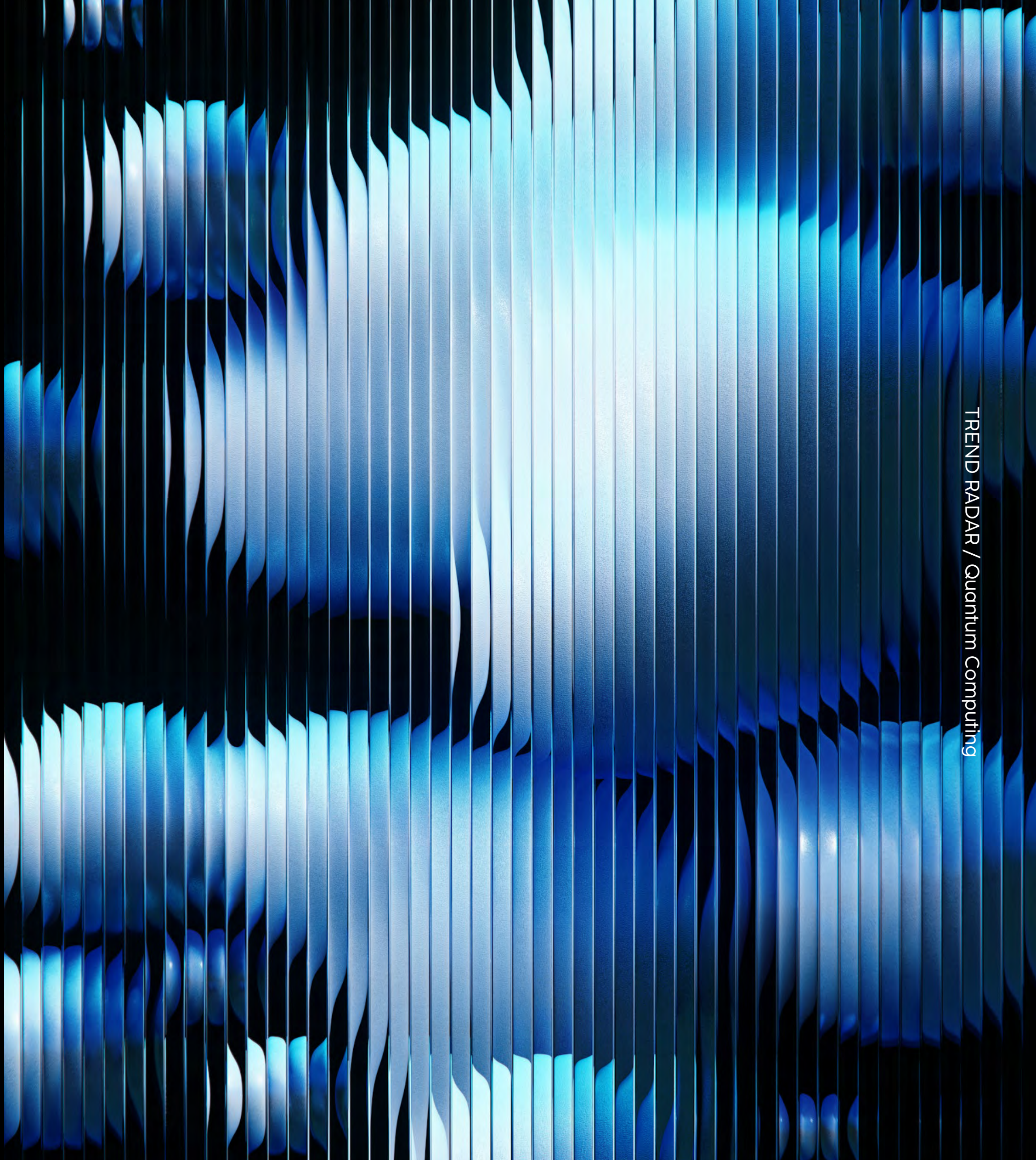
TREND RADAR

QUANTUM COMPUTING

The emerging technology that is redefining what's possible.



