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# REPORT
# SPAIN QUANTUM INDUSTRY

AMETIC 2023 - ENGLISH VERSION

# Credits and acknowledgements

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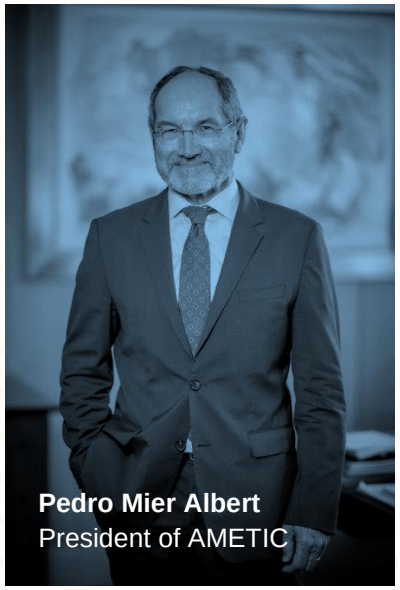
If you would like to join AMETIC's Quantum Information, Computing and Cybersecurity Working Group or for more information, please write to us at: innovacion@ametic.es

# Editorial



**Pedro Mier Albert**
President of AMETIC

One of AMETIC's main objectives since its foundation has been to pay attention to new disruptive technologies, for the benefit of its member companies and Spanish industry as a whole.

Quantum technologies are set to play a disruptive role in the coming years due to the impact they will have on many areas, most notably in terms of mass computing capacity and secure encrypted communications, fields in which they will mark a new era, according to all forecasts.

In order to facilitate access to information and collaborate in creating and consolidating a Spanish business ecosystem of quantum technologies, in 2017 AMETIC formed a Working Group on Quantum Technologies, one of the results of which was the publication in April 2019 of the document *"La España cuántica: Una aproximación empresarial"* ("Quantum Spain: a Business Approach"), the first to be published in Spain. Three years on, we are now putting the updated document in your hands (or on your screen).

We hope that this document will contribute to a better understanding of what quantum technologies are and how they will affect the different business sectors, as well as highlighting the main quantum stakeholders and projects in Spain, the European strategy and the opportunities for boosting the Spanish quantum ecosystem and promoting the discovery that Spain has highly talented professionals and scientific institutions, both of which are at the highest international level.

In addition to the important activity of AMETIC's Quantum Technologies Working Group, AMETIC has been renewed as a member of the Strategic Advisory Board for the Quantum Technology Flagship, the main instrument promoted by the European Commission, as well as being a member of the European Quantum Industry Consortium (QuIC), as part of which we are also the national chapter, and belonging to the UNE standardisation working group on Quantum Technologies.

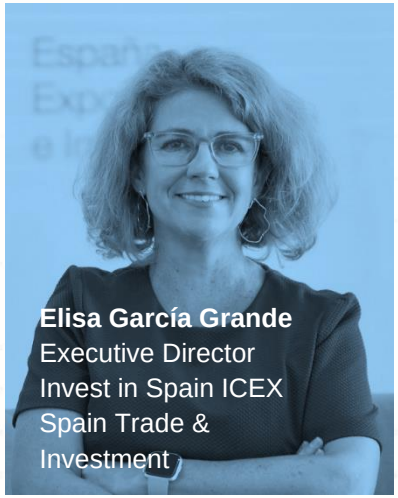
At AMETIC, we are convinced that if we are capable of joining forces and aligning the scientific and university community, technology centres, public administrations and the business sector, Spain can play a relevant role in the future of this strategic and promising sector, and we will dedicate our best efforts to achieving this.

AMETIC encourages the business sector to join the movement to ensure that Spain seizes the opportunity and becomes a *"quantum country"*.

We hope you find the report interesting and useful.

September 2022

# Introduction



**Elisa García Grande**
Executive Director
Invest in Spain ICEX Spain Trade & Investment

Quantum technologies have extraordinary disruptive potential and are creating projects in the market that are capable of transforming the most strategic sectors of society. Quantum computing promises to offer computing power of a magnitude that will revolutionise traditional computing and the way we process information, and it will also be possible to use it to efficiently solve complex problems in areas such as artificial intelligence, cryptography, data security and machine learning. The potential industrial applications of quantum computing are numerous and have a high transformative potential in many sectors, such as health sciences, the automotive industry, logistics, commerce, the aerospace industry, energy and environment and even finance.

However, quantum technologies still present many challenges in the technology sector, as powerful quantum computers need to be developed. This is also the case in the economic area, because quantum computers are extremely expensive to build and maintain and, lastly, do present a significant challenge in terms of the availability of the qualified and specialised talent required for their development.

In a global world, the race to meet and overcome these challenges is already underway, and Spain is positioning itself with the ambition to become a quantum hub in southern Europe. Spain has a number of advantages that make it a very interesting destination for the development of quantum technologies.

In the theoretical field, Spain has world class researchers in the fields of theoretical physics and materials physics, and there are even some small Spanish companies and startups that are beginning to apply the results of their theoretical research to the quantum technologies industry.

The Recovery, Transformation and Resilience Plan Funds represent a great opportunity to consolidate and boost the promising Spanish quantum ecosystem. These funds have been used to launch the Quantum Spain project, an initiative promoted by the Ministry of Economic Affairs and Digital Transformation through the Secretary of State for Digitalisation and Artificial Intelligence, which addresses the creation of a quantum computing ecosystem for Artificial Intelligence (AI) based on a public-private cooperation model. With a budget of 22 million euros, the project will invest in infrastructure, talent and research from 2022 to 2025.

In terms of infrastructure, the Quantum Spain project will make quantum computing capabilities available to companies via the Spanish supercomputer network (RES).

The first milestone to be achieved by the Quantum Spain initiative is the construction of the first quantum computer in southern Europe, which will be installed this year at the Barcelona Supercomputing Center (BSC-CNS) and will be integrated into the MareNostrum 5 supercomputer, which will be the most powerful in Spain and among the most advanced in Europe and the world.

The development of quantum technologies in Spain represents an interesting business opportunity for Spanish and foreign investors in the sector. With the aim of facilitating these investments, ICEX España Exportación e Inversiones decided to collaborate with AMETIC's Quantum Information, Computing and Cybersecurity Working Group by sponsoring the "Quantum Spain report: A Business Approach", which seeks to facilitate the understanding of what quantum technologies are, and to further increase the attractiveness and potential of Spain as a quantum country.

# About this document


It is a pleasure to present the update and reprint of AMETIC's first report on "Quantum Spain: a business vision", which we published three years ago.

We are "immersed" in the third quantum revolution. This is the telecommunications, cybersecurity and quantum computers revolution, which is having an immense impact on business and society.
We are living through a crucial and exciting moment in this "quantum history", which is a "dream come true" for physicists, a real "nightmare"' for engineers and a great "opportunity" for companies.

**What has happened in the past three years in Spain?**

Spain continues to be one of the world leaders in "quantum talent" with professionals like Darío Gil, Sergio Boixo, María Marced and Ignacio Cirac. The number of supply companies has multiplied, both multinationals, SMEs and new start-ups, and most importantly, new demand companies have started very relevant "quantum" projects in Spain and internationally.

In addition, public authorities have promoted specific projects and increased their funding.

AMETIC's Quantum Technologies Working Group has established itself as the business hub benchmark in Spain and Europe. At the moment, Spain has over fifty member companies both on the supply and demand side.

This means growth, internationalisation and leadership.

We wanted a "useful" document that would allow companies to learn about the current state of quantum technologies, but more importantly, to offer information and tools to start incorporating these technologies into their business processes.

The objectives of the document are as follows:

- To report on the current state of the art and advances in the different areas of quantum technologies.
- To provide information on companies, organisations, projects and funding.
- To make recommendations for supply and demand companies to join and consolidate this emerging market in Spain.
- To listen to the companies that will have to do business using these technologies. For this reason, we have asked eleven professionals from different business verticals and specialists in these technologies to explain their vision and expectations.
- To establish the basis from a business perspective for the "National Strategy on Quantum Technologies - ENTC".
- To open ourselves up to the principles of "quantum ethics".
- We have included an extensive section on project funding in the form of an ANNEX.

**AMETIC's Quantum Technologies Working Group** is continuing to work on drafting two new documents: A compilation of *"Use cases and success stories"* and an in-depth document on ethics and corporate responsibility.

I would especially like to thank the authors and the eleven excellent business professionals who participated in the interviews for their involvement and

excellence. And, of course, I extend my thanks to the entire AMETIC team represented by its President.

This document will serve to awaken the interest of companies in these truly disruptive technologies, which are already having a substantial impact on their business processes and in all areas of economic activity.

Within AMETIC's *"quantum"* Group, we are convinced that the question is not *"when"*, but *"who"* and if Spain will be one of the leaders... because if Spain is not one of them, what does it matter when?

Let us not forget that *"the world is quantum*".

# Contents

# Quantum Technologies

Quantum physics is a long-established scientific discipline, introduced by Max Planck in the 20th century, when he 'quantized' the energy states of the photon. This area of science has developed and evolved over the years with scientists like Schrödinger, Heisenberg, Dirack and Feynman, to name but a few. At the same time, a range of quantum technologies has been being developed by taking advantage of this new knowledge. But what do we mean by quantum technologies? When we talk about quantum technologies, we typically refer to quantum sensing and metrology; quantum communications; and quantum computing and simulation.

## What do we mean by Quantum Technologies?

### *Sensors and metrology*

Sensors are one of the first applications of quantum technologies. Their technological implementation has high levels of maturity, with sensors already being used in production environments. Quantum sensors have higher sensitivity and resolution to external effects than their classical predecessors, e.g. for measuring electric currents, magnetism, gravity or time.

