The background features a complex, abstract visualization of quantum computing and artificial intelligence. It consists of a dense network of glowing orange and blue lines and nodes, resembling a neural network or a quantum circuit. The lines are interconnected and radiate from a central point, creating a sense of depth and complexity. The overall color palette is dominated by warm oranges and yellows, contrasted with cool blues and purples. The lighting is dramatic, with bright highlights and deep shadows, giving the impression of a futuristic, high-tech environment.

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Quantum Computing and Artificial Intelligence: the silent revolution

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1



Why Quantum and Artificial Intelligence?

1

Why Quantum and Artificial Intelligence?

The combination of AI and quantum technologies can have a significant impact on fields such as fundamental sciences, medicine and industry. So why do we say it is a silent revolution? It is "silent" because the breakthroughs in quantum technologies, accelerated by artificial intelligence, are taking place at an experimental and industrial level, and are still emerging technologies. In other words, the foundations of the quantum revolution are being laid, although they remain unnoticed by the public at large. When they emerge, it will be a **boom that will surely catch the uninitiated by surprise.**

The Bankinter Innovation Foundation has held its **Future Trends Forum** think tank, bringing together nearly forty world experts to study this topic, analyze the state of the art of these technologies and make recommendations regarding the challenges and opportunities they present.

Quantum technologies are a set of techniques and tools based on the laws of quantum physics and used to address complex problem solving. They fall into three main groups:

01

Quantum computing, which is used to perform faster and more accurate calculations than classical computers for certain types of problems, typically optimization, simulation, machine learning and artificial intelligence problems.

02

Quantum communication, which enables the secure transmission of information over long distances and, potentially, at higher speeds than classical communications.

03

Quantum measurement (also called **quantum sensing**), which refers to the use of quantum phenomena to measure and detect very weak signals.

Quantum cryptography lays across the first two. It is one of the most interesting industrial applications.

Quantum technologies have the potential to offer significantly higher performance and processing power than traditional technology. Furthermore, they are taking new approaches to **problem-solving** and, therefore, developing **new scientific approaches and algorithms**. This is what the expert **Brian Lenahan** calls a **quantum inspired attitude**.

Then there is **advanced AI**, capable of processing large amounts of data and **finding patterns** that may be difficult for humans to detect. Through **machine learning**, it can adapt and learn from new situations. Artificial intelligence, especially in the field of reinforced machine learning and, more specifically, **generative Artificial Intelligence**, has been advancing steadily for a year now, in a way that leads to a **paradigm shift**: the rules of the game are about to change, say our experts. From teaching to programming, from personal assistants to content generation, from Internet searches to customer service. Solutions like **ChatGPT** can radically change the way we communicate with each other and the way we interact with machines, while at the same time raising all-important questions and ethical dilemmas—some reflection is necessary to minimize unintended consequences.



**Brian
Lenahan**

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What areas will be disrupted first by joint quantum technologies and AI innovations?

The experts agree that there are already some use cases in the **design of encryption algorithms** when fault-resistant quantum computers become a reality. And also, in the **use of AI to accelerate scientific processes** that lead to new physical findings on how quantum computers should behave, and processes that lead to research into new ways of measuring, resulting in new sensors (quantum sensors).

In the medium to long term, they will disrupt everything from medicine to logistics, from the design of new molecules and materials to finance, education, transportation and space exploration. In fact, 48% of IT leaders surveyed in EY's **2022 Quantum Readiness Survey** believe that **quantum computing will play a major role in their industries by 2025**.

The biggest challenge for the industry is to **understand what Quantum Computing is** and how, combined with AI, it can affect all its processes—for good and bad—, while **calling out exaggerated promises from substantiated potential realities**. This report aims to respond to this challenge: by analyzing the areas that will be greatly influenced by the Quantum and AI revolution, we can be prepared to make the most of the opportunities that are sure to present themselves.

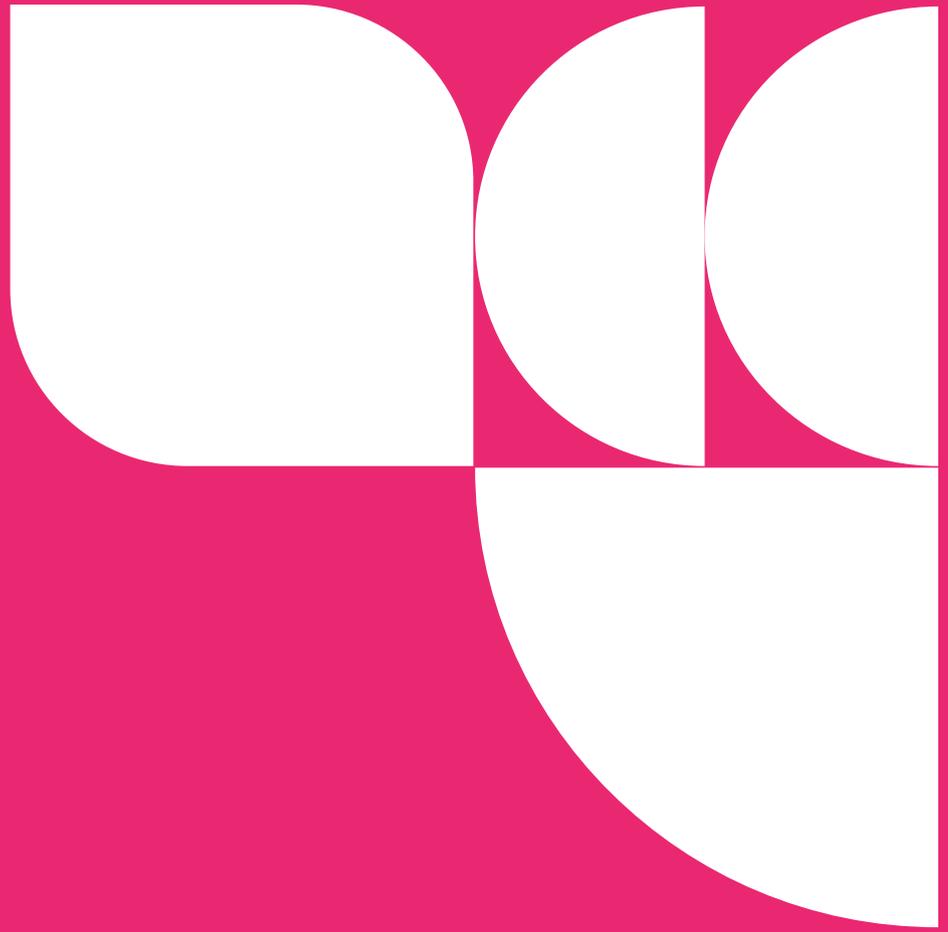
This report provides the keys to join the Quantum + AI revolution:

- The **state of the art** in these two fields and how they mix and feed on each other.
- The **future** in the short and medium term, presenting **the challenges and opportunities** for the players involved—startups, industry, public administration, education—and society and large.
- The new **training** needs and the **professional profiles** that will be required.
- The **ethical implications** of quantum technologies and artificial intelligence, and the need for a **regulatory framework** to combat everything from bias to inappropriate use.
- **Specific challenges and opportunities for Europe and Spain** in the coming years.
- And finally, a series of recommended actions and forecasts from our experts for companies and institutions to be prepared to take full advantage of quantum technologies and advanced AI.

ChatGPT synthesis

The combination of quantum technologies and artificial intelligence has the potential to revolutionize fields such as fundamental sciences, medicine, and industry. However, this is currently a "silent revolution" as the breakthroughs are still emerging technologies. Quantum technologies include quantum computing, communication, and measurement, while advanced AI is capable of processing large amounts of data and finding patterns. Jointly, these technologies will disrupt everything from medicine to space exploration. The biggest challenge is understanding how quantum computing and AI can affect all processes, while also addressing ethical concerns. This report provides insights into the state of the art, challenges, opportunities, training needs, ethical implications, and recommended actions for companies and institutions to take advantage of these technologies.

2



**Quantum
Technologies**

2

Quantum Technologies

Quantum technologies are based on the behavior of matter and energy at the quantum level, that is, at the atomic and subatomic level. Progress in the control and manipulation of individual atoms and photons is one of the most outstanding achievements of quantum physics in recent years. These advances have enabled scientists to develop a number of very promising quantum technologies, such as quantum communication (which uses quantum teleportation), quantum sensing and quantum computing.

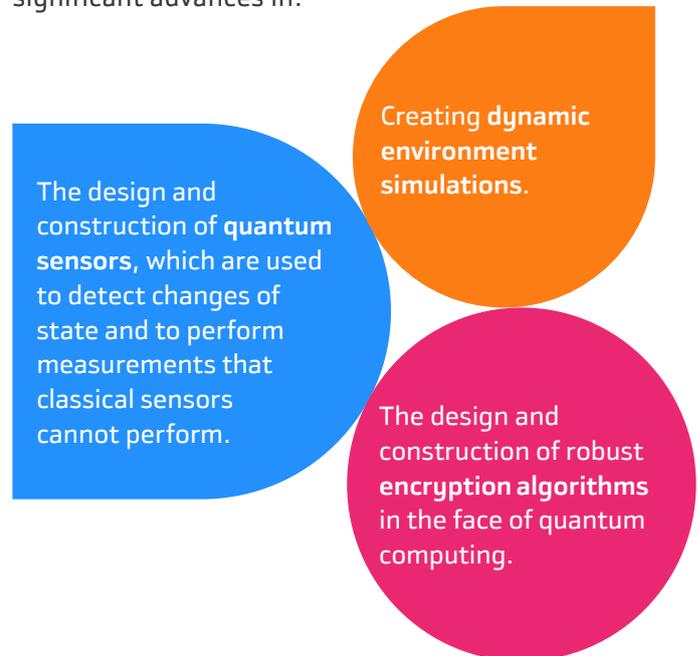
The basic unit of quantum information is the **qubit**, and it can take any value in a continuum of quantum states. Unlike a bit, which is the basic unit of information in classical computing and can have two states (zero or one), a qubit can be described by a linear combination of both states at the same time (quantum superposition).

Qubits process information differently from classical computing, thus enabling more efficient problem solving for some types of problems. Since they can store many more states per unit of information, they can operate with **much more efficient algorithms at a numerical level**. However, they are very sensitive, and **their state can be altered by simple observation**, which poses challenges in their use and practical application.

State of the art in quantum technologies

That very property, the ease of being altered, has led to great advancements in secure quantum communications.