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00 Summary

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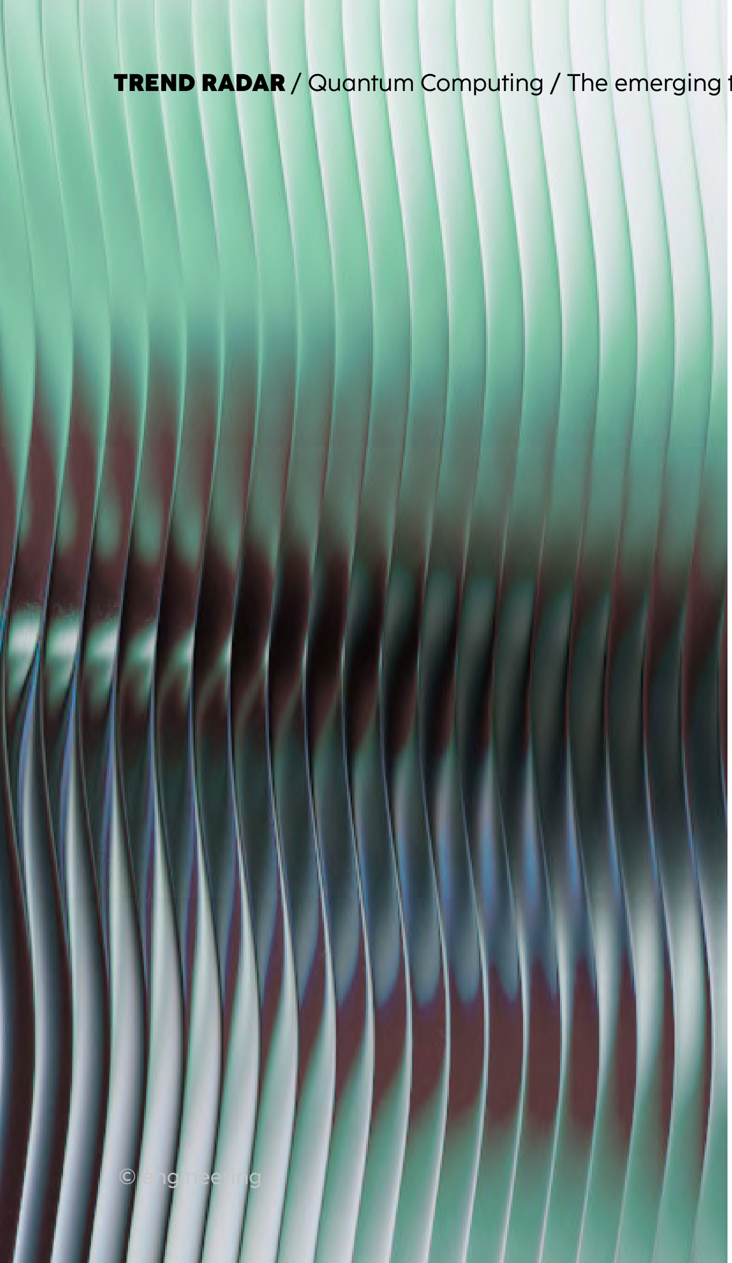
The new frontier of innovation



The new frontier of innovation

The world we live in today faces **urgent global challenges** such as climate change, energy transitions, and the evolution of healthcare systems. This historical moment demands the development of innovative, high performance, and deeply transformative solutions capable of overcoming the **exponential growth of complexity**.

Modeling dynamic phenomena, analyzing vast volumes of data, and anticipating constantly evolving scenarios all require ever greater computational capacity.

In this context, **Quantum Computing marks one of the most radical technological revolutions of our time**, promising to rewrite the rules of computation.
By overcoming the constraints of the binary system, it allows for the simultaneous management of a **multitude of possibilities**, thanks to the principle of **quantum superposition**. This isn't simply about **boosting computational power** or reducing the time needed for complex calculations. It represents a **true paradigm shift**, enabling us to **tackle problems in new ways** that even today's most advanced supercomputers struggle to solve, such as those in Artificial Intelligence, molecular simulation, resource optimization, and predictive analytics.