Each technology implements its own mechanism to perform the measurement, but typically one or more of the following quantum phenomena are used: quantized energy levels, quantum coherence, quantum entanglement, super-radiance, amongst others.

### *Communications*

Communications, and specifically in the short to medium term, their security, will be revolutionised by the advent of quantum key exchange. This type of mechanism, in one of its simplest versions, uses the properties of the quantum non-cloning phenomenon and a number of classical communication protocols to exchange a symmetric encryption key between two points. This mechanism called quantum key distribution (or QKD) offers the guarantee that the exchanged key has not been observed by a potential attacker, and is not vulnerable to the adversary's computational capacity or mathematical skills (as classical cryptography is, including post-quantum cryptography). In the longer term, the possibility of teleportation via entangled cubits (the basis for quantum repeaters) paves the way for interconnecting networks of quantum devices over long distances and underpins the construction and deployment of the future Quantum Internet.

### *Computing and simulation*

Quantum processing technologies are expected to have the greatest impact, as the processing power of this technology grows exponentially with the number of qubits we are able to control interlinked with each other. Although still in its infancy, this technology promises to solve problems that are currently not tractable using classical computing. Among other applications, quantum computing excels in its ability to simulate quantum effects, such as the behaviour of atoms and particles.

## Is there a real risk of 'quantum winter'?

Advances in quantum physics in recent years have brought with them accelerating technological developments, achieving progress in this field that seemed impossible only a few years ago.

Because of this progress and the significant economic return it could bring, both public and private investment is very intense. The European Union is flying the banner for quantum technologies through its 10-year Quantum Flagship, with a planned investment of €1 billion. Many European countries have a national quantum technologies strategy and/or national programmes for funding quantum technologies. All major technology companies are investing heavily in quantum and are starting to offer associated services. Start-ups in the field have proliferated, some with local focus. Numerous territorial ecosystems that seek to accelerate the application of these technologies through research, technological development and innovation have also started to consolidate. As a result, quantum resonates in specialised and non-specialised media.

This current situation of enthusiasm, or hype, raises some analogies with what has happened previously with other technologies and, especially, due to its proximity, is the case of Artificial Intelligence. **When the expectations of a technology are misaligned with the reality of what it can offer, since technological development follows a certain process, which is very complex in this case, after the period of enthusiasm**, there can be a period of cooling, i.e., a reduction of investments (with the consequent disbanding of talent), changes in priorities, discrediting of the private sector, a halt in technological development, pessimism, etc. In the case of Artificial Intelligence (AI), this was called the "AI Winter" or *winters*, as there were several. Although 'Quantum Winter' tends to refer to quantum computing, a drop in enthusiasm for quantum computing could also weigh down ongoing investments and efforts in quantum communications (which would lose its primary motivation of securing communications and interconnecting quantum computers), and setting up sensor systems (which largely depends on investment in basic science).

The Spanish market for quantum technologies has limited RD&I funding, is highly dispersed throughout the country and has a small domestic market, with few large companies acting as drivers. A cutback in investment policies could derail the emerging Spanish ecosystem, and accentuate the brain drain to other countries or to better-funded lines of research.

In order to avoid a 'Quantum Winter', we in the industrial sectors believe that we must:

1) Maintain **public policy interest**, in the form of national and regional strategic plans that set clear medium- and long-term objectives, and commit sufficient financial resources to develop them.

2) The industry must define a **vision of impact** as the first step for a national strategy, which will allow for the continuation of public policies on training, RD&I programmes, etc. This vision will be based on the strengths of the country and the industry. This vision should include progress indicators to measure how the vision is being implemented, and to detect possible stagnation.

3) The public administration should act as an early adopter to enable an initial market demand to develop the industry. For example, this could be achieved using instruments, such as innovative and pre-commercial public procurement.

4) Quantum technologies should **be incorporated into other fields of knowledge** or disciplines, with a higher level of technological maturity and in a more consolidated form on the market, facilitating synergies with them. An example of this type of synergy could be quantum computing and high-performance computing. This should enable a continuous flow of activity in this field between supply and demand.

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# 02 QUANTUM SPAIN

# Quantum Spain

Since the last report published in 2019, the emerging Spanish industrial ecosystem of quantum technologies has advanced thanks to publicly funded initiatives, such as Quantum Spain[1], or public-private initiatives, such as the CUCO project[2], industrial leaders who have embarked on new projects (as we will see in the interviews section), as well as a whole system of technology centres, associations and regional ecosystems, which help to create knowledge, technology transfer and market dynamisation.

Despite progress, this ecosystem remains small and incohesive. It needs to continue to grow internationally, especially towards Europe, which will be its main market in the coming years. Retaining and attracting talent must become a priority, as well as technology transfer from research centres to new start-ups with the capacity to attract private investment. Spanish industry leaders must be drivers of demand, as well as national and European public funding to further develop the ecosystem.

In order to map this emerging Spanish quantum technologies ecosystem, the following is an index of the main companies (by size), end users (demand) that have initiated projects, technology and RD&I centres, the main national and regional initiatives with public funding, as well as national and regional associations.

## Companies (by size and alphabetical order)

The following is a list of companies based in Spain that offer services or products relating to quantum technologies.

| Name | Size | Description |
|---|---|---|
| Accenture | Large company | Technology consultancy services company. Multinational company offering quantum technologies services covering the whole spectrum: strategic consulting, implementation, architecture design, etc. https://www.accenture.com/es-es |
| Amazon Braket | Large company | Multinational company offering the Amazon Braket service. A fully managed Amazon Web Services (AWS) cloud service designed to provide quantum computing users with remote access to a single development environment. The main feature it offers is the option to access several quantum services from a single architecture. https://aws.amazon.com/es/braket/?nc1=h_ls |
| ATOS | Large company | French IT services company. They have a quantum computer simulator called the Quantum Learning Machine. Focus on HPC and quantum computing. https://atos.net/es/spain |
| Deloitte | Large company | It has a global strategy to address quantum computing as a consultancy and service, differentiated by technology and industry, supported by different sites and supplier partnerships. It undertakes proof-of-concepts with customers to apply quantum-inspired technology, and develops a plan to disseminate and bring customers closer to real-life case studies. https://www2.deloitte.com/es/es.html |
| EY | Large company | Multinational professional services company. It offers consultancy and implementation services for quantum and quantum-inspired technology projects. https://www.ey.com/es_es |

[1] https://portal.mineco.gob.es/es-es/comunicacion/Paginas/211026_np_cuantico.aspx

[2] https://www.cuco.tech/

| Name | Size | Description |
|---|---|---|
| GMV | Large company | Multinational technology group in the aerospace, defence, cybersecurity, intelligent transport and IT industries. It engages in projects in the fields of computing, communications and quantum sensing. Among others, it leads the CUCO project, and participates in the CARAMUEL project, leading the field segment for the task. https://www.gmv.com/es-es |
| Grant Thornton | Large company | Grant Thornton in Spain is the world's sixth largest professional services firm for auditing, business consulting, technology and innovation. It works on implementing projects across different verticals (finance, insurance, energy, automotive, retail, etc.) using disruptive technologies: Blockchain, AI, Quantum Technologies. https://www.grantthornton.es/ |
| Ibermática | Large company | After over 45 years' activity in the Information and Communications Technology sector, Ibermática is ranked number 8 among the top Information and Communications Technology companies on the Spanish market, bringing together almost 3,800 professionals and representing a turnover of over €258 million. Since 2019, the Ibermática Digital unit has been set up as the department from which it offers the market highly innovative solutions and which encompasses Ibermática's commitment to Quantum as the next step in AI. It integrates quantum solutions from access to the most suitable quantum computers for each use case, to consultancy, integration of these solutions in the customer's process, through to the development, modelling and deployment of quantum solutions. It is currently part of the Ayesa group. https://ibermatica.com/ |
| IBM Quantum | Large company | Multinational company. It offers one of the first publicly accessible quantum computers based on superconducting qubits. It has the IBM Quantum Composer and IBM Quantum Lab platforms that enable cloud access to quantum computing services. Developer of its own quantum software called Qiskit. https://www.ibm.com/quantum |
| Keysight | Large company | Electronic manufacturing company producing wavefront generation modules and digitisers using programmable FPGA technology. They are based in Barcelona following the acquisition of Sygnadine, a former ICFO spin-off. https://www.keysight.com/us/en/home.html |
| Microsoft | Large company | Multinational company. It offers the Azure Quantum service, which is a complete cloud development stack for quantum computers. It provides access to quantum computers from different manufacturers. https://www.microsoft.com/es-es |
| Telefónica | Large company | Multinational company. Their main focus is on quantum communications. Together with UPM and Huawei, they have launched the MadQCI quantum communications network. This network is a world first, demonstrating the application of quantum cryptography to commercial optical networks and its integration with network operation through SDN (Software Defined Networking) technologies. https://www.telefonica.com/es/ |
| Arquimea Research Center | SME | A private research centre created to develop ideas and get involved in projects of high technological and social impact, through a multidisciplinary strategy. They have a Quantum Computing department. https://www.arquimea.com/ |
| aQuantum Software Engineering | SME | Quantum software development and consultancy company. Created from the aQuantum research group, founded by the company alhambraIT and the Alarcos research group from the University of Castile-La Mancha. They are developing a quantum software development platform for the hybrid solutions ecosystem. https://www.aquantum.es/ |
| Cinfo | SME | Cinfo is a company based on talent and commitment. The team is made up of specialists in different fields: Artificial Intelligence, video encoding, IoT, Bigdata, AndroidTV, UI/UX, software design and development. https://www.cinfo.es/home/ |