In addition, quantum science is making very significant advances in:



In the latter field, quantum computing is expected to decrypt current encryption algorithms, and work is being done on two types of solutions: in the short and medium term, on so-called **post-quantum cryptography**, creating new algorithms that will be resistant to quantum computers in the future. In the long term, on **quantum key distribution (QKD--Quantum Key Distribution)**, a secure communication method that implements a cryptographic protocol involving quantum mechanical components. It allows two parties to produce a shared random secret key known by them two only, which can then be used to encrypt and decrypt messages.

Artur Ekert, Professor of Quantum Physics at Oxford University and Founding Director of CQT Singapore, points to **the all-important scientific discoveries and physical demonstrations as the basis for progress in quantum technologies**. He illustrates this with **this year's Nobel Prize in Physics**, which has been awarded to John F. Clauser, Alain Aspect and Anton Zeilinger for "experiments with entangled photons, establishing the violation of Bell's inequalities and pioneering quantum information science."

For Ekert, quantum computing is one of the most complex and sophisticated experiments humankind has ever produced, even more so than traveling to the Moon. The aim is to have hundreds and hundreds of qubits working together, controlled with astonishing precision. Achieving this would prove that quantum theory is correct and represents a good description of nature. Not achieving this would be an even better scientific outcome, because it would open the door to making even more precise theories about how nature works, and to experimenting with various theories to arrive at post-quantum computation. In short, and given that the representation of information is physical, **advances in physical theories will always lead to advances in computation that we cannot imagine today**. The key to success in this field, says Prof. Ekert, is to innovate. Both in science and in experimenting and building solutions: **if you innovate and come up with new ideas and solutions that others don't have, you will have a competitive advantage that cannot be replicated without enormous effort**.

**Artur
Ekert**

 Ver vídeo



Regarding the baseline technologies used, there are many quantum systems in the world and many approaches to building quantum solutions, as **Stefanie Barz**, Professor at the University of Stuttgart and Director of the Center for Integrated Quantum Science and Technology (IQST), explains. Different approaches currently coexist, depending on the physical elements they are developed on:

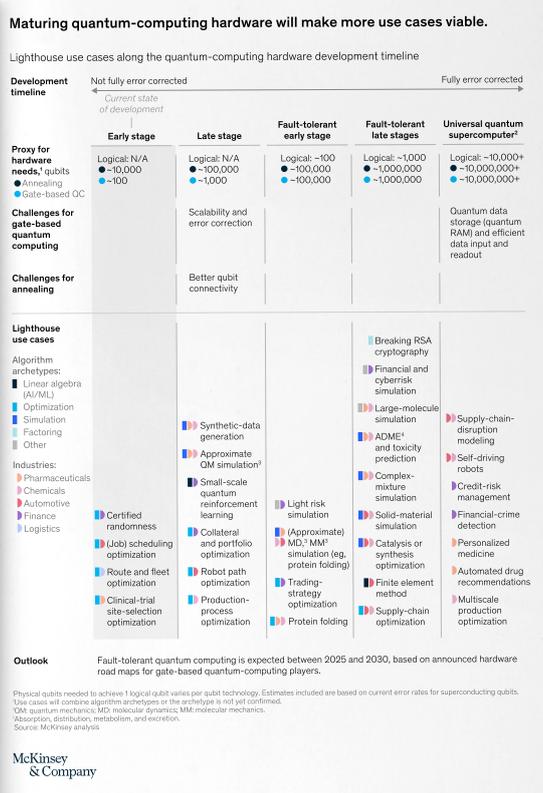
Quantum computing can create, and control qubits based on **atoms, photons, superconductivity, or defects in crystalline materials**—such as diamonds. Each of these technologies has its own strengths and weaknesses, and all of them are developing rapidly and in parallel. Today, experts are uncertain as to which of them will eventually prevail or whether they will coexist, as the field is constantly evolving, and new baseline technologies are likely to emerge in the future.

Experts believe that quantum computing will be truly advantageous on a widespread basis in some 10 years. The fundamental problem is the number of errors, which must be reduced by several orders of magnitude, says **Ignacio Cirac**, Director of the **Max Planck Institute for Quantum Optics** and scientific member of the Max Planck Society.

Even so, and based on the current state of the art, Cirac is optimistic and thinks that **applications will emerge that no one is contemplating today.**

Ignacio Cirac

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Similarly, **quantum communications** use quantum mechanical principles to transmit information from one place to another in a secure manner. The most advanced technologies can be **optic fiber, satellite, line-of-sight** or **mobile**.

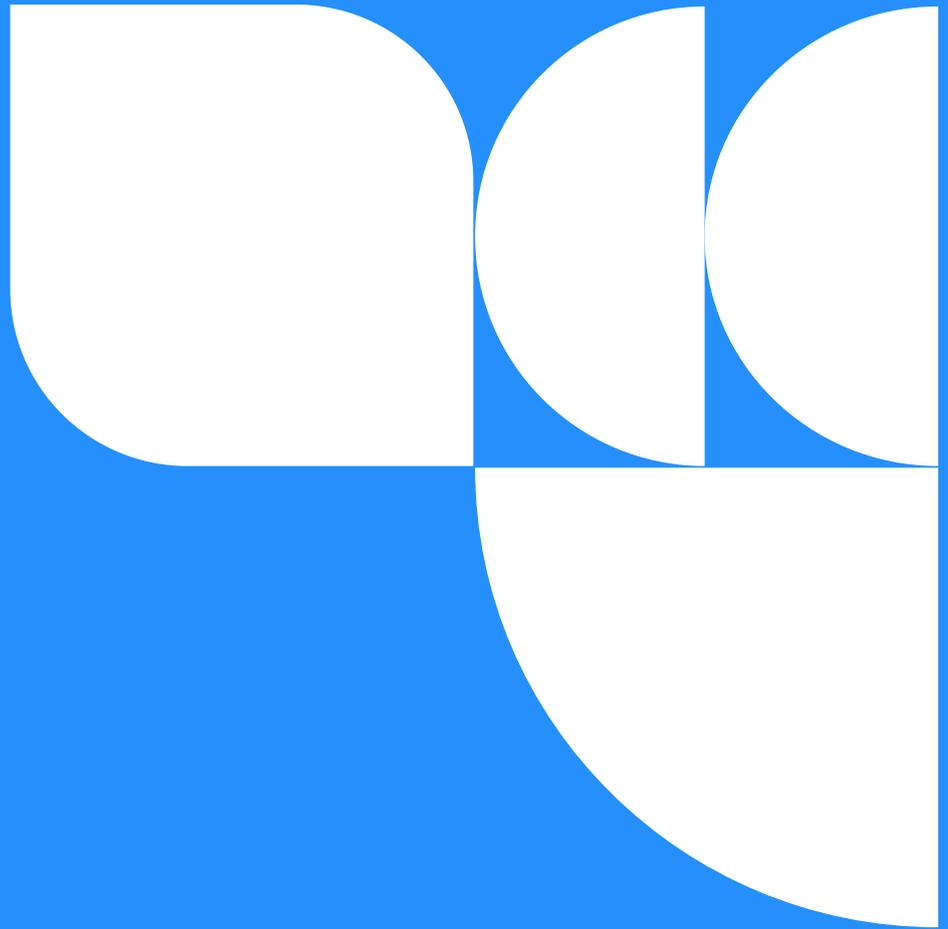
Finally, **quantum sensing** uses principles of quantum mechanics to measure physical quantities with high precision. Quantum **position and velocity, electromagnetic field, temperature** and **pressure** sensors are among the most advanced technologies in this field.

As with quantum computing and quantum communications, each of these technologies has its own strengths and weaknesses, and new technologies are likely to emerge in the future. They would all share a strength: **high accuracy** versus existing solutions. They also share a weakness: they are extremely **difficult to implement** and **require special conditions** to work optimally.

ChatGPT synthesis

Quantum technologies are based on the behavior of matter and energy at the atomic and subatomic level, allowing for promising developments in quantum communication, sensing, and computing. Unlike classical computing, qubits can exist in quantum superposition, allowing for more efficient algorithms. Quantum science is making advances in creating dynamic environment simulations, quantum sensors, and encryption algorithms. Quantum computing is expected to decrypt current encryption algorithms, leading to the development of post-quantum cryptography and quantum key distribution. Different quantum systems exist for developing quantum solutions, with uncertainty over which will eventually prevail.

3



Advanced Artificial Intelligence

3

Advanced Artificial Intelligence

The architect of the silent revolution is the combination and feedback between quantum technologies and artificial intelligence.

Quantum and AI enhance each other, explains **Stefanie Barz**: **Quantum computing can accelerate AI, enabling faster and more efficient algorithms.** And also, AI can accelerate the design of new quantum hardware and software.

"The combination of Quantum Computing and AI will lead to computing powers 100 times greater than today's in 10 years and 10,000 times greater in 20 years".

Calum Chace

What is the state of the art in artificial intelligence? What types of AI solutions are we moving towards? How does it combine with quantum technologies? **Calum Chace**, a world expert on Artificial Intelligence and its impact on all of us, provides an overview of the topic:

After the breakthrough of **machine learning** already a decade ago, the next milestone has been **transformer models**: a type of neural network architecture introduced in 2017 by Google researchers. They are used for various natural language processing tasks, such as language translation and text summarization.

The milestone after that, barely a year old, is **generative AI**, which refers to **Artificial Intelligence systems that can generate new content** based on some input. This can include generating text, images, code or even music. These systems typically use various types of machine learning (supervised, unsupervised, reinforcement) to learn from a large data set and then generate new and original content.

And the evolution of this type of system is unstoppable. As an example, Calum Chace tells us that **OpenAI's GPT-3** text generator has 175 billion parameters

The most interesting trends in AI, according to this expert, are:

The combination of Quantum Computing and AI will lead to computing powers 100 times greater than today's in 10 years and 10,000 times greater in 20 years, contradicting those who argue that Moore's law is dead. On the contrary, **growth will be exponential rather than linear.**

In 10 years, the use of "*smart glasses*" instead of "*smart phones*" will be commonplace, including their augmented reality capabilities. They will be personal assistants capable of solving a large number of requests.

At the same time, the use of **autonomous vehicles** and increasingly general-purpose **robots** will become widespread.

In addition, there is progress with the inception of the **Metaverse** which, together with **virtual and augmented reality**, will bring **new social, economic and financial models.**

Finally, there will be **dramatic advances in healthcare**, with the **discovery of new drugs thanks to AI and quantum computing** and new ways of understanding and interacting with the human body and, in particular, the brain, through Brain-Computer Interfaces (BCI) based on quantum computing and AI.



**Calum
Chace**

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Quantum machine learning and BCIs

Quantum machine learning is about using quantum devices to perform more efficient machine learning calculations. Some experts also use the term when it comes to using machine learning to better control quantum systems—to optimize quantum gates, to control states, or to better calculate the quantum phases of matter. That is, when machine learning is used to simulate quantum systems more efficiently.

