National Quantum Office and supported by a network of government agencies working together to support ecosystem development, enterprise growth, and real-world quantum deployment. Agencies include the Ministry of Digital Development and Information (MDDI), the Economic Development Board (EDB), the Infocomm Media Development Authority (IMDA), the National Research Foundation (NRF), Enterprise Singapore, and SGInnovate.

Dr. Clifton Phua, Director of Labs at IMDA's BizTech Group, sees a flywheel effect. "Real use cases create demand, demand attracts capability, capability drives investment, and investment strengthens the quantum computing ecosystem."

A multi-pronged strategy

Singapore has invested more than SGD700 million in quantum technologies since 2002, reflecting a sustained national commitment to the field. Singapore's National Quantum Strategy, launched in 2024, builds on this strong foundation, committing an additional SGD300 million over five years. The strategy takes a more coordinated approach to strengthening its quantum ecosystem, spanning research, engineering, talent, and collaboration. This whole-of-government effort spans complementary agencies that together support research and deployment pathways, help local firms scale, and attract foreign quantum companies to the city-state. The strategy has four focus areas:

Scientific excellence. Singapore has built a strong base in frontier quantum research through institutions like the Centre for Quantum Technologies, which is a global leader in areas including quantum communications and sensing.

Engineering capabilities. National platforms such as the Quantum Engineering Programme and the National Quantum Processor Initiative have strengthened Singapore's ability to translate research into deployable quantum technologies.

Partnerships. International and industry partnerships form a core part of Singapore's approach to quantum, helping local researchers and companies access infrastructure, co-develop use cases, and plug into global quantum value chains.

Talent and research-to-industry translation. Singapore is investing in scholarships, industry-linked programs, and national platforms to develop talent and translate research into real-world applications and commercial opportunities.

This emphasis on strengthening the quantum ecosystem extends into academia. At the National University of Singapore, quantum computing research has never been treated as a standalone academic pursuit. Researchers work closely alongside public agencies to explore credible use cases.

According to George Loh, Associate Vice President (Strategic Partnership) at the university, success has depended less on the number of partnerships than on their depth: "You need partners who are willing to invest and experiment for the long term, not those looking for short-term returns."

Loh points to openness and public commitments as essential tools for aligning stakeholders and maintaining momentum in an uncertain field. "What I appreciate is transparency—having a clear roadmap that shows where we are going and how progress will be measured," he says.

Ultimately, Singapore's strategy is about preparedness in the face of uncertainty. By building national platforms and cultivating dense networks of collaboration, Singapore has established an ecosystem through which quantum advantage can emerge. "As a government, we can't afford to wait and see," Choy says. "We have to prepare for quantum now."

George Loh's advice:

"Seriously commit and build a core team first—even three or four people can be enough to begin."

"You need partners who are willing to invest and experiment for the long term, not those looking for short-term returns."



George Loh
Associate Vice President (Strategic Partnership),
National University of Singapore

"As a government, we can't afford to wait and see. We have to prepare for quantum now."



Choy Yong Cong
Director of International Affairs and Quantum Policy and Strategy,
Ministry of Digital Development and Information