| Name | Size | Description |
|---|---|---|
| DAS Photonics | SME | Platform integrators in the defence, avionics and space industries. Spin-off from the Nanophotonics Technology Centre at the Polytechnic University of Valencia. They participate in the CUCO project. https://www.dasphotonics.com/ |
| Entanglement Partners SL | SME | First quantum consulting company created in Spain and Latin America. Its main activity focuses on strategic and technological consultancy relating to quantum technologies. https://www.entanglementpartners.com/ |
| G2-Zero | SME | Start-up created by IMN-CNM (CSIC) researchers to manufacture single photon sources, with applications in communication and quantum technologies. https://g2-zero.com/ |
| Inspiration-Q | SME | Technology-based company created from the CSIC. It designs and markets quantum and quantum-inspired solutions for optimisation, simulation and machine learning problems. https://www.inspiration-q.com |
| iPronics | SME | It develops programmable photonic integrated circuits for all layers of industry. Photonic processing for greener hardware in communications, sensor and computing applications. https://ipronics.com |
| IQM | SME | Leading pan-European quantum computer company with its headquarters in Espoo, Finland. It has recently opened a subsidiary in Spain (Bilbao), focusing on quantum finance and co-designing quantum computers. https://www.meetiqm.com/ |
| LuxQuanta | SME | LuxQuanta is an ICFO spin-off based in Barcelona. Focused on providing quantum key distribution (QKD) systems and technologies for integration into existing network infrastructures. https://www.luxquanta.com/ |

| Name | Size | Description |
|---|---|---|
| Multiverse Computing | SME | European leader in quantum computing. With 70 employees in San Sebastian, Toronto, Paris and Munich. They have a portfolio of over 30 patents. They have their own product: Singularity. This is dedicated to applying quantum computing and "Quantum Inspiration" to problems in different fields of application: finance, economics, aerospace, health, automotive, industry 4.0, logistics, etc. https://multiversecomputing.com/ |
| Qcentroid | SME | It is the first company to deliver Quantum technology to Web3 ecosystems; offering Quantum capabilities, HW and algorithms to Web3 organisations and projects. It provides quick, easy access to quantum algorithms. https://qcentroid.xyz/ |
| Qilimanjaro | SME | They design and market annealer-type quantum computers. They manufacture the complete stack: quantum chip, control software and development libraries. https://www.qilimanjaro.tech/ |
| Quantum Mads | SME | They offer the hybrid QSaaS tool that enables their customers to tackle the most challenging industrial problems. Its aim is to dissect the intrinsic dynamics of complex industrial systems and create innovative, hardware-independent solutions. https://quantum-mads.com/ |
| Quanvia | SME | Focused on implementing quantum computing applications and opening up the spectrum of quantum computing to a wider audience. They offer research, consultancy and training services https://www.quanvia.com/ |
| Qurv | SME | Spin-off of ICFO. They manufacture wide-spectrum image sensors. Their sensors are based on quantum dot (or well) technology. This technology enables signals from the visible to the short-wave infrared range to be detected, and can be integrated with today's low-cost, high-end CMOS sensors. https://www.qurv.tech/ |

| Name | Size | Description |
|---|---|---|
| QuSide | SME | They design and market high-quality, ultrafast entropy sources for random number generation (using quantum principles).<br>https://quside.com/ |
| Serikat Servicios Informáticos | SME | IT services company that has been introduced to quantum computing through the CDTI Cervera Q-OPTIMIZA project, involving an optimisation system based on quantum computing.<br>https://serikat.es/ |
| TTI Norte | SME | TTI provides state-of-the-art antenna and radio frequency solutions for satellite communications.<br>They participate in the H2020 project QMICS to create a microwave-based quantum local area network. This architecture will be used to implement quantum communication protocols, such as teleportation between two superconducting quantum nodes.<br>https://www.ttinorte.es/qmics/ |
| VLC Photonics | SME | A photonic chip design company offering integration services for multiple fields, such as fibre optics, microwave photonics, optical sensing, instrumentation, biophotonics, etc. It is currently part of the Hitachi Group.<br>https://www.vlcphotonics.com/ |

Source: Own wording.

## Technology and R&D centres

Spain has an excellent and large group of technology and R&D centres that are helping to create the Spanish quantum technologies ecosystem by creating internal groups specialised in quantum technologies, establishing technology-based spin-offs, or engaging in knowledge transfer.

| Technology centre | Description |
|---|---|
| BSC | This is Spain's national supercomputing centre. It leads the Quantum Spain project as head of the Spanish Supercomputing Network. https://www.bsc.es/ |
| CESGA | The mission of the Galician supercomputing centre is to contribute to science through research and applying high-performance computing and communications. They lead the Galician Quantum Technologies Hub, and have recently tendered for the construction of a quantum computer. https://www.cesga.es/ |
| CSIC | In addition to participating in various national and European programmes, the CSIC has created the Quantum Technologies Platform (https://qtep.csic.es), a project involving 35 research groups across 18 of its own and joint institutes, which collaborates with universities and companies to develop quantum technologies (computing, communication, sensing), manufacture these and transfer them to industry. The start-ups G2-Zero and Inspiration-Q are the result of this initiative. https://www.csic.es/es |
| CTIC | A Technology Centre specialising in Data and Artificial Intelligence technologies. It has a line of specialisation in quantum computing and, together with the QHPC Group from the University of Oviedo, has developed the QUTE Platform that emulates a 38 qbit quantum computer. www.fundacionctic.org |
| CTTC - Centre Tecnològic de Telecomunicacions de Catalunya (Telecommunications Technology Centre of Catalonia) | Leader in physical, access and network layer technologies for terrestrial telecommunication networks, working on quantum communications and QKD as well as their impact and integration in optical networks and security enhancement in 5G and the future 6G. https://www.cttc.cat/ |
| DIPC | International benchmark in basic research in the field of materials science, with lines of research in quantum chemistry and computer modelling, the development of new materials and nanoscale properties. http://dipc.ehu.es/ |
| Eurecat | Eurecat has a research group on Quantum Computing, which is integrated into its Digital Technologies department. The group's research focuses on designing and implementing quantum machine learning algorithms (Quantum Machine Learning) as well as solving optimisation problems using different quantum computing paradigms. https://eurecat.org/es/ |
| i2Cat | A research leader in 5G/6G, IoT, immersive technologies and space communications. It is working on quantum communications, QKD and their integration into Internet protocols and future 6G satellite networks. https://i2cat.net/ |
| i3B | The Ibermática Institute of Innovation (I3B) is an applied research entity created by Ibermática at the end of 2005, whose aim is to promote innovative solutions and services by using Information and Communications Technology, following an innovative system through people and processes. I3B was created in response to the growing demand for innovation in the services sector. Currently, I3B has a staff of 70 highly qualified researchers and its activity is oriented towards running research, development and innovation (R&D&I) projects relating to technologies associated with Artificial Intelligence and Quantum Computing, in addition to other fields. https://ibermatica.com/i3b/ |

| Technology centre | Description |
|---|---|
| ICFO | It participates in different European and national programmes. These are international benchmarks for photonic sciences. It has created several spin-offs, such as QuSide and LuxQuanta. https://www.icfo.eu/es/ |
| ICN2 - Catalan Institute of Nanoscience and Nanotechnology | A leading researcher at the nanoscale, it works on examining the quantum behaviour of matter, with a focus on quantum materials and their technological applications, such as quantum computing and quantum communications. https://icn2.cat/en/ |
| IFAE | Benchmark in theoretical and experimental physics, high energy physics, astrophysics and cosmology, as well as applied physics, such as medical imaging and quantum computing. https://www.ifae.es/ |
| IMDEA Nanoscience Institute | An interdisciplinary research centre focused on the field of nanoscience, nanotechnology and molecular design, with programmes in quantum nanodevices, nanomagnetism and nanomedicine, to name but a few. https://www.nanociencia.imdea.org/ |
| TECNALIA | TECNALIA is the largest applied research and technological development centre in Spain, and a benchmark in Europe. It is working on computing and simulation, sensorics, QKD communications and PQC. https://www.tecnalia.com/ |

Source: *Own wording*.