Under the first meaning, there is much hope that the **HHL algorithm** (for solving systems of linear equations) will have an exponential gain in a quantum computer compared to classical devices, but there are still great challenges in this field, such as loading large amounts of data into quantum computers and developing quantum computers large enough for algorithms such as HHL, which require millions of qubits—let us not forget that today's order of magnitude is in the hundreds of qubits, as explained by **Lucas Lamata**, Professor at the University of Seville, and expert in quantum artificial intelligence and quantum machine learning. For Prof. Lamata it is essential that today's quantum computers, called NISQ (Noisy Intermediate-Scale Quantum), manage to solve useful problems for industry and society, as this would boost the growth of the field of quantum technologies. In fact, work is being done on **neuromorphic quantum computing**—based on the simulation of biological neural networks to create machine learning systems—, which could help with the development of more advanced artificial intelligence systems, such as quantum neural networks and quantum machine learning algorithms. The technology is also expected to have applications in areas such as molecular simulation and algorithm optimization.

Quantum machine learning systems are also being explored for **brain-computer interfaces (BCIs)**, systems that establish direct communication between the brain and a computer. Electrical activity, produced when neurons fire to communicate with each other, is processed and decoded to an electronic device to perform a desired action. These actions range from **restoring lost functions to augmenting our capabilities or home automation control**.

The combination of quantum computing and quantum sensors with AI is a turning point in the creation of BCIs, which will accelerate innovations exponentially, in the words of **Javier Mínguez**, Co-Founder and Chief Scientist of **Bitbrain**.

Lucas Lamata

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Javier Minguez

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Generative artificial intelligence

Fundamental AI models include neural networks, expert systems and machine learning algorithms. They are used to build AI systems that can perform specific tasks, such as pattern recognition, natural language processing and decision making. They are **pre-trained with large amounts of data** through **self-monitoring**. This pre-training is done once and then adapted and transferred to many tasks, depending on the desired result.

Different methods are used to perform self-monitoring, such as masked language modeling, which consists of randomly masking the elements of a sentence and having the system predict the missing token. This is explained by **Iryna Gurevych**, Professor at the Technical University of Darmstadt and creator and Director of the Ubiquitous Knowledge Processing Lab (**UKP Lab**).

Generative AI is part of advanced AI. It focuses on creating systems that can generate new and original content. These systems use machine learning techniques to analyze large amounts of data and learn to generate content that mimics the way that humans create content. In short, **generative AI is an emerging technology that has the potential to revolutionize the way content is created and accessed in the future.**

By way of example, there is a highly advanced model, GPT-3 now embedded in **ChatGPT**, a **text**

generation model that interacts in a conversational way. Regarding the **generation of original images** through generative AI, there are, for example, **DALL-E 2**, **Stable Diffusion** or **Midjourney**, capable of creating images from a description in natural language.

The biggest challenges facing generative AI are the **high cost of creating models** and the **high need for computational capacity**. According to Iryna Gurevych, **quantum AI could substantially mitigate the existing efficiency problems.**

In addition to generative AI, there is a **huge potential for new AI tools to develop quantum technologies**, for example, when introducing AI into **digital twin solutions for quantum systems**—a virtual representation of a physical system or process, which is used to simulate and analyze the behavior and performance of a system or process. One example is the development of new **graphics tools for designing quantum circuits**, such as those developed by Future Trends Forum expert **Asier Arranz**, head of Robotics and Embedded AI at NVIDIA.

AI for Quantum Technologies:
Optimisation of hardware
Quantum software
New quantum computing schemes
Data analysis

Quantum for AI:
Using quantum algorithms
Quantum subroutines
Achieve a quantum advantage

Source: **Presentation by Stefanie Barz at the FUTURE TRENDS FORUM**



**Assier
Arranz**

Quantum and AI enhance each other: Quantum computing can accelerate AI, enabling faster and more efficient algorithms. Also, AI can accelerate the design of new Quantum hardware and software".

**Stefanie
Barz**



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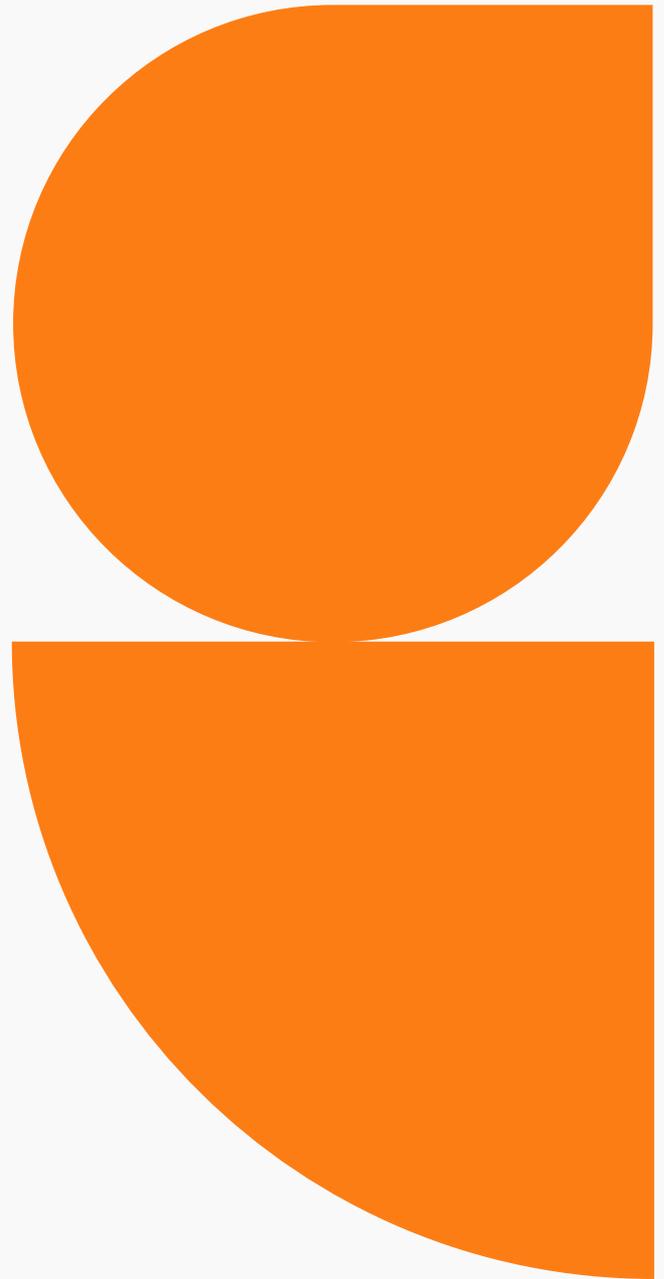
**Iryna
Gurevych**

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ChatGPT synthesis

This chapter provides an overview of advanced artificial intelligence and its integration with quantum technologies. Calum Chace, an AI expert, explains that quantum computing can accelerate AI, and vice versa. He predicts that the combination of quantum computing and AI will lead to computing powers 100 times greater than today in 10 years and 10,000 times greater in 20 years. Chace also discusses milestones in AI, including transformer models and generative AI, which uses various types of machine learning to generate new content. In addition, the chapter explores quantum machine learning and brain-computer interfaces and their potential to accelerate innovations. Finally, the author explains the use of self-monitoring and other methods to train AI systems.

4



Opportunities and Challenges of Quantum Technologies + AI

4

Opportunities and Challenges of Quantum Technologies + AI

The big business opportunities will present themselves in two main areas, according to Professor **José Ignacio Latorre**, Director of the Singapore Quantum Technologies Centre and CRO (Chief Research Officer) of the Abu Dhabi Institute of Technology Innovation:

- the design and development of the **physical** (hardware) **components** needed to create quantum computers and quantum sensor systems.
- the design and development of **quantum algorithms**. Especially in the following industries:



**José
Ignacio
Latorre**

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1.

Finance

for example, evolving the **Monte Carlo method** with quantum circuits and for new risk management solutions.

2.

Chemistry

in the analysis of molecules and design of new materials.

3.

Optimization

applied to logistics, value chains, hydrodynamics, etc.

4.

Artificial intelligence

in the development of quantum machine learning solutions.

5.

Cybersecurity

Implementing post-quantum cryptography algorithms.

Regarding the **major challenges before quantum technologies**, Prof. Latorre points out:

01

Scientific challenges: in particular, addressing result coherence, which is compromised by the physical environment. In addition, creating algorithms for real and useful use cases and advancing the maturity level from prototyping to production systems.

02

Public challenges: governments should speed up bureaucratic procedures on the one hand, and on the other hand, they should support powerful investments in quantum technologies, boosting the industry.

The first thing to bear in mind is that there is too much hope that the combination of quantum technologies and AI will suddenly solve the major problems affecting humanity, such as climate change or hitherto incurable diseases, as **Ignacio Cirac** warns. That said, they are of great help in solving specific problems and, perhaps, in the long term, in tackling problems of greater significance—specifically, in everything related to **cryptology** and in solving **scientific problems in physics and chemistry**, which could have very positive implications for industry. One of these scientific areas where Quantum Computing can make a difference is in the study of **superconductivity** at room temperature (today it is achieved at temperatures around -260°C , close to absolute zero (-273.15°C)). The proposed theoretical models cannot be validated with classical computing and can be validated with Quantum Computing algorithms.

03

Industry challenges: The main challenge, as mentioned at the beginning of this summary, is to understand the basis of quantum technologies and their application potential. In addition, it faces the challenge of acquiring and retaining specialist talent, capable of determining where and how to invest.

In addition, quantum computing is **inspiring new algorithms** that can run on classical computers more optimally than current ones.

As **Brian Lenahan**, founder and president of the **Quantum Strategy Institute**, points out, one way to meet these challenges is, on the one hand, to work in **hybrid environments** where quantum computing and traditional computing coexist, through **cloud computing** solutions. On the other hand, to teach professionals, at all levels of an organization, to have an attitude of quantum curiosity. In other words, to promote "quantum inspired" thinking, by asking the question:

What would be a quantum logic approach to this problem?

Disruptive applications in the real world

Photon-based quantum computing

Within quantum computing, one of the most promising branches is that which relies on **photons**, or particles of light, to represent and manipulate information. Photon-based quantum computing is potentially more efficient than other forms of quantum computing in certain tasks such as communications, as **Stefanie Barz** explains. She also points out that the use of photons instead of other quantum systems, such as atoms or ions, may allow greater scalability and ease of implementation in practice.

