Digital Skills & Jobs Platform

# From Futuristic Tales to Real-World Quantum Advancements in Europe

## How quantum technology is reshaping European industry, security, and health and the quantum skills this transition demands

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# Executive Summary

For much of the 20th century, quantum technology existed only in the realm of imagination, in thought experiments dreamed up by physicists, in the pages of science-fiction novels, and in the speculative visions of futurists who described computers of impossible power and communication that could not be intercepted or broken. Today, this imagined world is becoming real. Across Europe, quantum computers are moving from laboratory curiosities to commercially relevant machines in which quantum communication networks are protecting critical government infrastructure from eavesdropping, and quantum sensors are enabling medical devices that can map the human brain without so much as touching it. Europe has placed quantum technology at the centre of its digital strategy, investing €1 billion through the Quantum Flagship programme and embedding quantum ambitions in its cybersecurity, health, and industrial policies. But the journey from futuristic tales to a functioning quantum economy is not only a story about hardware and algorithms. It is equally a story about people, skills, and the readiness of a workforce and a society to inhabit a genuinely new technological world. This brief follows that journey -from the imaginative origins of the quantum idea to the practical advancements reshaping European industry and public services today - and asks what it will take to make the most of the new world quantum technology is opening.

# Keywords

#Quantum technology, #Quantum computing, #Quantum skills, #European quantum ecosystem, #Quantum Flagship

# About the Author

Dr. Nedžad Pirić is a researcher, academic supervisor, and consultant specializing in digital transformation, digitalization, and digital economy, with extensive experience spanning the private sector, international development, and higher education. He holds Ph.D. in Economics and Business. He serves as Adjunct Professor at GlobalNxt University, Malaysia, where he delivers academic supervision of DBA and PhD research proposals. His professional career spans over two decades of international work, including senior HR management roles, asset and business development management internationally and in Bosnia and Herzegovina, and leadership positions in digital transformation at the EU Tech Chamber. Since 2022, he has been serving as Senior Program Digitalisation Expert on EBRD- and EU-supported Go Digital programmes in the Western Balkans, supporting the digital resilience and innovation capacity of SMEs across the region. Since 2026, he has also served as Advisory Board Member of the EU–Western Balkans Business Council in Brussels.

# What did we once imagine quantum technology could do and why did it seem so far-fetched?

The story of quantum technology begins not with engineers or entrepreneurs, but with storytellers and dreamers. Long before the first qubit was manipulated in a laboratory, the strange implications of quantum mechanics had already captured the popular imagination. Science-fiction writers of the mid-twentieth century conjured worlds, in which computers solved in seconds problems that would take classical machines into the age of the universe. They described unbreakable code based on the laws of physics rather than the difficulty of mathematics, and communication channels so secure that no eavesdropper could ever intercept a message without being immediately detected. These were not merely entertaining fantasies. They were intuitive extrapolations from a body of physics that genuinely seemed to promise something categorically different from anything that had come before. Over a century ago (125 years to be precise, Max Planck laid the foundations of quantum theory, paving the way for revolutionary discoveries. What was once the realm of science fiction is now, in the year 2026, becoming a reality through a series of extraordinary achievements in quantum technology.

The theoretical foundations of these visions were laid in the first decades of the twentieth century by physicists grappling with the behaviour of matter at the subatomic scale. When Erwin Schrödinger proposed his famous thought experiment of a cat simultaneously alive and dead, a vivid illustration of the quantum principle of superposition, he was not describing science fiction; he was highlighting the genuinely counterintuitive logic of quantum mechanics.

Quantum mechanics has remained remarkably stable as a theoretical framework for nearly a century, but from the 1980s onwards physicists and computer scientists began to ask a different question - not "what does quantum mechanics tell us?", but "*what can quantum mechanics do for us?*" Richard Feynman's 1982 proposal that a quantum computer could simulate quantum systems far more efficiently than any classical machine (Feynman, 1982) transformed quantum computing from a theoretical curiosity into an engineering target. Peter Shor's demonstration in 1994 that a quantum computer could factor large numbers exponentially faster than any classical algorithm further cemented the case that the engineering effort was worth pursuing (Shor, 1994). The futuristic tales, it turned out, had a rigorous mathematical foundation.