## Regional partnerships and ecosystems

The important stakeholders in the Spanish quantum technologies ecosystem also include business associations, technology hubs and different territorial ecosystems. Such entities help to streamline the market and create synergies between different stakeholders.

| Partnership or ecosystem | Description |
|---|---|
| AMETIC | Working Group on Quantum Information, Computing and Cybersecurity, belonging to AMETIC's Innovation Committee.<br>AMETIC is the Voice of the Digital Industry in Spain.<br>The Quantum Technologies Group comprises over 50 supply and demand side companies.<br>It actively participates in the AMETIC Congress in Santander by organising the "Quantum Table" and awards the AMETIC prize for "Business Excellence in Quantum Technologies".<br>In addition, it has collaborated with the Industry 4.0 Commission on publishing a document on the application of Quantum Technologies in the industrial field, compiling different use cases.<br>It is a member of the Quantum Industrial Consortium QuIC and represents this organisation in Spain. It is a member of the Quantum Strategic Advisory Board for the EU Flagship. It is a member of the UNE CTN 071/SC14 "Quantum Technologies" working group.<br>https://ametic.es/es |
| APTE / DISRUPTIVE | The Association of Spanish Science Parks has created the DISRUPTIVE Platform to study, disseminate and promote disruptive digital technologies. This Platform has a working group on quantum computing, coordinated by the CSIC's Quantum Technologies Platform.<br>https://ptedisruptive.es/conocimiento/grupos-trabajo/ |
| barcelonaqbit bqb | A think tank and professional network for quantum technologies with 17,000 "qualified quantum contacts" on LinkedIn.<br>It recognises the work of dissemination information on quantum technologies via LinkedIn through "bqb Quantum Top Voices".<br>http://www.barcelonaqbit.com/<br>https://www.linkedin.com/in/barcelonaqbit/ |

| Partnership or ecosystem | Description |
|---|---|
| Council for Quantum Technologies of Catalonia | A council created by the Government of Catalonia in June 2021 that brings together the main players in quantum technologies in Catalonia. It is chaired by Andreu Mas Colell and promoted by the Government of Catalonia. https://cido.diba.cat/legislacio/11990223/acord-gov1012021-de-6-de-juliol-pel-qual-es-crea-el-consell-de-les-tecnologies-quantiques-de-catalunya-departament-de-la-vicepresidencia-i-de-politiques-digitals-i-territori |
| Gipuzkoa Quantum | The Department of Education for the Basque Government and the Provincial Council of Gipuzkoa signed a collaboration agreement in September 2021 with the aim of jointly promoting the development of a Quantum Technologies Hub in Gipuzkoa. https://www.gipuzkoa.eus/es/-/aldundia-eta-jaurlaritza-lankidetzan-arituko-dira-gipuzkoan-teknologia-kuantikoen-polo-bat-garatzeko |
| IKUR | The Ikur 2030 Strategy issued by the Basque Government's Department of Education is committed to developing four emblematic areas or niches by 2030, including quantum technologies. https://www.science.eus/es/ikur |
| Madrid Quantum Network | It boosts European capabilities in quantum technologies, cybersecurity and industrial competitiveness; it is focused on providing quantum key distribution as a service. https://www.upm.es/recursosidi/offers-resources/soluciones-tecnologicas/madrid-quantum-network/ |
| Galician Quantum Technologies Hub | The Hub was created to make Galicia a European and international benchmark in quantum computing and communication by 2030, both at an academic and research level, as well as at a business and commercial level. https://www.cesga.es/polo-de-tecnologias-cuanticas-de-galicia/ |
| Quantica - Mediterranean Valley of Quantum Science and Technologies | Creation of a hub model similar to Munich Quantum Valley. Led by ICFO, and with support from the Department of Science and Universities for the Government of Catalonia. https://dogc.gencat.cat/es/document-del-dogc/index.html?documentId=923673 |
| QuantumCAT | This is the quantum technologies hub for Catalonia. It aims to develop projects on technologies that are currently in the laboratory so that these can be implemented at the industrial level. The Hub includes both research institutions in Catalonia and industrial players in this field. It has received funding from the European Regional Development Fund (ERDF) within the ERDF programme, and from the RIS3CAT programme. https://quantum-cat.cat/es/inicio/ |
| Quantum Computing Spanish Association in Informatics | Qspain is a Quantum Computing Think Tank created as a non-profit association formed by full members. Its aim is to foster and promote the development of quantum computing and its applications from Spain. https://qspain.org/ |
| Quantum Ecosystem (Bizkaia) | The Bizkaia Provincial Council's strategy to consolidate the region's international position in the field of quantum technologies and to become a benchmark hub for knowledge and future developments in the field of quantum. https://web.bizkaia.eus/es/web/comunicacion/noticias/-/news/detailView/22203 |
| Quantum World Association QWA | An independent international start-up organisation with a focus on quantum technologies. It is based in Barcelona. Its mission is to empower and accelerate the deployment of Quantum Technologies in enterprises, connecting users, suppliers and opinion leaders. www.quantumwa.org |
| Spanish Quantum Information and Technologies Network | National Network funded by the State Research Agency (AEI), which has been under the Ministry of Science and Innovation since 2014 and which brings together the main groups for quantum technologies and information, both theoretical and experimental, in Spain. It promotes the organisation of meetings, summer schools and, in particular, the ICE congress. https://www.ritce2020.hbar.es |

Source: Own wording.

## National and regional projects and initiatives with public funding

The following is a list of the main regional, national and European projects and initiatives that have received public funding, with the participation of Spanish companies, contributing to streamlining the Spanish national ecosystem. For each project or initiative, the source of funding, the approximate amount and the project leader are identified.

| Project | Description |
|---|---|
| PERTE VEC (Strategic Project for Economic Recovery and Transformation for developing electric and connected vehicles) Renault | Industrial innovation ecosystem for electric, autonomous and connected vehicles. Multiverse Computing is participating in this project by contributing to creating new quantum algorithms to better support new test platforms and other operations relating to electric, connected and autonomous cars. https://thequantuminsider.com/2022/09/07/multiverse-computing-joins-electric-vehicle-alliance-led-by-renault-to-advance-auto-industry-in-spain/ |
| Quantum Communications Supplementary Scheme | Research project financed by the recovery funds and the autonomous communities, with the participation of Castile and León, Catalonia, the Community of Madrid, Galicia, the Basque Country and the CSIC's Quantum Technologies Platform. The central theme of this scheme is quantum communications, but it also includes contributions towards sensing, quantum computing and algorithms, for example. https://www.ciencia.gob.es/Estrategias-y-Planes/Plan-de-Recuperacion-Transformacion-y-Resiliencia-PRTR/Planes-complementarios-con-CCAA/Comunicacion-cuantica.html |
| AgrarIA project | Within the AgrarIA project, GMV and CSIC will lead a pilot project using quantum machine learning to try to predict the yield of agricultural crops. https://www.csic.es/es/actualidad-del-csic/un-equipo-del-csic-utilizara-inteligencia-artificial-cuantica-para-predecir-el |
| CUCO project | CUCO is the first large industrial consortium of quantum computing at the national level in Spain with the aim of advancing scientific and technological knowledge of quantum computing algorithms, supported by the CDTI within the Misiones 2021 programme and supported by the Ministry of Science and Innovation under the Recovery, Transformation and Resilience Plan. https://www.cuco.tech/ |
| QUANGO project | Together with ICFO and 6 other partners, in January 2021, Sateliot launched the QUANGO project "cubesat for QUANtum and 5G cOmmunication", funded through the H2020 call for tenders. This project will design and prototype the key elements of a satellite mission aimed at providing internet of things services and quantum key distribution. https://cordis.europa.eu/project/id/101004341/es |
| Q-SiNG | A project resulting from the 2021 call for tenders by EDF to develop a quantum-based inertial navigator and gravimeter. https://defence-industry-space.ec.europa.eu/system/files/2022-09/Factsheet_EDF21_Q-SiNG.pdf |
| QFirst and Q-eNVy | QFirst aims to develop quantum components (quantum hardware) for ultra-resolution sensors using solid-state physics technologies based on vacant nitrogen centres. It is coordinated by TECNALIA with collaboration from the UPV/EHU, TEKNIKER, the Materials Physics Centre and AVS NEXT. Q-eNVy backs the above initiative with a scientific-technological infrastructure to support RD&I in this field of knowledge. These initiatives are supported by the Basque Government's ELKARTEK and AZPITEK programmes, respectively. |
| Quantek | This organisation studies problems, challenges and limitations of quantum technologies, analyses possible applications in Basque industry, and subsequently disseminates both applications and capabilities. It focuses on Quantum Software Engineering, Quantum Optimisation and Simulation (Computation and Simulation), Quantum Security and Communications and Quantum Computing Ecosystem building. It is funded by the Basque Government's Elkartek Programme. https://www.quantek.eus/ |

| Project | Description |
|---|---|
| Quantum Spain | Creation of the first quantum computing ecosystem in Southern Europe, based on a public-private cooperation model; an open quantum supercomputer, serving the research community, companies and public entities. https://quantumspain-project.es/ |

Source: Own wording.

REPORT

# SPAIN QUANTUM INDUSTRY

AMETIC 2023 - ENGLISH VERSION

Ametic
LA VOZ DE LA INDUSTRIA DIGITAL

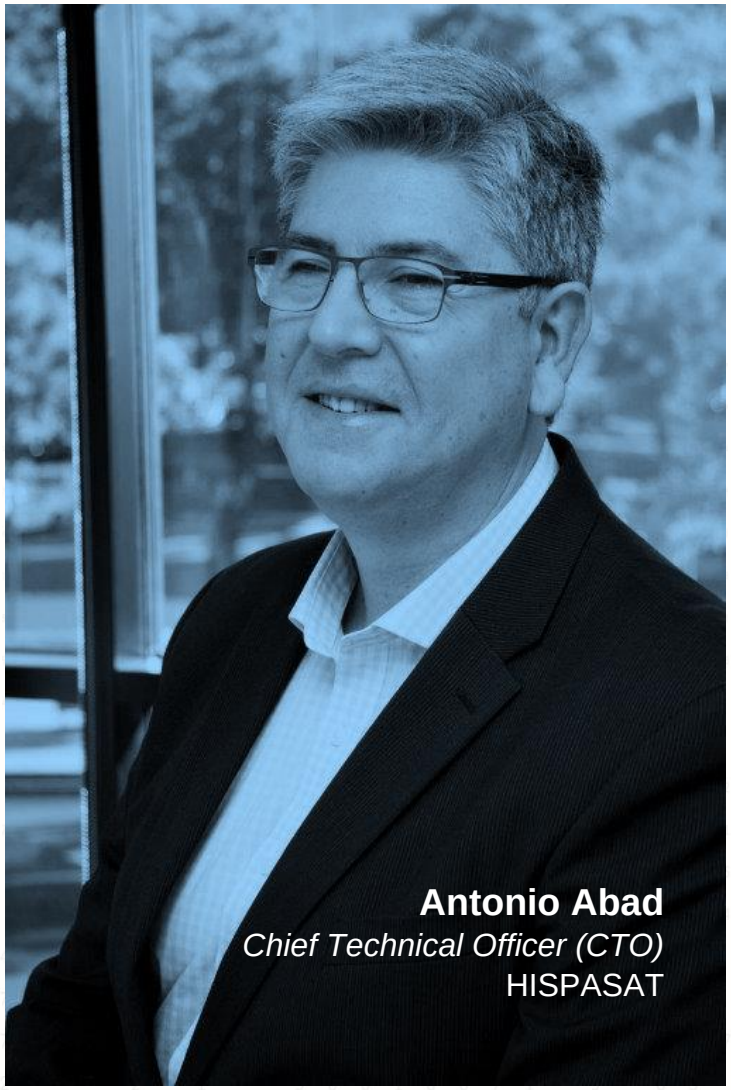
aniversario 50
1973 - 2023

# 03 INTERVIEWS

# Interviews

As we have seen in the previous sections, a large number of initiatives are being carried out in Spain, driven by the public administration and the supply sector, with the aim of creating services, innovative products and a strong, cohesive ecosystem. However, these efforts would come to nothing if the demand side did not follow suit.