Although much development remains to be done, experiments have already been performed with 76-photon quantum machines and, a few months ago, an experiment was performed with a **219-photon machine that, for a very specific case, demonstrated quantum supremacy.**

One example of how efforts are being made to bring photonic quantum computing into the real world is the **PhotonQ** consortium, of which Stefanie is the lead scientific coordinator.



Cloud Computing as a catalyst for Quantum Computing

There are major disruptions about to see the light of day, thanks to the **symbiosis between Quantum Computing, Artificial Intelligence and Cloud Computing**, in the words of **Alessandro Curioni**, Vice President for Europe and Africa at IBM and Director of IBM Research Zurich.

The combination of Cloud Computing, Quantum Computing and Artificial Intelligence can have significant impact on processing power and decision-making efficiency. And **the first area that is already having an impact is science.** According to this expert, it is changing and accelerating the way we do science. **According to Darío Gil**, Director of IBM Research worldwide, the acceleration of the scientific method is already a reality, using Artificial Intelligence to detect discrepancies and quantum computing to resolve them, for example, applied to the **research and discovery of new materials.**

According to IBM's roadmap, 5 years from now, we could have **4,000 qubit quantum computers** with coherence and a manageable number of errors. These quantum computers will do specific tasks at which they are very good in combination—thanks to Cloud Computing—with traditional supercomputers, which are very efficient for other things. At that point, Alessandro is confident that we will be able to tackle humanity's major problems much more successfully.

Alessandro Curioni

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Quantum sensing in action

Applications of **quantum sensors** to defense and navigation are advancing significantly. Among others, a **quantum radar**: a remote sensing method based on quantum entanglement.

Also noteworthy are the advances being made in **healthcare**, with quantum devices capable of measuring human magnetic fields, which are beginning to be used for the early detection of tumors.

Another area of application that **Esperanza Cuenca**, head of Strategy and Outreach at **Multiverse Computing**, points out is in the **detection of oil wells using quantum gravimetry**.

The biggest challenge pointed out by the experts, in addition to those listed above, is to move from experimental and demonstration environments to real environments, with scalable and robust solutions. And, in parallel, to work in the regulatory and normative field so that quantum solutions do not increase inequalities or are not used unethically.



Esperanza Cuenca

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The biggest challenge for quantum technologies is to move from experimental to real environments with robust and scalable solutions.

ChatGPT synthesis

The combination of quantum technologies and AI presents business opportunities in the design and development of hardware and algorithms for industries such as finance, chemistry, optimization, artificial intelligence, and cybersecurity. The challenges ahead for quantum technologies include addressing coherence, creating useful algorithms, and advancing from prototyping to production systems. The industry also faces the challenge of acquiring and retaining specialist talent. While the combination of quantum technologies and AI has significant potential to solve specific problems, it is unlikely to tackle problems affecting humanity, such as climate change or diseases. Photon-based quantum computing is one of the most promising branches of quantum computing, potentially more efficient in certain tasks such as communications. The symbiosis of quantum computing, AI, and cloud computing has a significant impact on processing power and decision-making efficiency. Quantum sensors are advancing in applications for defense, navigation, healthcare, and the detection of oil wells.

Key sectors for high impact and future applications

Industry

The development of **quantum sensors** capable of very high precision measurements will be key to optimize manufacturing processes. In addition, the Transportation and Automotive industries will provide the most innovative solutions, according to **Thierry Botter**, CEO of the **European Quantum Industry Consortium (QuIC)** and investment partner in **Quantonation**, the first European venture capital fund dedicated to quantum technologies.



Thierry Botter

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Telecommunications

Much progress is being made in **quantum key distribution (QKD)**. For example, **Hispasat**, in collaboration with the **National Cryptographic Center**, has registered a patent to connect two quantum computers using a geostationary satellite, by means of interlaced photons. This initiative is part of the **Caramuel** program, the world's first geostationary orbit satellite mission aimed at quantum key distribution, says **Antonio Abad**, **HISPASAT**'s Technical Director.

Antonio Abad

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Finance

Leading institutions are backing Quantum Computing to solve simulation, machine learning and optimization problems, to create new **financial models** for credit rating, risk, portfolio optimization—although quantum computing cannot completely solve this challenge, it may be able to identify more optimal portfolios than existing conventional optimizers; it will also be able to do so more quickly, allowing much more frequent portfolio updates, as **Esperanza Cuenca** points out—, credit analysis and fraud detection.

In addition, financial institutions across the board are working on **secure communications with quantum cryptography**, as **Sergio Gago**, General Manager of Quantum Computing at Moody's, points out. To learn more about quantum applications in financial institutions, we recommend the document *A Survey of Quantum Computing for Finance*.



Sustainability and climate risk

There is a huge business opportunity around quantum technologies and AI, through the **European Green Deal** and **Next Generation** funds. The key will be for new technological solutions to have a **triple sustainability purpose: social, economic and environmental**, says **Carlos Kuchkovsky**, co-founder and CEO of **QCentroid**, a company that offers a QaaS-Quantum as a Service-platform.



Carlos Kuchkovsky

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Pharmaceuticals and biotechnology

Quantum Computing solutions together with AI will provide new opportunities to **better understand the nature of diseases** and to **identify new drugs** by designing and selecting **new molecules** and optimizing their properties, says **Gopal Karemore**.



Gopal Karemore

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Sergio Gago

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New business models with Quantum Computing

Within the sectors mentioned above, very promising initiatives are already being launched, with new business models emerging around quantum technologies and AI.

Who are the key players in the Quantum Computing universe? Who will lead the way?

According to the experts attending the forum, **large corporations will lead the adoption of quantum technologies**. The ranking they believe will be as follows →

That said, all stakeholders should support, through agreements and investments, a process led by R&D, as pointed out by **Daniel Granados**, Research Professor and Executive Director of **IMDEA-Nanoscience**.

Below are some initiatives from large corporations and from the entrepreneurial ecosystem.



Daniel Granados

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Large corporations

Large corporations are already investing in quantum computing research and development to become more competitive in sectors such as finance, energy and pharmaceuticals.

Generally speaking, **corporations should start preparing themselves**. This is what **Sergio Gago** calls "quantum ready". How? By engaging profiles that are familiar with the possibilities of quantum technologies, and that lead the search for concrete and clear business cases.

This expert believes that corporations should approach quantum technologies with the understanding that **quantum supremacy**—a term that refers to the ability of a quantum computer to solve problems a classical computer cannot solve—is still many years away if it happens at all. And, at the same time, knowing that **there are real opportunities**.

In the very short term, just like Professor Latorre says, **there are opportunities around the components to build the necessary hardware.** Many large engineering companies are investing in this area and already generating business. There is also a **growing consulting and proof-of-concept development business.**

One proposal of the experts for the industry to be ready is to create **vertical Quantum Computing ecosystems**, focused on problems shared across a given type of industry: finance, manufacturing, logistics, etc.

There are already many large companies, such as Honeywell, Alibaba, JPMorgan or ExxonMobil, that have started to invest in quantum computing technology and there is a nascent movement to form partnerships between large corporations and research institutions and universities, in order to access the latest advances in quantum computing.

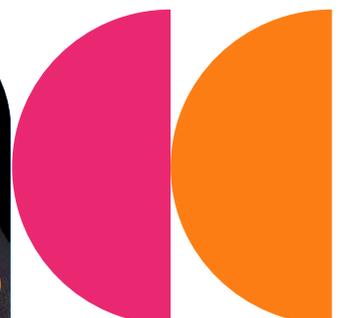
For their part, large IT providers such as Google, IBM and Microsoft are investing in the development of quantum computers and providing cloud-based access to their quantum computing resources for researchers and companies. So, for example, at IBM, in addition to developing the hardware and software needed for Quantum Computing, they are creating a **community of developers and users**, a place of constant interaction that feeds back their suggestions. At present, IBM has 26 quantum computers, to which more than 500,000 users are connected, including researchers from more than 100 universities, as **Alessandro Curioni** explains. They achieve this through the open-source development environment **Qiskit**, so that anyone can work with quantum computers, in pulses, circuits and application modules. Curioni is committed to the **symbiosis between traditional computing and quantum computing**, supported by the cloud. According to this expert, just as today there are specific processors for graphics (GPUs), which enhance the graphic processing performance and tasks related to image processing, there will be **quantum processing units** specifically designed to perform complex mathematical calculations

quickly and efficiently. And **these units will be in the cloud, available as an additional resource.**

Telecommunications as a sector is most actively pursuing innovations and solutions in quantum technologies, because of their potential to provide highly secure communication networks through the use of quantum key distribution (QKD) and to optimize networks through the use of quantum algorithms. As an example, Orange is involved in three European collaborative actions in quantum communications: the CiViQ (Continuous Variable Quantum communications) project, the OPENQKD (Open European Quantum Key distribution testbed) project and the QOSAC (Quantum Overarching System Architecture Concepts) research contract. In the near future, they will explore **use cases that point to a clear return on investment.** This is how **Carmen Reina**, Director of Data Culture at Orange, explains it.

Finally, the financial sector is another hectic sector, according to experts. There are two illustrative examples of financial institutions making progress in Quantum Computing: **JPMorgan Chase** and **Goldman Sachs**. The former is researching machine learning, cryptography, portfolio optimization and Monte Carlo simulations, while the latter is also actively researching where and how Quantum Computing can be applied in finance, with advanced developments, for example, in the **pricing of complex derivatives.**

Carmen Reina



"In the future, there will be quantum processing units in the cloud, available as just any other resource".

Alessandro Curioni

Startups

The startup universe is no stranger to the quantum + AI phenomenon. They have the opportunity to innovate and offer specific solutions for certain sectors and can also provide access to these technologies through the cloud. In addition, they can develop supporting technologies, such as programming software, simulation tools and machine cooling systems.

Some of the initiatives in which Spanish entrepreneurs are involved are illustrated below:

SandboxAQ is a **SaaS** company that combines AI and quantum technology. This spin-off of **Alphabet** is based in North America and is developing three business areas, as explained by **Marc Manzano**, Head of Quantum Security at this company:

01

Quantum simulation and optimization, which merges computational methods based on Artificial Intelligence and quantum to do forecasts and guide business decisions with very high accuracy. Applicable to a large number of sectors: drug discovery, materials development, financial modeling, supply chain logistics, etc...

02

Quantum sensing solutions, which take advantage of the inherent instability of quantum states to detect minute changes in the physical world, such as motion or electric and magnetic fields, that would otherwise be undetectable. Combining these properties with artificial intelligence, SandboxAQ is developing quantum sensing applications for the healthcare sector and

03

Post-quantum cryptography solutions (PQC), in line with the new standards that are emerging in this field.