So, how did the quantum dream cross the bridge from imagination into the laboratory and into Europe's strategy? The transition from thought experiment to working technology did not happen overnight, nor did it happen in one place. It emerged from decades of patient, often unglamorous experimental physics mostly conducted in European universities, in which researchers developed the techniques needed to isolate, manipulate, and measure individual quantum systems with ever-greater precision and reliability. The Nobel Prizes awarded in 2012 to Serge Haroche (France) and David Wineland (United States) for their work on measuring and manipulating individual quantum particles represented a landmark recognition that the engineering of quantum systems had become a genuine scientific discipline, not merely a speculative one. European laboratories were at the heart of this transition, and institutions such as the University of Innsbruck, TU Delft, ETH Zurich, and Sorbonne University accumulated the experimental expertise that now underpins the continent's quantum industrial base.

Europe's political recognition of this opportunity was crystallised in 2016, when the European Commission published its Quantum Manifesto, a document signed by over 3,400 researchers and industry representatives calling for a coordinated European effort to turn quantum science into quantum technology. As a result, the Quantum Flagship was launched in 2018 as a ten-year, €1 billion initiative spanning quantum computing, quantum simulation, quantum communication, quantum sensing, and the foundational science that connects all four (European

Commission, 2023). The futuristic tales of powerful quantum computers and unbreakable quantum networks became now, officially, a matter of European industrial policy.

What distinguished Europe's approach was not simply the scale of its investment but its explicit recognition that quantum technology is a systemic challenge which requires simultaneous progress in hardware, software, applications, standards, and skills. National programmes in Germany (over €2 billion committed to the Quantum Computing Initiative), France (the Plan Quantique), and the Netherlands (Quantum Delta NL) added further depth, creating a layered ecosystem in which fundamental research, applied engineering, and commercial scale-up could proceed in parallel rather than in sequence. The bridge from imagination to reality was truly being built - from both ends - at once.

# What do terms like qubit, superposition, and entanglement mean and why do they matter?

Before examining what quantum technology is already doing in European hospitals, government networks, and industrial facilities, it is worth pausing to establish what quantum technology is and what distinguishes it so fundamentally from the classical computing and communications systems that underpin our current digital economy.

The European Commission defines quantum technologies as "a new generation of technologies based on the unique physical properties of quantum mechanics, such as superposition and entanglement, which allow quantum systems to process information in ways that are impossible for classical computers" (European Commission, 2023). At the heart of this definition are three concepts that appear throughout any serious discussion of the field.

A qubit (short for quantum bit) is the basic unit of quantum information. Unlike a classical bit, which can be either 0 or 1, a qubit can exist in a superposition of both states simultaneously. This is not a metaphor or an approximation: it is a physical property of quantum systems that allows a quantum computer to explore many possible solutions to a problem at the same time rather than testing them one by one. Entanglement is a second property in which two or more qubits become correlated in such a way that the state of one instantly determines the state of the other, regardless of the physical distance between them. This property is the foundation of quantum communication and quantum sensing, enabling levels of coordination and security that are physically impossible to achieve with classical systems. Quantum interference, a third key property, allows quantum computers to amplify correct solutions and cancel out incorrect ones during computation, making the process of arriving at an answer fundamentally more efficient for certain classes of problem.

These properties do not make quantum computers universally faster than classical ones. They make quantum computers categorically better at specific types of problem: simulating molecular and chemical interactions, optimising complex logistical systems, breaking and building cryptographic codes, and sensing physical phenomena at levels of precision that classical instruments cannot reach. It is precisely this targeted advantage, rather than a general-purpose speed improvement, that explains why quantum technology is attracting such focused investment in healthcare, cybersecurity, and industrial optimisation which are three domains this article examines.

# What does the new quantum world look like in Europe today and who is already living in it?

Perhaps the most important corrective to the lingering perception of quantum technology as a future promise is this: quantum technology is already here, in Europe, delivering practical results in fields that matter to citizens and organisations today. Futuristic tales describe a world transformed by quantum machines; the transformation has begun, even if it remains incomplete and unevenly distributed.

## How is quantum technology already changing European healthcare?

In healthcare, the gap between science fiction and scientific practice is narrowing at remarkable speed. For example, quantum sensors are now being used to build a new generation of wearable brain scanners. Magnetoencephalography (MEG) systems based on quantum sensing technology have been clinically validated in hospitals in the United Kingdom, Germany, and the Netherlands, offering sensitivity comparable to traditional superconducting systems without the need for cryogenic cooling (Boto et al., 2022). These devices are opening new possibilities for the diagnosis of conditions that affect millions of Europeans such as epilepsy, dementia, and traumatic brain injury in clinical settings that were previously inaccessible to high-precision neuroimaging. At the same time, European pharmaceutical companies are beginning to run quantum chemistry simulations on near-term quantum hardware to model molecular interactions that remain intractable for classical computers, with the aim of accelerating the discovery of new treatments.