Although quantum computers are not yet ready for widespread applications, **research is advancing rapidly**. Pilot experiments and early real-world use cases are already demonstrating the **disruptive potential of Quantum Computing** and **enabling the industrialization of advanced technologies**.

In this Trend Radar, we explore the innovative features of quantum computing, examine its medium and long term outlook, and highlight **Engineering's commitment** together with businesses, academia, and public institutions to turning this technology into a **concrete lever of innovation** for a more **resilient future**.

The new quantum technology

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The new quantum technology

Quantum technologies can be grouped into four distinct areas:

- **Computing** (the use of qubits to rapidly solve complex problems);
- **Communications** (secure transmission via entanglement and quantum cryptography);
- **Sensing** (ultra precise measurements enabled by quantum properties);
- **Simulation** (modeling of complex systems for scientific and technological purposes).

Among these, **Quantum Computing** stands out as one of the most transformative domains, thanks to its potential to solve problems **exponentially faster** than traditional computers.

Quantum computing is built on three core pillars: **hardware, cloud infrastructure, and software**.

Quantum hardware consists of physical devices that perform calculations by leveraging the principles of quantum mechanics, requiring extremely high levels of precision and stability.

Cloud infrastructure makes quantum processing **remotely accessible and scalable**, allowing users to experiment with quantum resources without owning specialized hardware.

Quantum software focuses on developing **algorithms and applications** that exploit the unique properties of quantum systems, enabling the resolution of problems that would be infeasible for classical computers.
While classical computers rely on binary bits (0 or 1)

to store and process data, quantum computers use qubits. Qubits can be implemented using different types of systems such as **neutral atoms, superconducting circuits, or photonic systems**, making them fundamentally different from classical binary units.

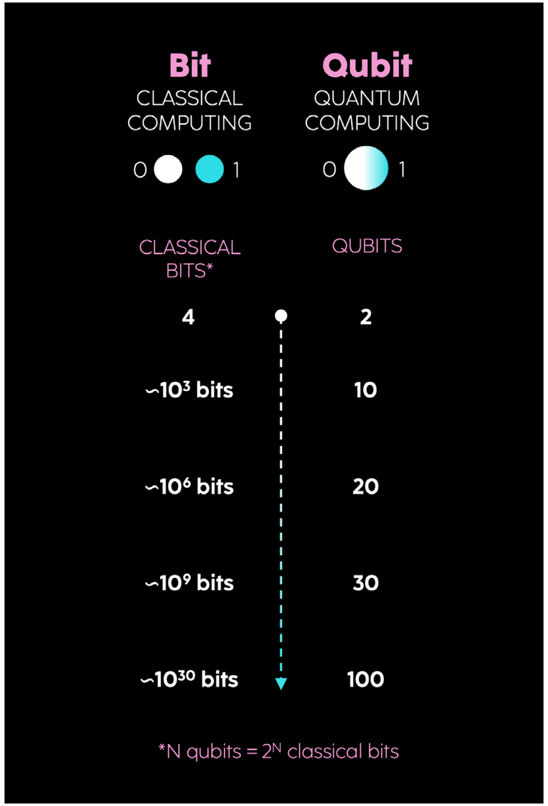
- **Superposition** - allows qubits to store and process an exponentially greater amount of information by existing in a combination of both 0 and 1 states simultaneously;
- **Interference** - enables quantum computers to amplify correct outcomes and cancel out incorrect ones, effectively guiding calculations toward optimal results;
- **Entanglement** - describes the interlinked state of multiple qubits, which collectively hold more information than individual ones and lead to a dramatic increase in computational power.

These principles **have no classical equivalent** and simulating them with traditional computers would require enormous resources and highly specialized hardware.

As a result, quantum computing holds enormous potential to transform how certain computational tasks are performed, offering the ability to solve problems currently deemed unsolvable, while unlocking new pathways for innovation and creativity.