Qilimanjaro Quantum Tech, is a startup that leverages its expertise in **superconducting qubits** to design next-generation **analog quantum processors** with **high-quality qubits**, which do not require quantum error correction and can therefore be commercialized faster. **Victor Canivell**, co-founder of this technology startup, explains why **a startup can succeed in the development and construction of quantum computers**, starting from academia (it is a spin-off of the University of Barcelona, the Barcelona Supercomputing Center and the Institute of High Energy Physics) and following with **transfer of knowledge from the scientists to the businesspeople**.

Multiverse Computing, founded in Spain in 2019, currently engages more than 80 professionals and has already grown from a startup to a **scaleup**. Headquartered in San Sebastian, it has subsidiaries in Canada, France and Germany. The company **develops quantum software**, specializing in vertical solutions, such as Finance, Energy, Mobility, Health, Defense or Aerospace. It has a SaaS platform that contains quantum and quantum-inspired algorithms developed and patented through proofs of concept that have been carried out for various clients, explains **Esperanza Cuenca**.

Quside, a spin-off of the Institute of Photonic Sciences (ICFO) has developed a Quantum Random Number Generator (**QRNG**), i.e. a system that uses quantum principles to generate random numbers. Their system is used in cryptography and other fields where there is a need for high-quality random numbers—in general, any situation where it is important to generate unpredictable results reliably, such as scientific research, simulations or games. The future of this startup looks bright, according to its co-founder and CEO, **Carlos Abellán**: a **Series A round** led by Trumpf Ventures, the investment arm of Trumpf, the world's leading industrial manufacturer of photonic components, was announced during the forum.

QCentroid, co-founded by Carlos Kuchkovsky, current CEO of the company, offers Quantum as a Service solutions for organizations and a marketplace for quantum HW and algorithms. This allows organizations to compare and find quantum-based solutions that they can integrate into their existing systems, through No-Code, APIs and Blockchain, or use them to create new applications that would have been otherwise impossible.

"Quantum sensing combined with Artificial Intelligence has enormous potential to improve people's health."

Marc Manzano

[▶ Go to profile](#)



ChatGPT synthesis

The chapter discusses the key sectors that will be impacted by quantum computing in the future. Quantum sensors will optimize manufacturing processes and transportation and automotive industries will provide innovative solutions. The financial sector will use quantum computing for simulations, machine learning, and portfolio optimization. Quantum cryptography is also being developed for secure communications in finance. Quantum computing combined with AI will improve pharmaceutical and biotech industries. The European Green Deal and Next Generation funds will focus on sustainability and climate risk. Large corporations, governments, and startups will lead quantum technology adoption. IBM, Google, and Microsoft are investing in the development of quantum computers and providing cloud-based access to their quantum computing resources for researchers and companies. Creating vertical Quantum Computing ecosystems, partnerships between large corporations, and research institutions and universities are proposed to advance quantum computing technology.

Opportunities and challenges in Europe/Spain

China is the country most likely to lead the quantum technology revolution, closely followed by the United States, according to a survey of the experts gathered at the forum. Experts such as Calum Chace warn of the danger of a duopoly in quantum technologies and AI being established between the US and China and widening the global digital divide.

But Europe is not idle: Today, there are public-private initiatives that are shaping a new ecosystem around quantum technologies.

Europe needs to be more strongly united, fostering a pan-European ecosystem to channel collaborations, investments, talent and strategies. In terms of talent, Europe is very well positioned as a generator of talent, but it is unable to retain it, due to a lack of competitive offers. While there are the same number of startups in the US as in Europe, the level of investment is 10 times higher in the US.

"Spain's great challenge is to retain and attract the best quantum talent."

Marc Manzano

Then, for the European quantum industry to be more competitive, it would be necessary to facilitate software patents. The U.S. accounts for half of the Intellectual Property registrations worldwide, with IBM, Microsoft and Google registering the most patents in recent years.

By way of example, a network of quantum computers is being built in Europe, one of them in Spain, through the European High Performance Computing Joint Undertaking (EuroHPC JU).

Europe needs to be more strongly united, empowering a pan-European ecosystem to channel collaborations, investments, talent and strategies."

Thierry Botter



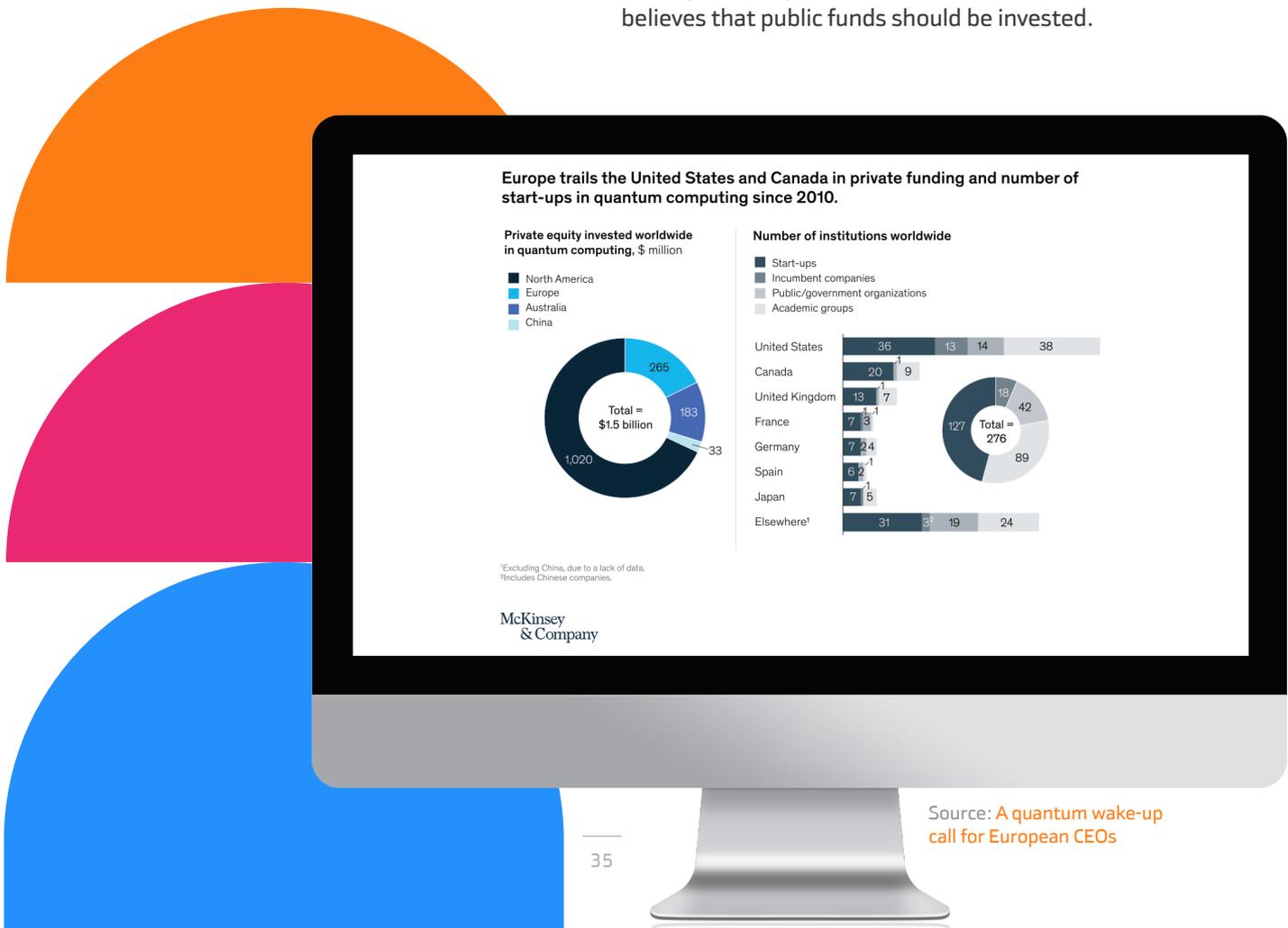
We have already seen how China and the US could eventually create a duopoly. **Carlos Kuchkovsky**, member of the World Economic Forum's Global Future Council on Quantum Computing and member of the Strategic Advisory Board of the European Commission's Quantum Program, outlines the European strategy, as well as the challenges to be solved. Regarding the latter, the most worrying ones are the lack of alignment between the European strategy and the various national strategies, how to connect quantum computing with algorithms in current business systems so that they are integrated into their workflows, the lack of a powerful tool for technology transfer between scientists and business, and the lack of investment muscle in Europe. According to this expert, Google and Amazon together may very well be investing more resources than the whole of Europe.

Meeting these challenges and seizing the opportunities is what the **Quantum Flagship** program, for which Kuchkovsky is an advisor, is all about: launched in 2018, it has a budget of at least €1 billion and a 10-year span. This initiative brings together research institutions, universities, companies and policymakers on an unprecedented scale.

Very recently, the first step towards the **definition of the first EU Strategic Research and Industry Agenda** has been taken. The ultimate goal of the SRIA will be to provide a comprehensive strategy on quantum technologies for the EU, considering and merging all ongoing industrial and R&D initiatives.

It is interesting to note that some experts point out that **Spain has a window of opportunity to lead in some quantum technologies**. One such voice is **Victor Canivell**, who believes that there are very good researchers in quantum technologies based in Spain and there are a few individual firm believers creating an ecosystem, engaging with large corporations and gaining visibility in other countries. For the technology startup model to take root in our country, it is necessary to get more investors to support quantum technologies and to attract and, above all, retain talent.

In fact, Spain is leading some Quantum Computing fields with the support of the public administration. Many of the startups that are emerging are founded by highly trained scientists. **Ignacio Cirac** is optimistic in this regard, although he would like to see more startups in components, i.e., in hardware, where he believes that public funds should be invested.



ChatGPT synthesis

Experts believe that China and the United States are most likely to lead the quantum technology revolution, which could create a digital divide. However, Europe is taking initiatives to develop a pan-European ecosystem to foster collaborations, investments, talent, and strategies. Europe needs to retain talent and facilitate software patents to compete with the US. Spain is building a network of quantum computers through EuroHPC JU, but the country needs to retain and attract the best quantum talent. The European Quantum Flagship program, with a budget of at least €1 billion, aims to address these challenges and seize opportunities. Spain has the potential to lead in some quantum technologies, but it needs more investors and talent to support and retain startups.

5



Ethics for quantum computing and artificial intelligence

5

Ethics for quantum computing and artificial intelligence

This chapter discusses some of the keys to the success of quantum technologies and AI as a society: ethical issues, training needs and the role of the media:

Ethics for quantum computing and artificial intelligence

Overall, the ethics of quantum computing and AI is a complex and rapidly evolving field that will continue to be a major bone of contention as the technology continues to advance. This is the thinking of **Theodore Lechterman**, Professor of Philosophy at IE University, who has been working at the **Institute for Ethics in AI at Oxford University**.