## What does quantum security mean for European governments and businesses today?

In cybersecurity and communications, the futuristic tale of an unbreakable, physics-guaranteed secure channel is becoming an operational reality. The European Quantum Communication Infrastructure (EuroQCI), a flagship initiative under the EU's Cybersecurity Strategyc, is developing a pan-European quantum-secured network connecting government institutions and critical infrastructure across all Member States (European Commission, 2024). National pilot systems are already operational or under active construction in Austria, Spain, the Czech Republic, and several other countries. These networks use quantum key distribution (QKD), a technique that was once a theoretical proposal in a physics paper and is now a commercially deployed protocol to protect sensitive communications from interception. The European Union Agency for Cybersecurity (ENISA) has simultaneously published detailed guidance on the transition to post-quantum cryptography, helping organisations across Europe begin protecting their data against the future threat posed by quantum computers capable of breaking current encryption (ENISA, 2023). The imagined world of quantum-safe communications is, in practical terms, already being built.

## Where is quantum optimisation already delivering results in European industry?

In industry and logistics, quantum optimisation algorithms are being trialed by European companies in sectors from aviation to energy. European airline companies and several national energy operators are already running proof-of-concept trials with quantum optimisation tools, with early results suggesting meaningful efficiency gains in route planning and grid load balancing that would be computationally prohibitive using classical approaches alone.

## Who will inhabit the new quantum world and what skills will they need to thrive in it?

Every technological transition creates a new landscape of skills and occupations, and quantum technology is no exception. But the human dimension of the quantum transition has a particular character that distinguishes it from previous waves of digital change. The skills required to build, deploy, and work with quantum systems are genuinely new and they cannot be acquired simply by updating existing knowledge. Also, the lead times involved in developing them are long. A quantum hardware engineer, a quantum algorithm developer, or a quantum network architect typically requires a decade or more specialised education and training. The workforce decisions that Europe makes today will shape the quantum ecosystem of the 2030s and beyond.

A practical framework developed under the Quantum Flagship identifies three tiers of quantum competence, each relevant to a different segment of the workforce. At the foundational tier, quantum awareness is the ability to understand without necessarily being able to calculate what quantum technology is, what it can realistically do, and where it is likely to affect different industries and professions. This level of literacy is essential for business leaders, policy makers, procurement officers, regulators, and informed citizens: the people who will make decisions about quantum technology without necessarily operating it directly. At the practitioner tier, quantum literacy for adjacent professionals covers the knowledge needed by software developers, data scientists, cybersecurity specialists, and engineers who will work alongside quantum systems, integrate quantum tools into existing workflows, or assess quantum risk in their organisations. At the expert tier, quantum specialists bring deep technical mastery of quantum hardware architectures, error correction, algorithms, or communication protocols, typically grounded in advanced postgraduate research. See *Figure 1* below for a visualisation of this.