However, **today's quantum computers still operate with a limited number of functional qubits**, which restricts their practical applications.

Ongoing research is focused on increasing qubit count and **developing error correction mechanisms**, with the goal of making quantum systems more reliable and effective even with relatively small-scale hardware.



03

The quantum shift in computing

The quantum shift in computing

Investment in quantum technologies is accelerating rapidly, led by pioneering companies developing quantum computers, superconducting circuits, optical systems, and the next generation of communication devices.

Globally and particularly in Europe, the number of quantum hardware providers is still relatively limited, although it is steadily growing.

At the same time, both **governments and enterprises** are focusing their efforts on advancing **quantum ready hardware and software**, positioning themselves to quickly embrace the future challenges and opportunities enabled by quantum systems.

Over the next five years, we can expect significant progress: more **powerful hardware**, enhanced **quantum error correction techniques**, and systems specifically designed to **optimize algorithms on today’s quantum architectures**. In the short to medium term, the goal is **not to replace**

classical systems, but rather to integrate today's technologies with quantum systems in **hybrid architectures** designed to achieve what is known as **quantum advantage** in specific problem domains.

Quantum computing is already showing significant promise across three major classes of problems:

- **Simulation of natural phenomena**, including chemical and biological processes;
- **Algebraic challenges**, such as those found in machine learning, differential equations, and matrix operations;
- **Quantum search and graph related problems**, critical for cryptography and network optimization.

As quantum technology moves closer to commercialization, these capabilities are opening **real world applications** across multiple sectors:

- **Industry** - accelerating the discovery of new materials and processes
- **Healthcare** - transforming drug development and personalized medicine
- **Finance** - enhancing risk analysis, portfolio optimization, and fraud detection
- **Transportation** - improving logistics, traffic management, and autonomous systems
- **Energy & Utilities** - optimizing power grids, resource management, demand forecasting, and infrastructure monitoring

Each of these sectors stands to benefit enormously from quantum computing's ability to **solve complex problems, streamline operations, and unlock new opportunities**, paving the way for **significant economic impact**.

Early adopters' companies and organizations willing to experiment and invest will be better positioned to gain a competitive edge as the technology matures.

Key Trends

$93 BN

PROJECTED MARKET REVENUE FOR QUANTUM TECHNOLOGIES BY 2040

$8.6 Bn

ESTIMATED SIZE OF THE QUANTUM COMPUTING MARKET BY 2027

458

PLAYERS IN THE QUANTUM COMPUTING & COMMUNICATION MARKET, 355 OF WHICH ARE NATIVE QUANTUM COMPANIES IN 2024

32%

PORTION OF R&D BUDGETS ORGANIZATIONS WILL ALLOCATE TO QUANTUM COMPUTING BY 2025

€17.7 Bn

ESTIMATED PUBLIC FUNDING FOR QUANTUM RESEARCH IN EUROPE BETWEEN 2025 AND 2029

- **CLOUD & INFRASTRUCTURE**
- **CYBERSECURITY**
- **ADVANCED ANALYTICS**
- **HYBRID COMPUTING**
- **ARTIFICIAL INTELLIGENCE**

TOP 3 BUSINESS BENEFITS

GREATER DATA SECURITY

ADVANCED SIMULATIONS FOR R&D

PROCESS OPTIMIZATION AND IMPROVED EFFICIENCY

Optimizing processes with advanced technological solutions to drive business growth.

THE DATA SHOWN REPRESENT OUR ANALYSIS BASED ON INFORMATION FROM MULTIPLE SOURCES (E.G., STATISTA)

Focus on

QUANTUM COMPUTING AND ARTIFICIAL INTELLIGENCE

The broader **quantum computing ecosystem** is built not only on emerging technologies but also on more traditional components such as classical computing resources for hybrid workflows, advanced control systems for qubit operations, and specialized expertise in quantum algorithms.

Though still in the experimental phase, these algorithms are already demonstrating **significant and measurable benefits**.