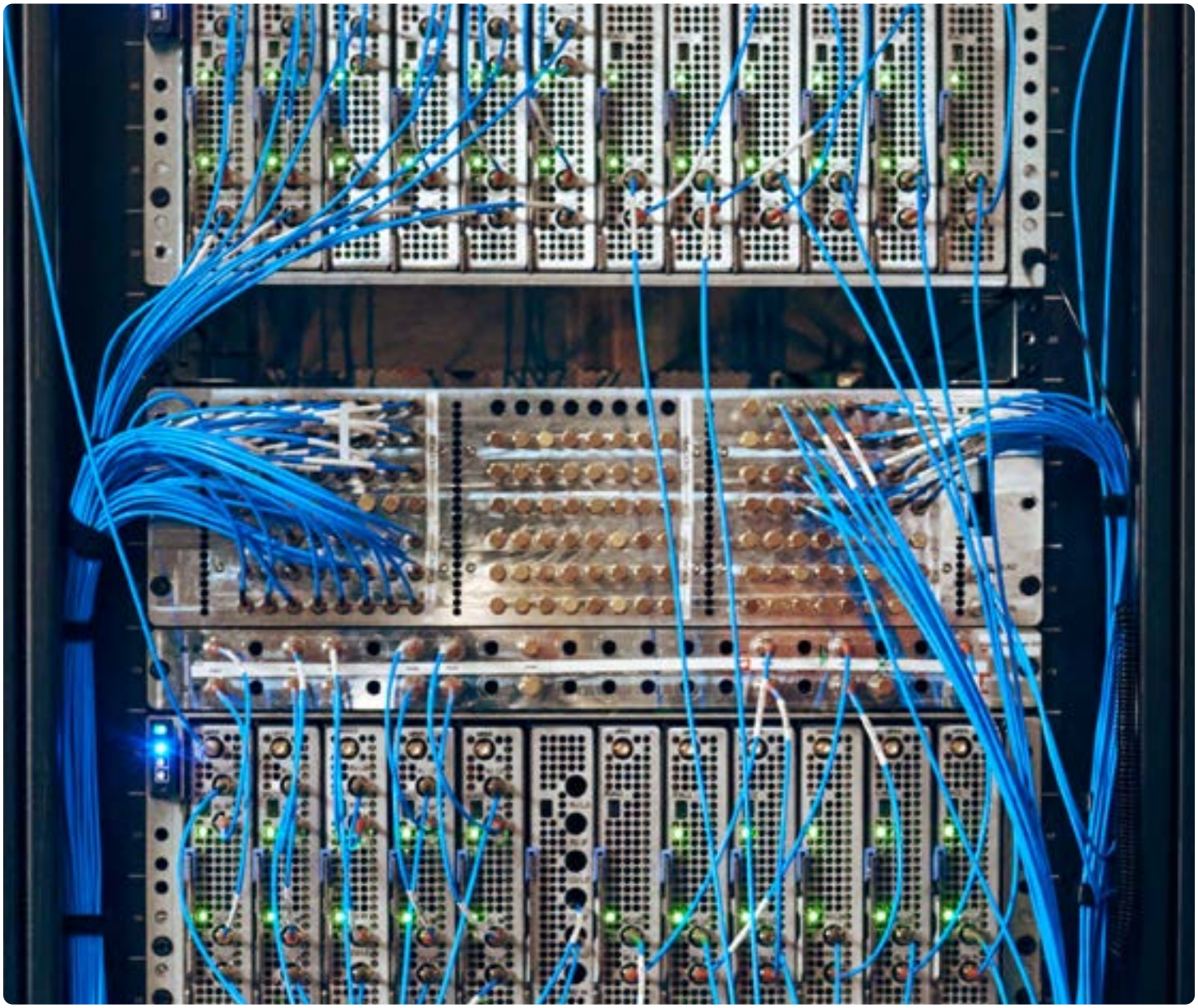
Bradesco

Banking on partnerships

Year quantum journey began	Industry
2019	Banking

Use cases

Portfolio optimization, risk analysis, macroeconomic variable forecasting



Dr. Jonatas Rossetti—who leads the quantum research team at Bradesco, one of Brazil's largest financial institutions—explains his bank's quest for quantum use cases, from portfolio optimization to forecasting.

How do you infuse quantum into Bradesco's innovation strategy?

I like to think of our quantum journey as supported by four pillars: research, experiments, training, and partnerships. Together, these pillars allow us to achieve quantum readiness.

Research helps us understand how the technology is evolving—hardware, software, opportunities, and limitations. Experiments connect that knowledge to real financial problems by bringing together quantum specialists and domain experts from across the bank. Training builds our internal capabilities. We offer many training paths within Bradesco to deepen knowledge and skills, such as quantum computing learning programs and courses.

But we can't progress alone—we need to be an active part of the quantum community. International conferences, local events, and joint research help us build credibility, attract talent, and position Bradesco as an innovation-driven bank.

What role do partnerships play?

For us, partnerships are fundamental because they allow us to accelerate learning and reduce uncertainty. Industry partners give us access to hardware and tools and educational materials, while academic partners help us develop methods that are not yet ready for production. Our partnership with the University of São Paulo, for example, helps us test hypotheses, explore algorithms, and exchange perspectives. From a broader strategic perspective, external collaborations help us stay close to the frontier without over-committing internally before the technology matures.

How does outside collaboration help you build internal business value?

For me, quantum advantage only exists if it creates value that outweighs the cost of investment. It's not enough to say an algorithm is better. We have to show that it improves operational efficiency or decision-making in a way that justifies the investment. That's why I prefer a diversified portfolio of use cases—portfolio optimization, risk analysis, forecasting—rather than betting everything on one problem. Collaboration helps us learn across these areas without locking ourselves into a single, risky path too early.

What are the key lessons from your quantum journey?

Quantum readiness doesn't come from hype or isolated pilot projects. Advantage won't be just about hardware or algorithms. Success flows from people, partnerships, and deepening understanding over time. Stay the course so that when the technology is ready, the organization is ready too.

Dr. Rossetti's advice:

"You don't need a large team to start. But you do need a dedicated one and a clear intention to grow capability and knowledge, both internally and through partnerships."

“External collaborations help us stay close to the frontier *without overcommitting* internally before the technology matures.”