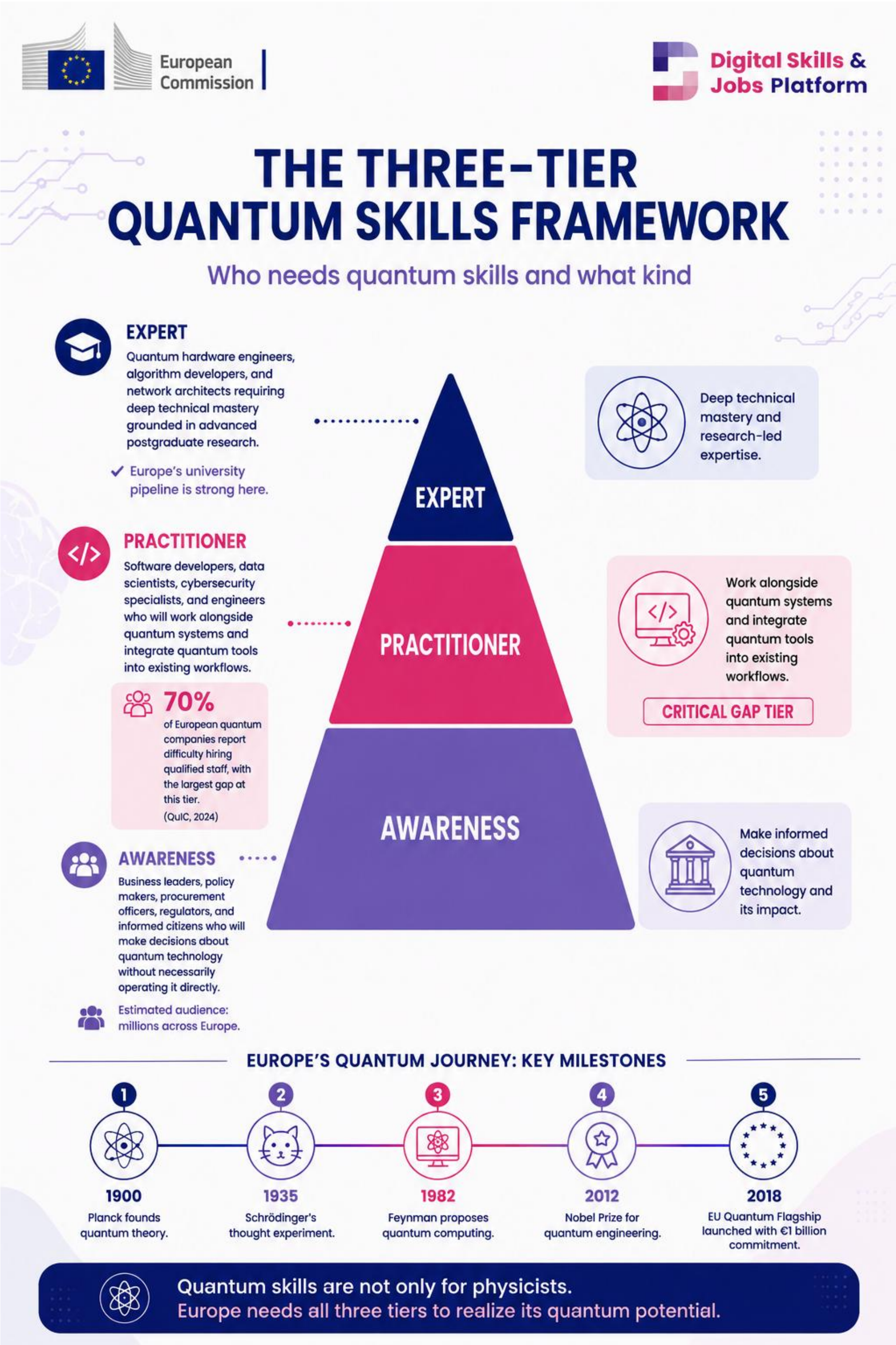
European Commission
Digital Skills & Jobs Platform
THE THREE-TIER QUANTUM SKILLS FRAMEWORK
Who needs quantum skills and what kind
EXPERT
Quantum hardware engineers, algorithm developers, and network architects requiring deep technical mastery grounded in advanced postgraduate research.
Europe's university pipeline is strong here.
Deep technical mastery and research-led expertise.
EXPERT
PRACTITIONER
Software developers, data scientists, cybersecurity specialists, and engineers who will work alongside quantum systems and integrate quantum tools into existing workflows.
PRACTITIONER
Work alongside quantum systems and integrate quantum tools into existing workflows.
CRITICAL GAP TIER
70%
of European quantum companies report difficulty hiring qualified staff, with the largest gap at this tier.
(QuIC, 2024)
AWARENESS
AWARENESS
Business leaders, policy makers, procurement officers, regulators, and informed citizens who will make decisions about quantum technology without necessarily operating it directly.
Make informed decisions about quantum technology and its impact.
Estimated audience: millions across Europe.
EUROPE'S QUANTUM JOURNEY: KEY MILESTONES
1
1900
Planck founds quantum theory.
2
1935
Schrödinger's thought experiment.
3
1982
Feynman proposes quantum computing.
4
2012
Nobel Prize for quantum engineering.
5
2018
EU Quantum Flagship launched with €1 billion commitment.
Quantum skills are not only for physicists.
Europe needs all three tiers to realize its quantum potential.

*Figure 1. The three-tier quantum skills framework.*

A 2024 survey by the Quantum Industry Consortium found that more than 70 per cent of European quantum companies reported difficulty in hiring qualified staff, with the largest gaps at the practitioner level rather than the expert level (QuIC, 2024). This finding pointed out a significant problem. Although Europe's universities produce world-class quantum physicists, the ecosystem currently lacks the broader layer of technically literate professionals who can bridge quantum science and commercial applications. Building this layer requires not only new curricula but also standardized competence frameworks such as the European Competence Framework for Quantum Technologies that allow employers, educators, and individuals to assess and communicate quantum skills in a common language. Importantly, the European Competence Framework for Quantum Technologies has been developed in alignment with DigComp, the EU's established digital competence framework for citizens (Cosgrove and Cachia, 2025), enabling quantum skills to be mapped onto a language already familiar to educators and employers across Europe.