Artificial Intelligence plays a crucial role in advancing quantum computing by enhancing system reliability, optimizing algorithms, and improving resource management.

It contributes to **error correction** by predicting and addressing computational faults and helps **reduce noise** through the analysis and mitigation of disturbance patterns.

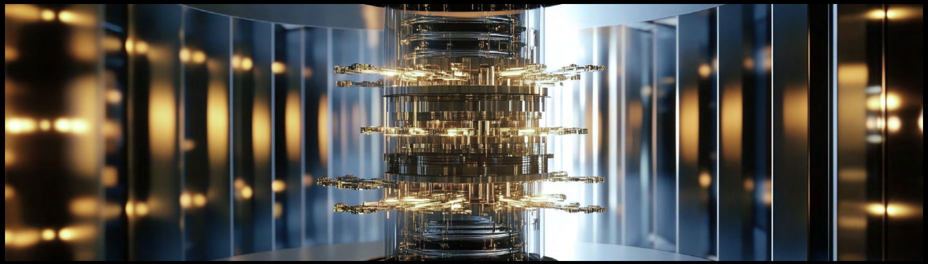
AI also strengthens the **design of quantum algorithms** using techniques like **reinforcement learning**, minimizing gate operations, and reducing errors. It automates the control of quantum hardware to ensure optimal device performance and system stability, while improving **qubit allocation and task scheduling**.

In addition, AI improves **simulation and benchmarking**, supporting the evolution of quantum systems and enabling smoother integration of **hybrid classical quantum environments**, which leads to **greater computational efficiency**.

Conversely, **quantum computing offers transformative potential for AI**, especially in the development of **Artificial General Intelligence (AGI)** systems with cognitive abilities comparable to humans, capable of understanding, learning, and applying knowledge across a wide range of tasks without needing to be explicitly programmed for each one.

Quantum-inspired algorithms can enhance the efficiency of existing AI models by reducing hardware requirements while improving performance.

Finally, the **superior processing power** of quantum computing allows it to tackle highly complex problems and process data at unprecedented speeds, significantly expanding the reasoning and decision-making capabilities of AGI systems.



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Our approach

Engineering has been engaged in research since 1987 and took its first steps in the field of AI in the 1990s.

Today, more than 410 professionals work within the AI&Data Technology Business Line, supporting over 150 companies and public administrations in adopting and leveraging AI, GenAI, and Data Analytics applications ensuring innovation throughout the entire data lifecycle. **Our approach combines deep business expertise with continuous research into frontier technologies, allowing us to build meaningful experience even before these innovations reach market maturity.**

Engineering's **R&D Lab**, with more than **400 researchers and data scientists**, tackles daily challenges in **AI research, advanced data management**, and **complex analytics** within **distributed and federated digital ecosystems**. The focus is on developing a **data-driven economy**, through the coordination and participation in numerous national and European research projects.

With an investment of around **€28 million** in 2024 in research, strong collaborations with universities and research centers, and over **110 active research projects**, about 60 of which integrate AI and Data technologies, we stand out as one of the leading private players in this field across Europe.

For over three years, **Engineering has been a sponsor and participant in the Quantum Computing & Communication Observatory**, the largest academic and scientific hub in Italy, coordinated by Politecnico di Milano. The Observatory serves as a pre-competitive reference point in the country, engaging a community of companies from both the demand and supply sides of technology as well as national and international experts.

We have also participated in the working group established by the Ministry of University and Research, in collaboration with the Ministry of Enterprises and Made in Italy, the Ministry of Defense, the National Cybersecurity Agency (ACN), and the Department for Digital Transformation of the Presidency of the Council of Ministers.
The working group brought together experts from the research community and institutional representatives to define a strategic framework aimed at strengthening Italy's position in quantum technologies and supporting the development of the **Italian national strategy for quantum technologies**.
Engineering is also among the co-founder of the **National Research Center on High Performance Computing, Big Data, and Quantum Computing (ICSC)**, one of the five National Centers established under Italy's National Recovery and Resilience Plan (PNRR) and acts as a strategic stakeholder in **SPOKE 10**, which is specifically dedicated to quantum computing.