Noting that **science and technology are far ahead of ethics and governance**, this expert proposes that part of R&D investments be allocated to research in the fields of ethics and governance to find out what might work and what areas should be developed. It would be a matter of **finding out how we can translate good intentions into effective management strategies**.

Lechterman says that one of the main ethical considerations surrounding quantum computing is the possibility that it could be used for **malicious purposes**. Because quantum computers are capable of processing large amounts of data at extremely high speeds, they could be used to **decrypt encrypted information** or to develop new and more powerful **weapons**. This could have serious implications for **national security** and **personal privacy**.

He also explains that, when we combine AI and quantum, a number of hazards must be considered, such as the existence of **biases**—both in the data and in the algorithms. In addition, many of the benefits of AI require us to give up data from our personal lives to the algorithms, which again puts our **privacy** at risk.

In addition to the illicit use, biases and danger to privacy, **the explainability of quantum computing and artificial intelligence systems** must also be resolved. Especially when we are talking about very large, very powerful and very advanced quantum computing solutions combined with AI with, in some cases, millions of parameters. It may be impossible to determine why a particular decision has been made and how to verify whether it is correct/fair. This raises the question of under what conditions there should be an obligation for such a system to explain how it arrived at certain results.

These questions need to be **addressed systematically** to think about what the best causes really are and how we should allocate resources when studying the different potentially beneficial uses of quantum computing and AI, explains Lechterman. **Companies that are able to lead the way in quantum ethics**, proving that they are trustworthy to their stakeholders, **will have a huge competitive advantage in a business that is so nascent** and yet has so much potential, he concludes.

Education and talent acquisition

Regarding **education and talent attraction and retention**, what plans are already in place and what strategies should be defined to have a **workforce learned in the field of quantum technologies and AI?**

The profiles needed are both scientific and business profiles that understand the implications of these technologies. At present, there is little specific training and experts agree that these are subjects that should be introduced in educational programs from early childhood.

The educational program launched by the U.S. government is worth mentioning: the **National Strategic Plan for Quantum Information Science and Technology Workforce Development**. The plan recommends a series of community actions and opportunities to increase the Quantum Information Science and Technology (QIST) workforce by **expanding training and education at all levels**, according to **Ángel Cabrera**, President of the Georgia Institute of Technology and trustee of the Bankinter Foundation of Innovation. The program

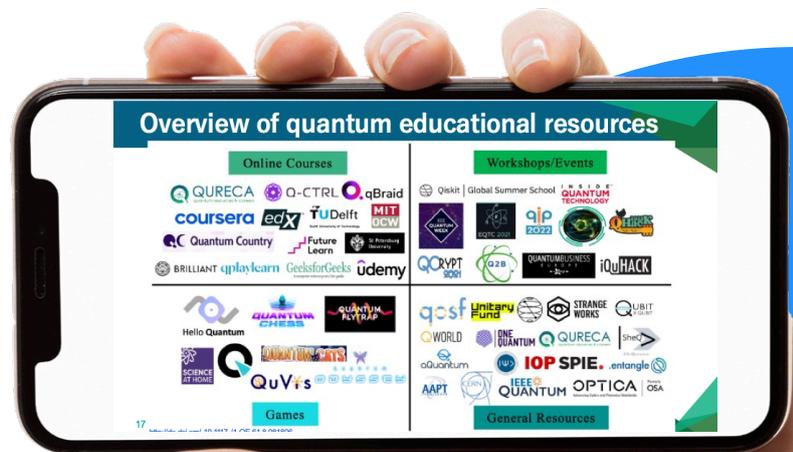
underscores the importance of continuing to collect data on workforce needs in industry, academia and government, and to **develop long-term learning opportunities to expand and broaden the talent pool**.

A professional profile specialized in a specific industry who also has quantum training will be fundamental in the future, as it will act as a **link between business and technology**, generating new specific solutions. This is the opinion of **Araceli Venegas-Gómez**, founder and CEO of **Qureca**, who notes the shortage of professionals trained in quantum technologies and points out the need for certain **quantum skills to be horizontal**.

Experts agree that implementing a new academic discipline takes time and that now is the time to design it.

Some of the specific training initiatives are:

"The talent for quantum + AI will largely come from spin-offs from universities and research centers."



A new narrative for Quantum and artificial intelligence

The media play an important role in educating society about quantum technologies and AI. And therefore, they have a responsibility to give them visibility and convey their reality and potential. Journalism must avoid the risk of hyperbole and predictions that do not come true, and, at the same time, know how to convey clear concepts of highly complex technologies, presenting the challenges and opportunities that open up in different fields. At the same time, we must **fight against the disinformation** often generated by social networks. So says **Scott Simon**, writer and journalist, director of several programs at **NPR**—the US public broadcasting service—and Trustee of the Bankinter Foundation of Innovation.

It's not just about explaining how the technology works. It's about taking the big picture and asking the hard questions in order to convey the information as fully and honestly as possible: "How are we going to use this? What are the potential risks and hopes of this technology? Who is going to use it? Who is going to own it? Who is going to have access to it?" And you also have to consider the political, cultural and social context, explains **Victoria Turk**, Director of Reporting for **Rest of World**, a mainstream technology publication focused on countries outside of North America and Europe.

**Scott
Simon**



**Victoria
Turk**



ChatGPT synthesis

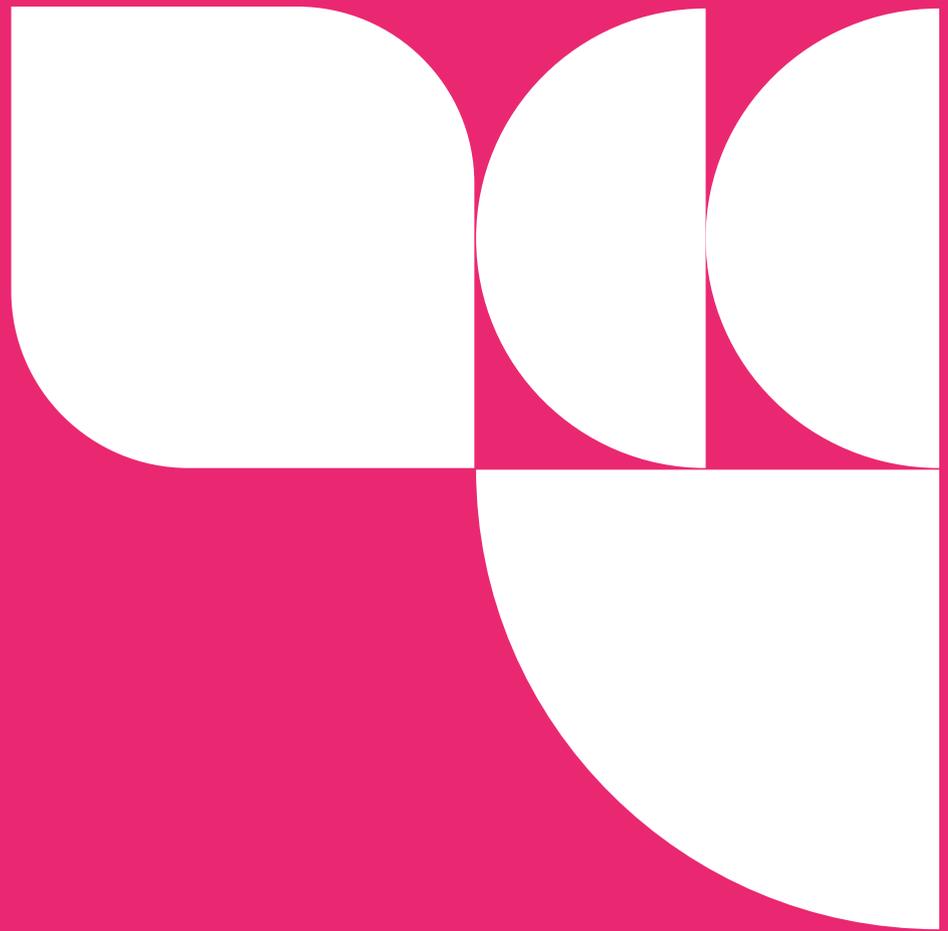
This chapter highlights the importance of ethics, education, and media in the success of quantum technologies and AI. The ethics of quantum computing and AI is a complex field that requires allocation of R&D investments to research in the fields of ethics and governance. The educational programs need to be introduced from early childhood to train a workforce learned in the field of quantum technologies and AI. The media have a responsibility to educate society about quantum technologies and AI and convey their reality and potential while avoiding hyperbole and disinformation. The professional profile specialized in a given industry and having a quantum background will be essential in the future. Specific training initiatives have been launched in the field of quantum technologies and AI.



Theodore Lechterman

[Go to profile](#)

6



Actions to Be Taken to Join the Quantum + AI Revolution

6

Actions to Be Taken to Join the Quantum + AI Revolution

In order for all stakeholders to have a roadmap to the opportunities and challenges arising from the sum of quantum technologies and AI, the following is presented:

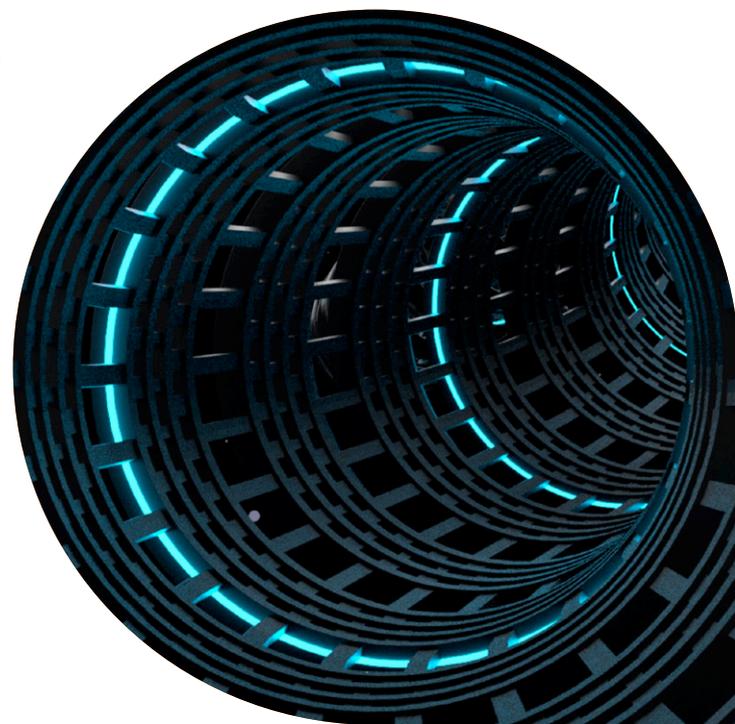
What business leaders should consider.