With the aim of giving visibility to quantum technology projects initiated by leading demand-side companies in Spain, AMETIC has invited those responsible for these projects to contribute an article. These articles reflect the views of the author and not those of AMETIC, or its members, and contain information that the author has freely chosen to share. As far as possible, AMETIC has included as authors a representation of leading companies in different industries, such as banking, pharma, aerospace, energy, automotive and telco.




We are currently experiencing the so-called *"second quantum revolution"*, which promises a paradigm shift, in which quantum computing will achieve the potential to solve problems in a way that would previously have been unimaginable. However, these new computational capabilities threaten the security of the encryption systems on which our society depends. It is therefore necessary to develop secure communications methods that are resistant to this threat.

Quantum Key Distribution (QKD) systems ensure authentication and privacy of communications by providing secure encryption keys, as the presence of an intruder is always detected and the compromised key is discarded. Ground-based quantum networks are currently being deployed in an experimental phase in several metropolitan areas in countries like China, Germany and even Spain. However, the range of such ground-based networks is limited to just over 100 kilometres, making satellite the optimal medium for transmitting these keys over longer distances.

The global quantum satellite communications market (including platforms, launches and services) is expected to reach USD 2.6 billion by 2030, with a cumulative turnover associated with services (mainly QKD) of USD 1.8 billion. We are currently validating the technology in orbit using experimental satellites.

There are, therefore, a number of challenges to be overcome in relation to satellite-based quantum technologies. Firstly, increasing the robustness of the quantum signals to mitigate the noise present in the free-space channel and thus achieving higher key transfer rates. Secondly, the system components must be built to withstand the demanding conditions they will be subjected to in space. Finally, photon sources and on-board telescopes are another barrier due to their current low level of technological maturity. As a result, projects are needed to fund the qualification, integration and in-orbit demonstration of such equipment.

**National level**

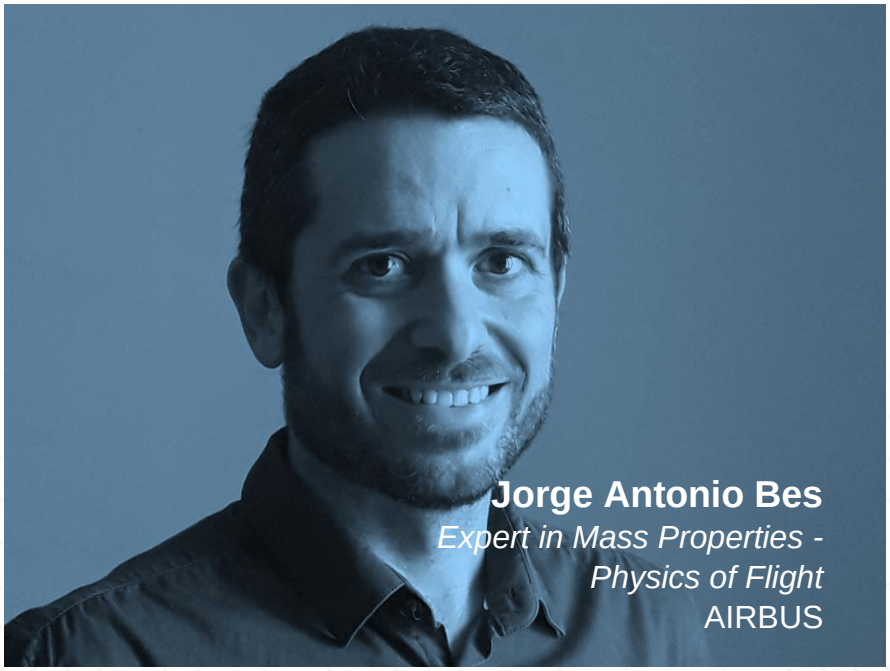
At the national level, Spain should address a plan for developing the technologies needed to design, create and potentially operate a quantum communications service, including the satellite. Such a service would be provided by an end-to-end system involving industry, operators, academia and national users. Such an ambitious task, focused on providing such a critical service, can only be undertaken through public-private collaboration; starting with proofs of concept and usability demonstrators, and culminating with the implementation of a system that meets the security requirements validated through certifications and that will be integrated into the European Commission's project for developing the future European secure quantum communications infrastructure (EuroQCI).

HISPASAT has recently obtained the support of the European Space Agency (ESA) within the framework of the ARTES “Competitiveness & Growth” Programme, through the Centre for the Development of Industrial Technology (CDTI), for its Caramuel Phase A project. This project aims to design, develop, launch and operate the first implementation of a QKD system from geostationary orbit. The space segment will be embarked upon as a hosted payload on an upcoming HISPASAT High Throughput Satellite (HTS). The new ground segment to manage and control the QKD service will allow its integration into the EuroQCI framework. During the project’s feasibility study phase, the different technological and design alternatives are being evaluated, according to the state of the art and the requirements of the services to be provided, leading to the definition and specification of the system and the associated development plan.

**Quantum talent**

In Spain, there is abundant know-how and a multitude of internationally renowned experts. An example is our Caramuel project consortium, made up of fourteen industrial and six academic partners, who are all leaders in their respective fields. In addition to the space industry and academia, the consortium includes the collaboration of operators like Telefónica and Cellnex, with whom we are analysing the interconnection with quantum ground-based infrastructures and with end users, such as Santander Bank and BBVA, in order to form an end-to-end system that meets the customers’ current and future security needs.

Finally, and in line with its mission, by working with national, European and international institutions, both public and private, AMETIC can promote policies and legislation that facilitate the development and use of satellite-based quantum technologies. Tasks could include the creation of collaborative centres, the development and coordination of roadmaps, collaboration with standardisation bodies (ITU or ETSI) and, of course, outreach aimed at accelerating the adoption of these innovative technologies, which are indispensable for secure communications in the sustainable society of the future.




At Airbus, we believe that quantum technologies will represent a paradigm shift in the way aircraft are built and operated.

That is why Airbus is closely following the evolution of these technologies, not only in the field of computing, but also in the areas of sensors and communications. We want to pioneer the use of these technologies to improve the performance of our products and services, as they will help us solve some of the most complex problems in the aerospace world.

At Airbus, we are not working alone but in collaboration with the world's best experts from academia and start-ups. Through Airbus Ventures, we invest in leading quantum technology companies like IonQ, QCWare, Q-Ctrl and C12 Quantum Electronics. We also collaborate with universities, such as the University of Bristol's Quantum Technology Innovation Centre.

In 2019, we launched the “Airbus Quantum Computing Challenge”, an open initiative aimed at the entire community of researchers, experts, universities and companies. Airbus proposed five real problems relating to the physics of flight, for which participants could propose a solution based on quantum technology.

These problems deal with issues such as optimising an aircraft’s climb phase, applying quantum technologies to CFD (Computational Fluid Dynamics), applying quantum neural networks to solving partial differential equations, optimising the wing box design in a multidisciplinary way, and optimising the aircraft loading process. The challenge garnered over 1,000 participants from 70 countries, and received 36 solutions. This demonstrates the significant global interest in the initiative.

The winner was announced in December 2020: Machine Learning Reply, an Italian company that came up with a brilliant proposal to solve the aircraft load optimisation problem. As a result of this challenge, Airbus and Machine Learning Reply worked together during 2021 to jointly explore this proposal and analyse how these complex calculations could directly impact the airline business, maximising the amount of cargo carried by aircraft and minimising the costs associated with this transport. In pursuit of this goal, different methods were studied, including those on quantum computers and employing quantum-inspired algorithms.

Airbus is actively working with its partners to investigate the advantages of quantum technologies and their potential for practical use. In particular, in the field of quantum computing, we work on use cases linked to Quantum Simulation (material behaviour simulations), Quantum Optimisation (fleet optimisation), Quantum Machine Learning (in data intelligence cases) and Quantum solvers (such as the aforementioned CFD).

Institutional support for such initiatives is key to creating consortia that can generate innovation at different levels, connecting supply and demand for quantum technologies, as well as helping to develop talent in such a new area.

AMETIC serves as a platform for companies to connect with each other, specifically those involved in the supply and demand of quantum technologies. As an association, AMETIC maximises the visibility of quantum technology companies, provides an environment in which use cases can be shared and brings the common needs and interests of companies interested in quantum technologies to institutions.