Dr. Jonatas Rossetti
R&D Specialist,
Bradesco

Conclusion

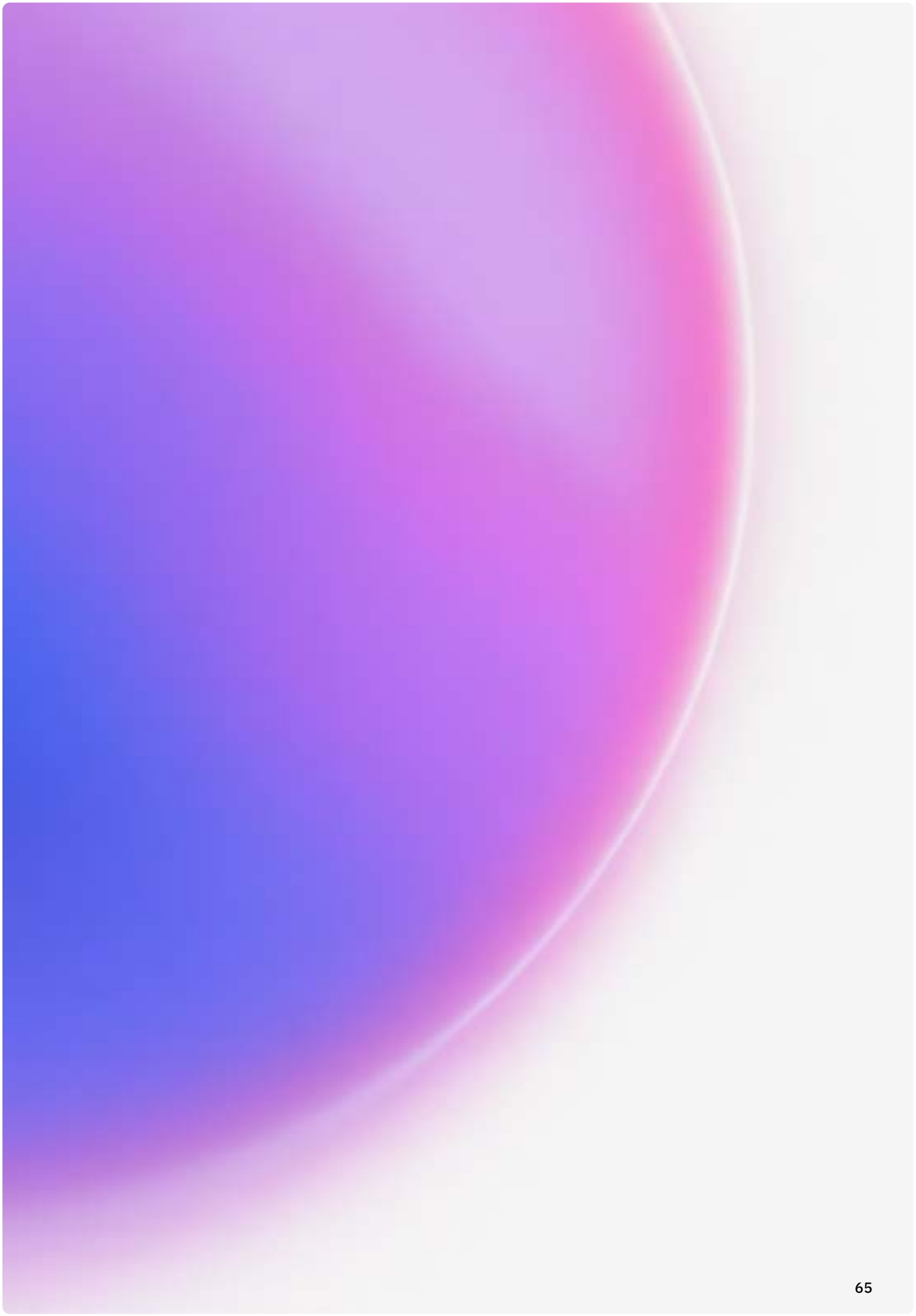
The journey ahead

Quantum computing is undoubtedly a transformative force, one that demands foresight and collaboration. Leading organizations aren't waiting for fault-tolerant systems to arrive—they're taking action now, homing in on specific, uniquely valuable use cases. Very often, progress is accelerating through ecosystems that connect businesses, government, academia, hardware providers, and research institutions.

Living at the frontier of innovation, first-movers are showing how quantum systems can augment—not replace—existing technologies, as hybrid architectures are deployed. Quantum and AI will work together to analyze complex problems that lie well beyond today's computational limits.

What once was decades in the future is happening now. Across industries and around the world, organizations are building the conditions necessary to seize a new competitive edge. The most successful will likely be those that invest early in building foundational quantum capabilities to avoid being left behind.

33% **increase in quantum investment when quantum and AI are framed as complementary.[1]**



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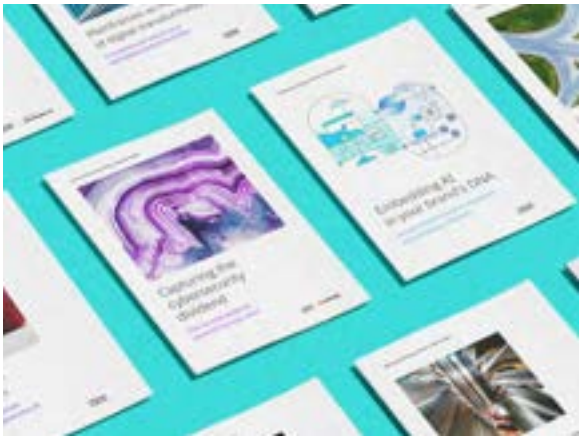

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Notes and sources

1. Heather Higgins, Florizoone Petra, Veena Pureswaran. Quantum is coming: 5 realities shaping the race to advantage. IBM Institute for Business Value. December 8, 2025. https://ibm.biz/quantum-readiness



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New Orchard Road
Armonk, NY 10504

Produced in the United States of America | June 2026

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