What kind of profiles will be needed.

How to promote Quantum + AI startups in Europe/Spain.

"There is much to be done and much to be discovered in quantum technologies. Unexpected applications and solutions will emerge that no one is contemplating today".

Juan Ignacio Cirac



Quantum strategy roadmap for business leaders

In order for corporate leaders to navigate the changes that quantum technology brings along with AI and also, to seek financial backing, both privately and publicly, a roadmap must be in place that contemplates:

- the impact of these technologies on existing business models,
- quantum trends that bring more value to the business,
- the professional profiles that should join the working groups on quantum strategy,
- the desirability of taking an offensive or defensive position against the competition, and
- the criteria to be taken into account when making decisions affecting the business in relation to these technologies.

Quantum technologies and new professional profiles

Based on the previous roadmap, where the roles that will be needed in business are determined, it is necessary to look for talent.

First, a decision must be made about what kind of skills and profiles are desirable: should they have a background in technology, business, or both?

Given the very early stage of these technologies, finding the type of training offered in the market needs to be addressed too.

Experts believe that **the problem at hand is not a technological problem; it is a change management problem.** Therefore, they recommend a similar approach to other challenges around new technologies introduced in business: cloud computing, digitization or cybersecurity.

We can use the same type of process to create or attract internal leaders, recruit external help, and train staff to know why this is important.



Promotion of Quantum + AI startups in Spain/Europe

Since quantum technologies are at a different stage of maturity than AI, some considerations about the former:

A quantum startup is different from any other technology startup in three broad categories:

- 1.- The difficulty of having the right technological talent.
- 2.- Uncertainty about the results. It is not yet known if and when quantum technologies will be scalable. For a specific task, such as the random number generation mentioned above by **Carlos Abellán**, we know that there already is a need and a solution, but in other cases it is not clear when quantum will have created a clear competitive advantage, if ever.
- 3.- Start-up cost. Basically, these are capital-intensive companies with long-term returns on investment. Combined with the other two factors, they are not interesting for venture capital.

The costs of patents, at least in Europe and particularly in Spain, to protect intellectual property must be added to the above.

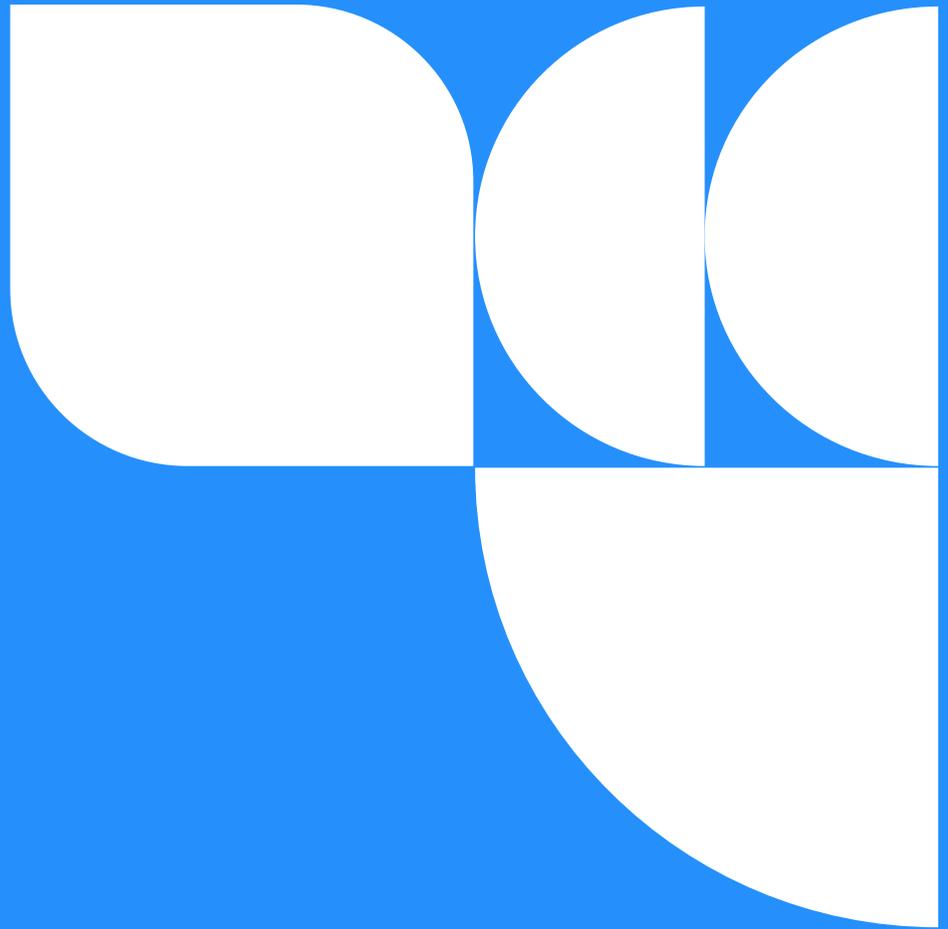
The solution? Trying to draw some parallels with other areas where this has happened before—such as the biotech industry. It follows that it is necessary to accelerate as much as possible the creation of ecosystems equivalent to **Media Labs** or **Kendall Squares**, which allow startups to have access to leading labs on a competitive basis.

Regarding AI startups, understanding that they are high-tech AI companies that usually come from a research center and have cutting-edge technology that still needs to expand in the market, two difficulties arise: **scaling the company** and **retaining talent**. The experts' proposal: create a technology transfer office (TTO), from which to address the problem.

ChatGPT synthesis

A roadmap is needed for stakeholders to navigate the opportunities and challenges of quantum technologies and AI, including considerations for business leaders, necessary professional profiles, and promoting startups. Talent must be sought after and trained for the early stages of these technologies. Quantum startups face challenges such as difficulty in finding the right talent, uncertainty about results, and high start-up costs. AI startups face challenges of scaling and retaining talent. Accelerating the creation of ecosystems for startups and creating a technology transfer office are potential solutions to overcome these challenges.

7



Quantum + AI Predictions

Quantum + AI Predictions

After presenting and analyzing the state of the art, as well as the challenges and opportunities, we conclude with some of the forecasts made by the Future Trends Forum experts regarding quantum technologies combined with artificial intelligence: what kind of actors will do what kind of actions and when? With what expected results? The following are the main projections for the future of quantum technologies + AI, if the actions proposed by the experts are followed:

Immediately

- From European governments, creation of quantum centers of excellence that incorporate all stakeholders, unify initiatives and generate traction.
- Creation of bootcamps (intensive and immersive courses) in Quantum + AI to generate quantum talent.

By 2025

- Creation of public funds to develop Quantum + AI solutions for major societal challenges.
- European venture capital funds will be set up to have the ability to invest in deep tech for the longer term. As a result, the 10-to-1 gap between the U.S. and Europe in terms of investment in quantum startups could be closed.
- Successful divestments ("exits") will occur and there will be a high survival of quantum and AI-driven startups

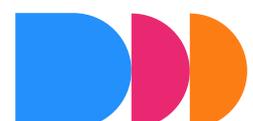
Between 2025 and 2030

- In five years, quantum engineering will be implemented as a new discipline, and in ten years, quantum concepts will be introduced throughout the education system.
- Large enterprises will scale quantum technologies efficiently by 2030, resulting in widespread use thereafter.
- At the end of the period, the quantum advantage will be achieved, i.e., quantum computers will outperform traditional computers in broad fields of application.

As of 2030

- **Upskilling and Reskilling** will be widespread to equip current professionals with quantum skills and there will be long-term quantum training strategy planning.
- The general public will be familiar with quantum technologies.
- Creation of vertical quantum computing + AI ecosystems to address customized solutions by industry sectors: finance, industry, health and pharma, etc.
- Around 2045, there will be professionals highly prepared for Quantum + AI from early childhood.

Players	Today	2025	2030	2035	2040	2045	2050
Public Administrations	<p>Urgent need for a single pan-European quantum strategy</p> <p>More public funding for basic science</p> <p>Develop a national strategy aligned with the very much needed European strategy to pave the way for the industry</p> <p>Creation of a center of excellence that brings together all stakeholders, unifies initiatives and gets traction</p>	<p>Reasonable, smart, sensible, and flexible regulation. Result: ingenuity will flourish</p> <p>Allocate public funds to work on Quantum + AI solutions to the great social challenges</p>					
Large corporations	<p>Transition to quantum and post-quantum cryptography</p> <p>Prepare their business quantum strategy</p>	<p>Fund quantum R&D</p> <p>Help governments develop quantum strategies</p> <p>Greater awareness and actions around Quantum + AI</p>	<p>Action: Quantum technologies scale efficiently. Outcome: greater availability</p> <p>Current professionals re-skill and upskill, long-term learning strategy is planned</p> <p>Create quantum computing + AI vertical ecosystems</p>				
Startups	<p>Support investors in high-tech funds</p> <p>Close the 10:1 gap between US and European investments</p>	<p>Focus on delivering practical solutions and on integration</p> <p>Grow and expand internationally</p>					
Education	<p>Quantum literacy: teach the basics in quantum at a very young age, training the teachers</p> <p>Create bootcamps (intensive and immersive courses) on Quantum + AI</p>	<p>Multidisciplinary fields penetrate quantum</p> <p>Teaching ethics beyond the technical approach</p>					There will be highly skilled professionals in quantum + AI from early childhood



Players	Today	2025	2030	2035	2040	2045	2050
R&D	More spin-offs from research centers		The quantum advantage: quantum computers beat traditional computers in broad fields of application			Artificial General Intelligence boosts quantum technologies	
Investors	<p>New financial instruments are developed</p> <p>Deep knowledge of the basic technologies and what they offer</p> <p>Bring experts in quantum technology to boards to detect real opportunities</p> <p>Promote commercial quantum possibilities in Europe</p>	<p>Venture capital funds emerge in Europe for quantum technology-driven startups</p> <p>R&D strategic investments supported by public funding</p> <p>Successful exits and high survival rate of startups with a quantum + AI core</p>					
Media outlets	<p>Make the problems we can solve today more visible</p> <p>Real success cases should be more prominent</p>	Go beyond the hype to make the industry accountable	The general audience is familiar with quantum technologies				



Finally, a thought from **Brian Lenahan**:

*"The challenges of how to scale quantum technologies, how to decrease errors and how to design new algorithms for Quantum + AI remain significant, but progress is being made and **Quantum + AI should provide some of the most exciting technological breakthroughs over the next decade.**"*

And a conclusion by **Dr. Latorre**:

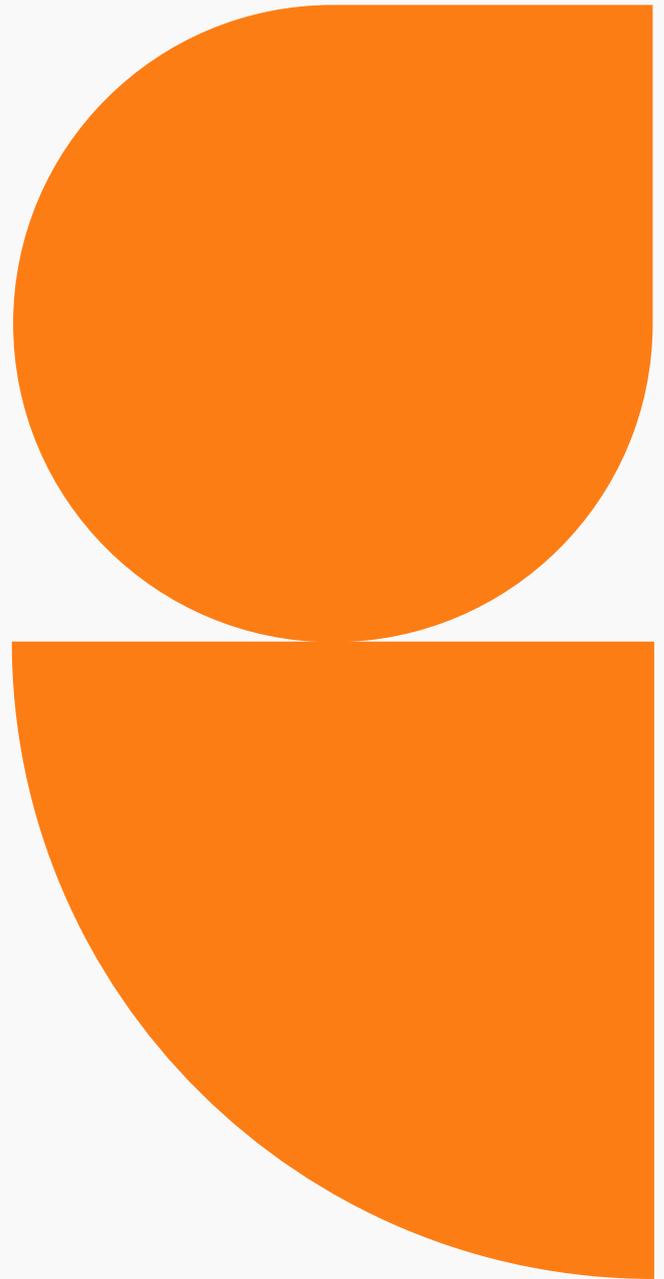
*"So much hype with unrealistic expectations can lead to **despondency**. Also, in the long run, **AI is more exciting than quantum technologies** and as of today **there is either no quantum talent or it is too expensive,***

BUT

*The pace of **scientific progress remains very remarkable, top talent choosing quantum technologies and technological sovereignty over quantum is paramount** given the current international geopolitical juncture."*

ChatGPT synthesis

Experts from the Future Trends Forum predict that the combination of quantum technologies and artificial intelligence will lead to exciting technological breakthroughs over the next decade. Immediate actions proposed include the creation of quantum centers of excellence and bootcamps for generating quantum talent. By 2025, public funds will be created to develop Quantum + AI solutions for societal challenges, and the gap between investment in quantum startups in Europe and the US could be closed. Between 2025 and 2030, quantum engineering will be implemented, and large enterprises will efficiently scale quantum technologies. By 2030, upskilling and reskilling will be widespread, and the public will be familiar with quantum technologies. The conclusion is that technological sovereignty over quantum is crucial, and the pace of scientific progress is remarkable.



Annex - Glossary

Annex - Glossary

Ranked in order of
appearance in the report.

Quantum rules

Quantum physics defines new rules of the game that may be counter intuitive. In a nutshell:

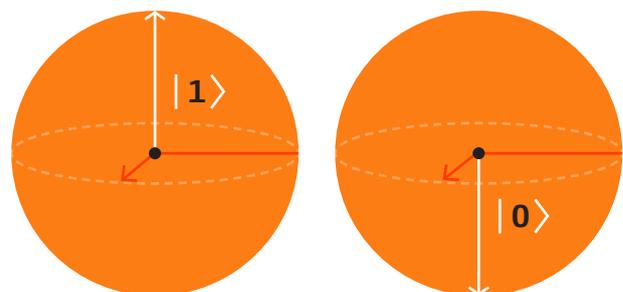
- Subatomic particles, such as photons and electrons, are described in terms of probability **waves**. These waves do not have a definite position or velocity but represent the probability of finding a particle in a certain position or with a certain velocity.
- It is impossible to accurately measure the position and velocity of a subatomic particle at the same time. This is known as the **Heisenberg uncertainty principle**.
- Subatomic particles can be in several states at the same time, a phenomenon known as **quantum superposition**.
- Subatomic particles may be connected across space and time in a way that cannot be explained by classical physics. This phenomenon is known as **quantum entanglement**.

Definition of qubit

The basic information element in a quantum system is the **qubit**, and it can take any value in a continuum of quantum states. Unlike a bit, which is the basic unit of information in classical computing and can have two states (zero or one), a qubit can be in a linear combination of both states at the same time (quantum superposition).

For example, a qubit can be in state $|0\rangle$ (zero) with a probability of 0.7 and in state $|1\rangle$ (one) with a probability of 0.3. This means that, if we were to measure the qubit, we would have a 70% probability of obtaining the result $|0\rangle$ and a 30% probability of obtaining the result $|1\rangle$.

They are usually represented as follows:



$$|\psi\rangle = \frac{|1\rangle + |0\rangle}{\sqrt{2}}$$

Source: <https://ecfm.usac.edu.gt/node/364>

The foundations of quantum technologies:

Some of the most advanced technologies in **Quantum Computing** are:

- **Atom-based** quantum computing: in this approach, atoms are used as qubits and their quantum properties are exploited to perform computations.
 - » *Pros:* atoms are highly stable and easily controllable, which makes them suitable for use as qubits.
 - » *Cons:* It is difficult to scale this technology and create quantum systems with many qubits.
- **Photon-based** quantum computing: in this approach, photons (particles of light) are used as qubits and their quantum properties are exploited to perform computations.
 - » *Pros:* photons have a high transmission speed, which makes them suitable for long-distance quantum communications.
 - » *Cons:* Photons are difficult to control and keep stable, making them difficult to use as qubits.
- **Superconductivity-based** quantum computing: in this approach, superconducting devices are used to create and control qubits.
 - » *Pros:* qubits can be created and controlled very precisely using superconducting devices.
 - » *Cons:* These devices are fragile and require extreme conditions (such as very low temperatures) to operate.
- **Defect-based** quantum computing: in this approach, defects in crystalline materials, such as diamonds, are used to create and control qubits.
 - » *Pros:* qubits can be created and controlled very precisely using defects in crystalline materials.
 - » *Cons:* As in the case of atom-based technology, it is difficult to scale this technology and create quantum systems with many qubits.

As can be seen, each of these technologies has its own strengths and weaknesses, and they are all developing rapidly and in parallel. Today, experts do not say which of them will eventually prevail or whether they will coexist, since the field is constantly evolving, and it is likely that even new core technologies will emerge in the future.

Similarly, in **quantum communications**, where quantum mechanical principles are used to transmit information from one place to another in a secure manner, the most advanced technologies include:

- **Quantum optic fiber** communication: In this approach, optic fibers are used to transmit quantum signals over long distances.
 - » *Pros:* optic fibers are stable and can transmit quantum signals over long distances with little loss of quality.
 - » *Cons:* The optical fibers are fragile and can be easily damaged.
- **Quantum satellite** communication: in this approach, satellites are used to transmit quantum signals over long distances.
 - » *Pros:* satellites can transmit quantum signals over long distances with little loss of quality.
 - » *Cons:* The high cost of deploying and maintaining satellites in space.
- **Quantum line-of-sight** communication: in this approach, direct lines of sight (e.g., through a telescope) are used to transmit quantum signals over large distances.
 - » *Pros:* Allows quantum signals to be transmitted over long distances without the need for optic fibers or satellites.
 - » *Cons:* Requires direct sight lines, which limits its range and flexibility.
- **Mobile** quantum communication: in this approach, mobile devices are used to transmit quantum signals over short distances.

- » Pros: Allows to transmit quantum signals over short distances in an easy and convenient way.
- » Cons: Maximum transmission distance is limited and can be interrupted by physical obstacles.

As we can see, and as with quantum computing, each of these technologies has its own strengths and weaknesses and new technologies are likely to emerge in the future. In the case of quantum communications, experts believe that it will be more likely that several of them will coexist to address different issues.

Finally, in quantum measurements or quantum sensing, where quantum mechanical principles are used to measure physical quantities with high precision, these are some of the most advanced technologies:

- Quantum **position and velocity** sensors.
- Quantum **electromagnetic field** sensors.
- Quantum **temperature** sensors.
- Quantum **pressure** sensors.

As with quantum computing and quantum communications, each of these technologies has its own strengths and weaknesses, and new technologies are likely to emerge in the future. In this case, the strength of all of them is common: **high accuracy** versus existing solutions. The weakness of all of them is that they are **difficult to implement** and **require special conditions** to work optimally.

HHL algorithm (Harrow-Hassidim- Lloyd)

This is a quantum algorithm, theoretically proposed in 2008, for solving systems of linear equations. Solving systems of linear equations is a common problem that arises both alone and as a subroutine in more complex problems. The HHL algorithm provides a solution to this type of problem with an exponential improvement in solving time over the best classical algorithm. For more information: [Quantum algorithm for solving linear systems of equations](#)

Ordenadores cuánticos NISQ (Noisy Intermediate-Scale Quantum)

Noise and decoherence are major problems for today's quantum computers, which also have trouble scaling beyond a few hundred qubits. They are called NISQ, literally, noisy intermediate-scale quantum computers. The good news is that algorithms have begun to be designed that, running on such NISQ computers, could solve problems that would have huge implications. For more information: [NISQ computing: where are we and where do we go?](#)

Neuromorphic quantum computing

Neuromorphic quantum computing seeks to physically implement neural networks in brain-inspired quantum hardware to accelerate their computational capacity. More information, here: [Quantum neuromorphic computing](#)

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