Fact & Figures AI & Data

60+ AI research projects

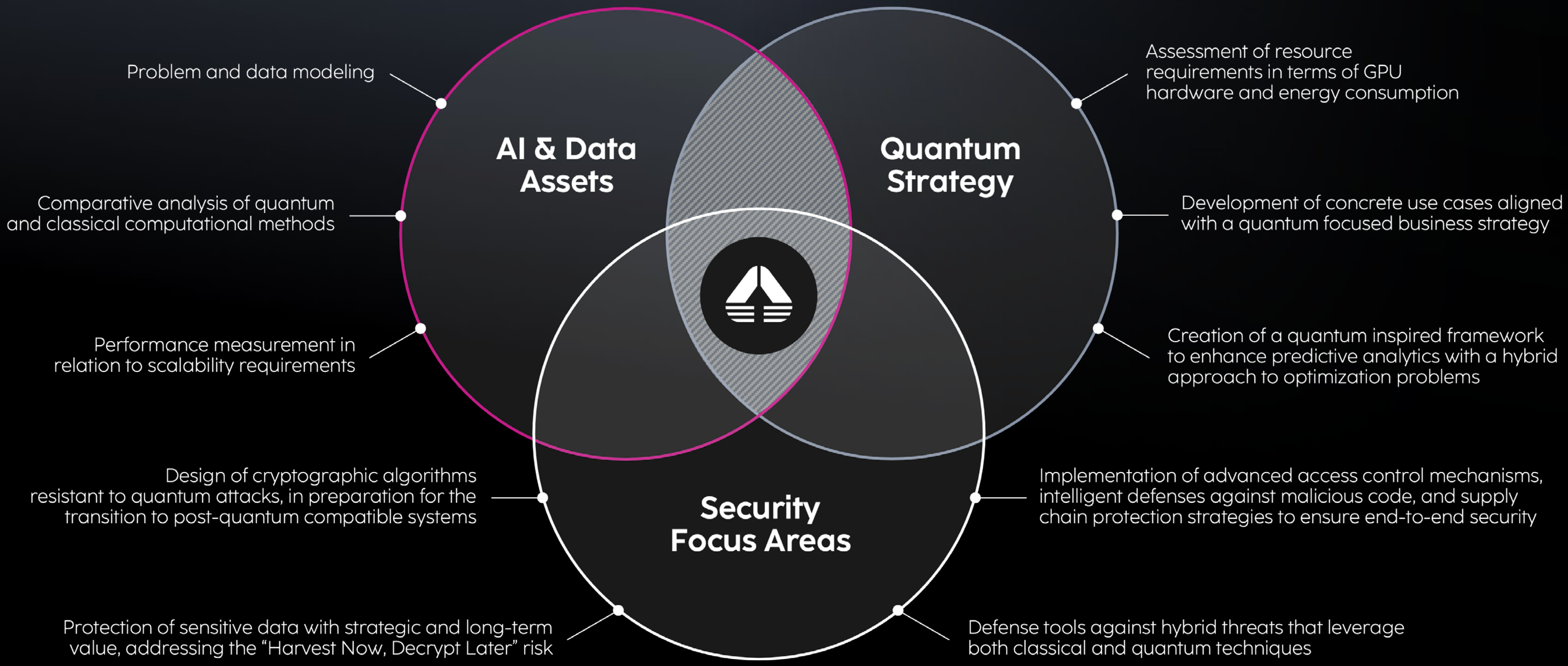
500 Certifications

20+ Partnerships and academic collaborations

30+ Years of experience in AI

Our approach

We combine our expertise and knowledge in AI & Data and Cybersecurity with the latest research advancements in the Quantum field to pave the way for the industrialization of this technology.