## How can Europe prepare its people for a world reshaped by quantum technology?

European education and training systems are responding to the quantum opportunity at every level, though the pace and depth of response vary considerably across Member States. At the postgraduate level, dedicated Master's and doctoral programmes in quantum science and quantum engineering have expanded substantially since the launch of the Quantum Flagship. Joint programmes between institutions in different Member States, linking, for example, TU Delft and the Technical University of Munich (TUM), or the University of Innsbruck and ETH Zurich are creating a genuinely European quantum research community with shared pedagogical norms and a culture of cross-border mobility. Structured industry placement components are becoming more common, helping to reduce the cultural distance between academic research and commercial application that has historically constrained European deep-tech commercialisation.

At the continuing professional development level, a new ecosystem of quantum upskilling pathways is emerging to serve the practitioner tier that the job market urgently needs. QuTech Academy in the Netherlands, the Quantum Future Academy in Germany, and similar initiatives in France and Finland offer structured short courses and micro-credentials accessible to working professionals who cannot undertake a full postgraduate degree. Cloud-based quantum computing platforms from IBM, Amazon, and Google provide hands-on access to real quantum hardware alongside educational resources, making practical quantum experience available across Europe without the need for local infrastructure. The European Skills Agenda, the Pact for Skills, and the Digital Education Action Plan all identify quantum technology as a priority area for public investment in upskilling and reskilling (European Commission, 2022) - policy alignment that is beginning to translate into concrete funding flows at national and regional level.

At secondary and primary level, the picture is more uneven and the stakes are high. Evidence consistently shows that interest in science and technology careers forms early, and that sustained exposure to frontier science at school is one of the strongest predictors of later specialisation. Quantum in Schools initiatives across Europe are developing age-appropriate resources and teacher training to introduce quantum concepts to students aged fourteen to eighteen, with a particular emphasis on reaching students from all backgrounds and regions, cultivating the curiosity and foundational knowledge that will feed the talent pipeline of the 2030s.

# Conclusion: the futuristic tale is over - the real story is just beginning

There is something quietly remarkable about the moment Europe finds itself in. The ideas that once seemed too strange to be useful, a particle in two states at once, two particles correlated across any distance, a measurement so precise it could detect a single graviton are now the operating principles of devices that are being installed in hospitals, government networks, and industrial facilities across the continent. The futuristic tales have not been proven wrong. They have been proven right, and the world they described is being built, incrementally and irreversibly, in real European laboratories, companies, and public institutions.

What remains uncertain is not whether quantum technology will transform the European digital economy, but whether Europe will be a shaper of that transformation or merely a recipient of it. The Quantum Flagship, the EuroQCI, and the national quantum programmes that complement them represent a credible foundation, but sustained commitment will be needed across multiple election cycles and funding periods to realise their potential. The decisions made in the next three to five years, on talent pipelines, on procurement frameworks, on post-quantum cryptography standards will determine which side of that divide Europe occupies.

Above all, the transition to a quantum-enabled world must be understood as a collective undertaking, not a specialist one. The futuristic tale is, in the most literal sense, becoming history. The real story of quantum technology in Europe is just beginning.

## Key Takeaways

- Quantum technology is no longer a future promise. Across Europe, quantum sensors operate in hospitals, quantum-secured networks are protecting government infrastructure, and quantum optimisation tools are being trialled in industry. The transformation is already under way.
- Europe has built a credible foundation. The Quantum Flagship, the EuroQCI, and national programmes in Germany, France, and the Netherlands represent over €3 billion in coordinated public investment, positioning Europe as a global leader in quantum research and policy.
- The critical gap is not at the expert level — it is at the practitioner level. More than 70 per cent of European quantum companies report difficulty hiring qualified staff, and the largest shortage is among software developers, engineers, and data scientists who can work alongside quantum systems, not among deep specialists.
- Building the quantum workforce requires action at every level of education. From secondary school curiosity to postgraduate specialisation to continuing professional development, Europe needs coherent, funded pathways that reach learners from all backgrounds and regions.
- The decisions made in the next three to five years will determine whether Europe shapes the quantum economy or merely participates in one built elsewhere. Talent pipelines, procurement frameworks, and post-quantum cryptography standards are all being set now.

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