Quantum computing is experiencing a time of burgeoning expectations in different industrial sectors. By the end of this decade, we can anticipate the development of fault-tolerant quantum computers. In the meantime, we will have access to small-scale devices that lack error correction, but can still assist us in exploring applications within our industries and advancing our in-house capabilities.

Experts estimate that some quantum benefits could be seen in devices implementing a few thousand qubits, which could happen within two to three years. The next developments will progressively hybridise quantum and classical computing (typically supercomputing or high-performance computing), expanding capabilities by combining the best of each world.

As far as the multi-energy industry is concerned, it stands to reason that this could materialise in one way or another. In our industry, we can group the applications of quantum computing into three categories: Firstly, the optimisation problems that are ubiquitous in logistics, planning or controlling our assets. It is possible that in this category, quantum computing could provide benefits in the near future. This could be achieved through more accurate solutions to existing problems or by allowing the exploration of more intricate and higher-dimensional problems. Secondly, simulation problems: specifically in molecular design and chemistry in general in applications like catalyst design or the capture and subsequent use of carbon dioxide. In this case, the advantage will be more in the medium term, as it is much more demanding in terms of computational capabilities. Thirdly, data-driven applications, such as machine learning, which is increasingly vital in customer-centric service delivery. Quantum computing has much potential for application in this industry as well. However, the ambitious programmes for digitisation and AI applications have not yet been fully implemented, so it may be more appropriate in this case to observe the results of these implementation programmes, in order to fine-tune the type of application in which to gain the much desired quantum advantage.

In addition, quantum computing could result in a reduction of several orders of magnitude in the energy consumption used in computing itself, with associated reductions in greenhouse gas emissions.

At Repsol, we are starting on the quantum journey by linking two revolutions: the energy transition and the second quantum revolution. By creating a multidisciplinary Quantum Advisory Team with representation from different parts of the company, we are ensuring early adoption across the board. After appropriate internal and external reflection and exploration exercises, our early adoption strategy has led us to leading the “Quantum Computing for a Sustainable Energy Industry” work package as part of the CUCO project (www.cuco.tech), funded by CDTI and with the participation of the most relevant research centres and companies in the country.

The current challenges are different. Handling technology development and learning times with a product-oriented culture, managing technology expectations and developing a sufficient technological approach to establish the most suitable strategic alliances.

It is time for all of us to join forces and take advantage of Spain's enormous quantum quarry. We must encourage civil quantum initiatives: popularisation of the technology, access to quantum computing infrastructures, dissemination and creation of specialised forums, professional training programmes at different levels, and monitoring and promotion of funding programmes for quantum initiatives.

Let’s do this on a continuous and sustained basis. Let's make a quantum path.


In order to address the impact of these quantum technologies, we differentiate between the Healthcare, Life Science and Electronics industries, as well as quantum technologies, sensorics, computing, without going into the communication or cryptography aspects.

With regard to quantum sensing, the **Life Sciences** environment will benefit from new methods / sensors / materials for diagnostics, specifically sensors to detect weak electromagnetic signals or temperature differences with very high accuracy. In addition, the use of new imaging techniques, such as high-resolution live-tissue magnetoscopy, will complement our current understanding and provide better diagnostics. New metamaterials or enhanced dyes for imaging are likely to be on the market soon; in this area, we already have applications for NV-diamonds.

When it comes to **Healthcare**, the process of adopting these methods is a little slower in daily operations. We could see improved wearables (temperature/acceleration/motion sensors) to monitor patients with chronic diseases or use metamaterials to improve tissue imaging. These technologies will also be applied to pre-clinical research.

In turn, the field of **Electronics** will produce new sensors and, at the same time, deploy all kinds of solutions to improve their analysis as well as quality control at all stages of production. The biggest impact is likely to be on integrated optical components.

**What about quantum computing?**

Using quantum computing to simulate material properties is one field of application. Currently, we only have initial proofs of concept. However, there is a shortage of suitable infrastructure to carry out significant calculations. There are algorithms that can calculate the fundamental states of primitive molecules, but the use of QC is not yet possible due to the limitations of HW. Specific algorithms that have demonstrated theoretical mathematical (exponential) speed-up, e.g. quantum Fourier transform, period search, etc., are not yet ready to be implemented on a significant scale.

In order to resolve optimisation problems, we have experimental evidence that, for certain classes of problems, hybrid quantum computer models (either annealing or QAOA) could play a key role in the near future, as they are tackling problems that are currently difficult to solve due to their complexity on classical, knapsack computers with a high number of variables.

In the field of theoretical computational chemistry for drug design, there have been efforts to utilize a secondary category of optimizations. However, there seems to be a shortage of hardware maturity to yield significant outcomes.

On the other hand, Quantum Machine Learning is a very interesting field in the current “NISQ” era. Classical machine learning approaches are being supplemented and improved, and quantum features are being used to enhance machine learning. The main challenge again here is encoding data so that quantum algorithms can work with it. An emerging field of current research is evaluating a better “ansatz” for quantum optimisation. We could say that we can eventually tackle specific problems that produce better quality results compared to classical convolutional neural networks.

Specific tailor-made solutions integrating HW control and specific chips are a promising way to explore quantum chemistry and material simulations on quantum hardware.

On the other hand, however, the main challenge is that there is no incentive to encourage their use. Another barrier is the lack of trained professionals (quantum natives), and a solid understanding of the potential applications (what is needed and where) and the resulting market (who will pay for it), and of course, finding use cases.

At the national level, Spain should commit to a plan for these technologies. In fact, ideally, there should be a single plan supported by all the Autonomous Regions. Part of the Next Generation funds and the plan for the recovery, transformation and resilience of the Spanish economy should be dedicated to these technologies.

**Merck's role in these technologies and talent development**

Within Merck, we have developed several projects in this area. To give a few examples, we developed algorithms for materials research in NISQ; a phototoxicity simulation project; a BAIQO research project under the auspices of the German BMBF together with LMU Munich for quantum Bayesian networks; project sponsorships with TUM Munich for using quantum applications; projects with the German Ministry of Education and Research whereby we consult and play the role of a potential user of quantum batteries; and development as a supplier of specific material for quantum sensors / processors (e.g. pure isotopes for NV-diamond CVD production). Also noteworthy is the Quantum Computing Task Force (QCTF) initiative, which we launched a few years ago, as a working group that explores and generates opportunities in the quantum computing environment for the pharma world. We know that one of the challenges facing our industry is to reduce drug development times, and we believe that one solution to expedite these processes may lie in quantum computing. This project is a great example of how, at Merck, we are committed to collaborating and creating alliances that allow us to promote these technologies and progress together.

Another issue is people; there can never be enough talent. In fact, we are likely to be only a few years away from having true “quantum natives”, who will learn to think in quantum terms from an early age. At Merck, we are committed to finding and retaining diverse talent, i.e. talent that has different ways and perspectives of approaching a given challenge, and here digital capabilities are, and will be, key for the future.

Although it is true that universities have achieved good progress in recent years and a high percentage of students are already familiar with the term “quantum”.

To implement quantum projects, we are seeing an emerging community also in the field of quantum biology. It is now up to the industry to dare to find its way into these communities. Currently, the field is more exploratory, and fundamental research is ongoing, which on the one hand is very attractive for pioneering, but at the same time in some cases not attractive enough to enter as a large corporation.

**On AMETIC's role**

I believe that AMETIC is already doing a great job in promoting awareness and adoption of these technologies. Creating working groups and efforts to raise awareness of these technologies among partners are vital in order to drive this forward.

Another focus for development that can be promoted by AMETIC is to encourage the search for use cases in order to be able to apply these emerging technologies.


The impact of quantum technologies on the banking industry is twofold

On the one hand, the threat posed by quantum computing to current public key cryptography has the potential to pose a risk to the confidentiality of information, the authentication of people and information sources, and to the usefulness of digital signatures. An example could be payment systems. As the BIS, the international authority in the field of payments, has said, quantum computing may put the confidentiality and integrity of payment systems at risk. And given the long-term sensitivity of financial data, it is essential to address this risk well in advance. [1].

Various analyses set the window of impact for quantum computing on cryptography to 2030[2] and 2045[3]. The risk to cryptography must be addressed long before it materialises and must be dealt with conservatively. Therefore, it can be expected that, after the standardisation of post-quantum cryptography by NIST [4] (2024) and the availability of commercial products adapted to these standards, a major transition activity will take place and should be completed by the mid-2030s at the latest. In this regard, the US National Security Agency (NSA) has set 2035 as the target date for the complete abandonment of classical cryptography that is vulnerable to quantum computers. But more important than that, it has set 2025-2027 as the date by which post-quantum cryptography systems must be used by default for many applications [5].

It is hopeful that the progress in quantum computing can enhance the optimisation of intricate calculations for vital banking processes like fraud detection, risk calculations, and portfolio optimisation. These improvements may mean an improvement in computing time, the ability to tackle more complex problems and a reduction in power consumption.

We do not yet see clear, reliable information about when quantum computing will be useful on practical scales to solve real cases in the banking business.

However, we see two main barriers to the practical adoption of quantum technologies:

1. Lack of reliable information on when quantum computing will be useful for solving practical real-world production problems.