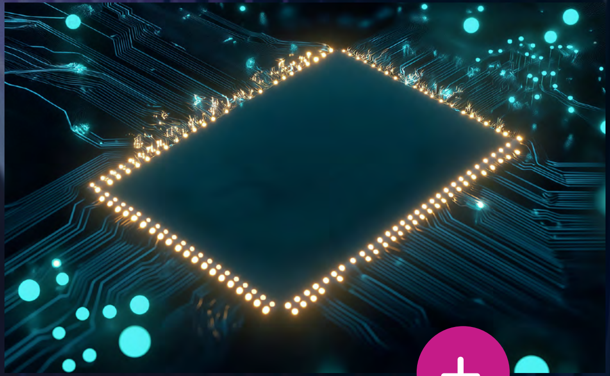


05 Our projects

USE CASE / ENERGY & UTILITIES

Quantum algorithms supporting predictive analytics

Quantum algorithms particularly the **Harrow Hassidim Lloyd (HHL)** algorithm applied to linear systems enhance several machine learning techniques and analytical methods that, in turn, support **Finite Element Methods (FEM)**, correlation analysis, and certain types of neural networks. By generalizing the algorithm using **Python based development tools** (such as the Qiskit framework) and **AWS cloud infrastructure**, it becomes possible to handle problems of **arbitrary complexity**.
Leveraging the **computational speed advantage** offered by quantum technology allows businesses to improve the effectiveness of data analysis techniques and significantly accelerate insights and decision making, with a direct impact on **process optimization**.



RESEARCH PROJECT / TRANSPORTATION

Toward a more efficient urban logistics ecosystem

The **QLMD project (Quantum Computing for Efficient Urban Logistical Ecosystem)**, part of Spoke 10 of the HPC National Center, addresses key challenges in urban logistics such as waste collection, last mile delivery, and customer pick up/drop off by fleet vehicles.

Quantum computing has been applied to **tackle NP Hard problem classes**, including the Travelling Salesman Problem (**TSP**) and Vehicle Routing Problem (**VRP**), with the aim of developing a constraint-based **optimization strategy** for complex systems.

This research project is funded by Italy's National Recovery and Resilience Plan (PNRR), Mission 4, Component 2.

06

Looking ahead: challenges and opportunities

Key capabilities

+ **Processing** of large data sets
+ **Optimization** of complex systems
+ **Simulation** of multiple scenarios

Looking ahead: challenges and opportunities

Quantum Computing has the potential to transform business operations by solving problems of **unprecedented complexity and scale**, while also enhancing data analysis, optimizing decision making processes, and boosting competitiveness across industries.

> A future powered by quantum computing promises greater speed, allowing us to tackle some of humanity's greatest challenges with more efficiency, precision, and scale.

However, despite its highly promising theoretical potential, **quantum computing still faces significant technical limitations**. Key challenges include the **limited availability and lack of standardization of qubits**, constraints related to **topology and connectivity**, and the **high number of logical qubits** required to solve complex optimization problems.

Moreover, current quantum systems suffer from low scalability and instability, which makes handling advanced computations difficult. Adapting classical problems to a quantum language also demands the development of entirely new algorithms.

That said, the quantum computing field is rapidly evolving, and many of today's technical hurdles are expected to be significantly reduced or resolved within the next 3 to 5 years.

Looking ahead: challenges and opportunities

Since many of the current challenges are tied to hardware development, a growing number of companies are investing in the design of algorithms and tools that will be ready to run on quantum hardware **as soon as it becomes available**.

As they prepare for the quantum era, businesses will first adopt increasingly advanced computational capabilities and specialized algorithms tailored to specific industries and business functions. Over time, quantum technologies will empower organizations to develop cutting edge software, offer quantum as a service platforms, and create entirely new products, markets, and business models.

The ability of quantum computing to process vast datasets, **optimize complex systems, and simulate intricate scenarios will fuel innovation across industries**.

These transformative capabilities promise to **revolutionize efficiency and unlock unprecedented business opportunities, reshaping how value is created in the digital economy**.

> As with any emerging technology, the ability to guide this evolution **responsibly** and with a human centered approach will be essential.

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