2. The shortage of talent, partly due to the lack of specific training schemes.

Regarding the first point, we should bear in mind that quantum computers are a nascent technology, still in the early stages of development. At the same time, a vibrant innovation ecosystem is emerging around quantum computing. Some stakeholders in this ecosystem raise expectations that do not match reality, thus generating great uncertainty. This situation

particularly negatively affects the adoption of quantum technologies for business purposes due to the difficulty of building reliable business cases. In this sense, assuming that self-regulation of the industry, which avoids raising expectations to unrealistic levels, is unlikely, we believe that some kind of impartial mechanism would be useful to assess the real achievements of the new solutions to some of the most relevant problems. This type of mechanism would create confidence on the consumer side in the value chain and the ability to plan for orderly adoption. As BCG states in its publication "*The race to quantum advantage depends on benchmarking*"[6], we believe that a reliable validation model is essential for industrial adoption of quantum computing.

In terms of talent generation, we note that many universities in Spain are developing specialised programmes in quantum technologies. It could be useful to encourage university-industry collaboration to make these programmes market-driven.

From a national perspective, we note that several countries have specific quantum technology programmes. In some cases, these are presented publicly by their top leaders (France and Germany).

Public administrations can play a relevant role in ensuring the generation and retention of talent in Spain, favouring the pre-competitive collaboration of the various stakeholders and facilitating the mechanisms to eliminate the uncertainty discussed above.

At Santander Bank, we are working on both of the impact dimensions discussed above. We are carrying out intensive awareness-raising and internal outreach work in both areas.

In terms of the impact on cryptography, we are devising a transition strategy to secure cryptographic systems in the face of quantum computers.

When it comes to applying these technologies to business problems, we are experimenting with some internal use cases that we consider relevant and likely to offer advantages in the short term.

These activities are enabling us to deepen our understanding of quantum technologies, as well as to identify and develop internal talent.

It is indeed true that there is talent in quantum technologies as well as talent with knowledge of the real needs of the banking sector. However, it is currently very difficult to find profiles with a combination of both skills.

The main gap is the lack of talent that understands the possibilities of quantum technologies and, at the same time, the real needs of the banking business. It is common to find publications on the application of quantum technologies to the banking industry that adopt an overly academic approach, which is far removed from the real problems. A collaborative approach is needed to combine the two approaches.

AMETIC is doing a very valuable job in disseminating and creating meeting points for the different stakeholders involved in quantum technologies in Spain. It is an extraordinary facilitator for the connection between academia and supply and demand companies in a pre-competitive environment. It also represents Spanish industry in international forums, such as the Quantum Industry Consortium and the Strategic Advisory Board for the EU Quantum Flagship. The "Quantum Spain Report" is, in itself, a useful guide to defining a broadly agreed national strategy. These actions are valuable and should be continued.

This work could perhaps be enhanced by developing and promoting national use cases with early practical utility, which could be exportable as benchmarks for national capabilities in quantum technologies. The fact that AMETIC is bringing together supply and demand side companies can be useful in setting targets for real use cases and models for validation.

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[1] https://www.bis.org/press/p220617.htm
[2] https://eprint.iacr.org/2015/1075
[3] Gartner - Taking the Quantum Leap Fact, Fiction or Fantasy
[4] https://csrc.nist.gov/Projects/post-quantum-cryptography
[5]https://media.defense.gov/2022/Sep/07/2003071834/-1/-1/0/CSA_CNSA_2.0_ALGORITHMS_.PDF
[6] https://www.bcg.com/publications/2022/value-of-quantum-computing-benchmarks

**Óscar Pallarols**
*Global Commercial Director*
CELLNEX

**A unique opportunity to position ourselves in Quantum Communications**

The use of quantum technologies for communications is gathering speed. And Europe does not want to lose this race in which Spain has sufficient credentials to play a relevant role.

Although the maturation cycle of quantum computing still has a long way to go, the application of quantum technology in communications is already a reality today. Artificial intelligence and new computing capabilities can solve encryption algorithms for encrypted content using mathematical logic. The barriers between computing power and the digital chain, which protects communications, have lowered, making this more affordable for hackers.

At Cellnex, we prioritize the implementation of quantum communication technology to enhance data and communication line security and reliability, and to stay ahead of hacking models. Despite the complexity of quantum computing, quantum communication is remarkably simple.

Our company has successfully taken part in the initial test of quantum cryptography utilizing our proprietary technology. This marks the first step towards the development of a future metropolitan network in Barcelona and the planned pan-European quantum communications infrastructure, known as EuroQCI. The ICFO (Institute of Photonic Sciences) has been instrumental in promoting this initiative.

The pilot test was conducted on a point-to-point fibre-optic network over a distance of 30 kilometres, with quantum key generation boxes made by a Catalan start-up at each end.

The test validated its efficiency in a series of programmed cyber attacks that set off alarm bells and validate the technology and the existence of an initial commercial product, although some of the barriers to adoption still need to be broken down.

Between governments, companies and developers, we will have to define the basic principles for contracting, operating, billing or maintaining these services, which are a priori fundamental for financial companies, utilities, health institutions, governments and their institutions.

Spain meets the requirements to become a benchmark for a quantum security ecosystem that will be indispensable. We have the solutions base developed by an exceptional group of scientists, so this can be transferred to the business market. We have world-class research and technology centres, from the aforementioned Institute of Photonic Sciences to one of the largest supercomputing centres in Europe, and our experts have been actively involved in the European quantum strategy.

Our network includes a diverse group of corporations engaged in telecommunications, telecommunications infrastructure, satellite operation, defense, aerospace, and communication industries. This broad network ensures a vast selection of quantum communication options.

Our team includes experts across the entire value chain, and the government has established a program called Quantum Spain to support our efforts.

Apart from aid and technological advancements, what we truly require are corporations that prioritise the future. Companies that are not solely focused on short-term profits, but are dedicated to building resilience and achieving long-term success. We also need to focus in order to choose projects that can really make a difference and enable high-level contributions, with efforts centred on a couple of large quantum rings in urban centres, for example. This is where support from business associations and interest groups is needed to convey the common interest to the authorities and to ensure Spain's relevance as well as the optimisation of the technology and telecommunications ecosystem that we have been creating in recent years.


*"The new Doctor Strange movie comes out this weekend in the multiverse of madness".* My eldest son told me this yesterday. He's a fan of the MARVEL saga and has heard me talk about quantum computing, so he's already planning to get me up to speed on the portal to the Marvel multiverse. Well, it's not bad: 2 hours of Action and Adventure.

Many concepts of quantum computing appear in science fiction films today, with the majority of them being totally misleading as to the true capability of this technology. In most of the movies, (I've also had to watch "Transformers") powerful quantum computers allow artificial intelligence technology to finally take off and we reach the Singularity.

Perhaps this will happen in the not too distant future.

Meanwhile, some of the most important applications of QC will be in the field of sensors. Bosch is a world leader in electromechanical sensors (MEMS). Quantum sensors will expand the field of application of current sensors, and we want to remain a world leader, so we will continue to invest in this field. QC will enable new products, services and improvements in engineering, logistics, production, etc.

At Bosch, we are running several Quantum Detection projects:

- A quantum magnetometer based on NV centres in diamond; we have created a start-up for this: https://www.bosch-quantumsensing.com/
- An NMR-based quantum gyroscope using atomic gases

In the case of Quantum Computing, we are also working on developing quality control algorithms for different applications.

However, there are significant barriers to adopting quantum computing:

1. Finding applications for which there is a significant market in the medium term.
2. Manufacturing QT-based products that are small and inexpensive. At present, most prototypes are large and unsuitable for marketing.
3. Apart from the usual barriers to adopting new technologies: finding funding for R&D for these new technologies or products/services.

Many EU Member States already have specific funding programmes for QT.

Spain is very active in QT, also at the European level. We see this in the distribution of QuIC members by state. After Germany, Spain has the second largest number of QT companies that are QuIC members.

A specific plan on quantum technologies in Spain should be established, with public administrations acting as facilitators of private initiatives.

This type of plan should coordinate the different public administrations when it comes to financial aid, as well as addressing one of the major problems we are currently facing: the retention of Spanish talent that must go abroad due to lack of opportunities in Spain. Talent in QT is scarce, so education and training is a very important issue.

What quantum machines will be able to achieve in the future remains to be seen, but there is no doubt that, without quantum theory, there would be no lasers, no semiconductors and no magnetic resonance imaging. We are now at the dawn of the age of quantum computing.

Just in case, I'm going to see the Doctor Strange movie. Not only to enjoy it with my son, but also because maybe Marvel knows something that we don't...

**Miguel Rodríguez**
*Lead Data Scientist*
IBERDROLA

The energy transition and the consequent decarbonisation of the economy is a key objective for all of us, and at Iberdrola, we have been working for years to make it a reality. Within this huge challenge, we believe that quantum technologies can play an important role in achieving our goals.

The integration of new sources of renewable generation and energy storage, in a decentralised manner throughout the grid, represents a new paradigm of great complexity that has not been seen to date in the electricity grid. We believe that quantum computing can help us ensure proper management and optimisation of all these agents on a large scale in real time.

Quantum simulation could also bring relevant innovations to our area of business, speeding up the discovery of materials that have greater energy storage capacity or cleaner fuels, causing a direct impact on the reduction of carbon emissions into the atmosphere.

Our industry has highly critical assets. Quantum communications and post-quantum cryptographic schemes offer the promise of guaranteeing correct, secure operation, even if current encryption systems can be compromised.

We believe that those who lead the way will have a clear competitive advantage, which is why, at Iberdrola, we have already launched various initiatives with the aim of familiarising ourselves with the types of problems that these technologies can solve. For the time being, we have focused on optimisation problems for which we are encountering limitations with current computing technologies.

Prior to launching these initiatives, we carried out extensive market research, which has enabled us to become aware of the current state of the industry. Through this study, we have seen that hardware, although evolving rapidly, has not yet reached the required level of maturity, and needs hybrid solutions to solve problems in a robust way on a reasonable scale.

Another major barrier to adoption that has been identified is the shortage of talent in quantum technologies, meaning that the few profiles that do exist are snapped up by large technology companies. Companies demanding these technologies need hybrid profiles, who know the business and are capable of identifying the problems to which quantum technologies can be applied and, within these, distinguishing which ones can be tackled in the short, medium and long term.

Given that current training in quantum technologies is mainly concentrated on PhDs, producing these profiles happens on a very small scale and they are very difficult to access for companies whose core business is not quantum technologies. For this reason, we believe that there is a

need to create other types of programmes that allow for people to be trained for these hybrid roles in quantum science.

However, we are aware that, in the short term, the main focus in terms of education will be to meet the high demand for these profiles by technology companies. As an alternative, we value the collaboration spaces that are being created at provincial or Autonomous Community level, such as Quantum Ecosystem under the Provincial Council of Bizkaia, where companies within the consortium are put in touch with experts who can guide them when developing their strategies.

However, in Spain, there is a lack of national coordination for all these initiatives. It is precisely when it comes to this aspect that the role of Ametic can be fundamental, acting as a meeting point for the main stakeholders, increasing talent and, together with the government, kick-starting national projects that will drive the sector and promote the creation of an industrial fabric prepared for the quantum revolution that is just beginning.


Quantum technologies, especially quantum computing and quantum communications, are having, at least theoretically, a completely transformational impact on the financial sector. These impacts are based on the ability of quantum computing to solve exponential problems with many dimensions or variables that cannot be solved today in a timely and adequate manner using classical computation. In terms of communications, these technologies will allow us to make communications much more secure, even knowing with a required probability in advance if someone is eavesdropping on our messages.

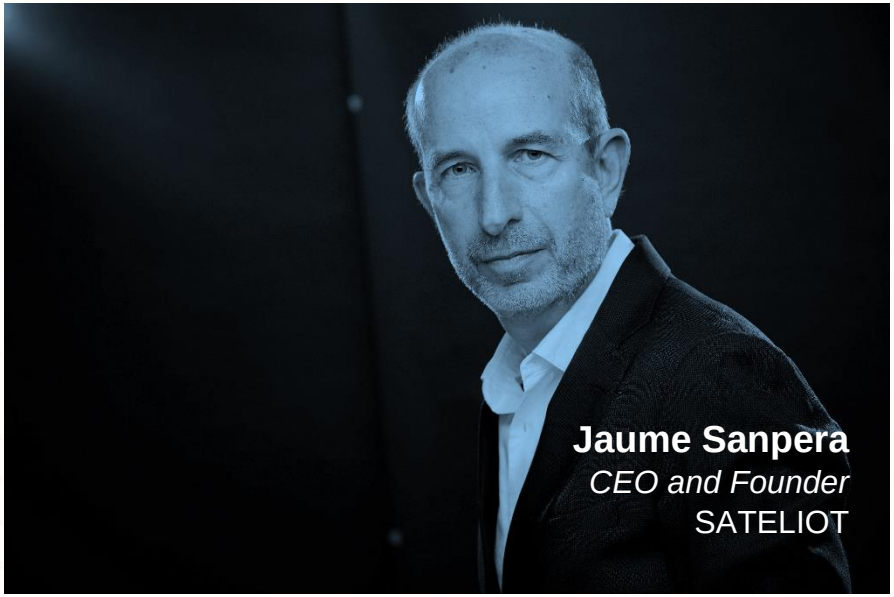
These theoretical advances (Shor's and Grover's algorithms, for example) require quantum computers with very large capacities. Thanks to advances in engineering that have made it possible to handle and control subatomic particles better than ever before, precisely those that we model governed by quantum laws, these theoretical impacts are getting closer and closer to also being both practical and real. Opinions differ as to when this moment of ground-breaking practical application may arrive, and it will depend above all on what kind of problem we are looking to solve by leveraging the advantage brought by the quantum approach over the classical approach. For some, it is less than 2 years away, for others over 10 years, but there is no doubt that the moment will come.

In the field of computing, there are many industries working on finding use cases in their industry to solving problems by applying a quantum solution that is better in terms of time, cost or accuracy than the classical one, if these exist. Regarding communications, work is already underway to standardise new algorithms and protocols based on non-quantum problems relating to these types of secure information exchanges (post-quantum cryptography). Much progress has also been made in going one step further, and making the communication channels and protocols themselves quantum (quantum communications and cryptography). The barriers to completing that step are engineering barriers, depending on the type of underlying quantum hardware we are talking about (superconductors, trapped ions, photonics, etc.), and they are also talent barriers; the demand for quantum talent far exceeds the supply, comprising general degrees with a lot of mathematics, physics and computational component, but with little specialisation in quantum computing, which needs to be a very advanced mix of these three disciplines.

At BBVA, with two of our values being to think big and put the customer first, after analysing the leading indicators for investment and patents in quantum technologies, we decided that it was necessary to initiate a line of research in this area in 2018, as part of our aim to be at the forefront of technology to ensure our customers can make the most of the opportunities brought by this new quantum era. Following the phases in the scientific method, we first collect data from our business areas. We have been looking for problems whose solution is a candidate for quantum advantage in asset management, risk management, corporate and investment banking – without focusing on hardware, since it is not our speciality and we do not know which underlying technology will be the winner (quantum annealers, on the one hand, and quantum

circuits based on superconductors, trapped ions or photonics, on the other), but always keeping an eye on this, since its evolution is fundamental for discovering the advantage. To all these potential problems, we apply the filters of business and customer impact, as well as the technical feasibility of solutions, in order to move on to the second stage of the scientific method, formulating hypotheses. In this second phase, our hypothesis was that we could find this advantage in the fields of optimisation (of portfolios, processes, etc.) and simulating variables (to value complex derivatives, simulating the underlying assets, by averaging the values of the derivative, or, if we take percentiles, to evaluate risks). Finally, in the third phase of the method, we test these hypotheses through several proofs of concept. We repeated these tests by diversifying both in terms of hardware and vendors, which is consistent with our approach of not focusing on the underlying technology. As a result, we believe that quantum optimisation is very close to having an advantage over classical optimisation, while for the advantage in variable simulation, we need lower hardware error rates, which seems to be coming along at a very fast pace.

As a last stop on our exploration of these quantum technologies, since 2021, we have been immersed in a project (CUCO) in consortium with six other Spanish companies, which are leaders in their sectors, to investigate the impact of quantum in each of our industries. This project exemplifies how public funds can bolster technological and scientific advancement in Spain. It receives partial subsidization from the CDTI through its Missions 2021 program, supported by NextGenerationEU funds. The advancement has led to an increase in job opportunities in the scientific field, fostering partnerships with public research institutions and promoting the spread of findings. This is especially crucial during the early stages of a pioneering technological breakthrough, where cooperation is more valuable than rivalry.




**We cannot be left behind in the quantum revolution**

The development of quantum technologies has great potential for growth and is a race in which Spanish companies, SMEs, and start-ups can and should play a crucial role in the ecosystem of those interested.. If we succeed in creating a strong industry in this field, we will be at the forefront of a technology that opens many doors to other disciplines and will undoubtedly be one of the main drivers of research and applied science in various fields.

In the case of Sateliot, this is an industry that we are obviously looking at. And we are doing so because of a basic fact that puts us at the centre of that interest. The distribution of quantum keys can only be done via satellite, as it is impossible to send them for cryptographic purposes over fibre optics more than 100 kilometres away.

This opens up a field of research and development in which we may launch a product in the not too distant future. At present, we do not expect quantum to have an impact on the satellite industry, but given the necessary conditions and investments, this may change within a time horizon of no more than three years.

For this to happen, a number of circumstances must occur. The first of these has to do with the strongest barrier to entry we face right now, technology. This concerns both the quantum principle itself and its application in the satellite universe. Therefore, the first step is to realise both technologies and to know how to combine them, which will not be easy.

Progress in this area depends on a number of factors. The first of these is the talent and capacity of Spanish researchers. And we certainly have that. In fact, Spain is home to one of the laboratories that annually tops the world ranking when it comes to quantum technologies. This is the ICFO, the Institute of Photonic Sciences, which is part of the Polytechnic University of Catalonia (UPC).

However, for this laboratory and other researchers in Spain to make substantial advances in the quantum world, it is essential that public administrations work in two directions. On the one hand, by devising a specific plan on quantum technologies, and on the other hand, by supporting private initiatives to jointly develop a national quantum industry.

The best way to make this last point effective would be through innovative public procurement. It would be incredibly beneficial if public administrations were committed to utilizing a quantum constellation for secure data encryption. This would greatly facilitate the financing of a business plan for its development by companies.

Spain is already taking some steps to make its way into this new world. The two plans with which the Government of Spain intends to promote these technologies are the starting point on a long and difficult road ahead.

The PERTE (Strategic Project for Economic Recovery and Transformation) on microelectronics and semiconductors and the Complementary Quantum Communication Plan to reinforce cybersecurity through RD&I are two important instruments for breaking new ground.

The first foresees an investment of €1.165 billion over the period from 2022 to 2027 to develop quantum chips. The second is more modest in terms of the amounts to be spent, as it only has a budget of €74 million, of which the Government of Spain will contribute €54 million, and the rest will be provided by the Autonomous Communities. This also presents a problem in that it only considers quantum technologies for satellites in geostationary orbits and not for those in low altitude orbits. The question is why is it limited to GEOs? We should open up that range so that it would be possible to use these aids in any of the current satellite technologies. Let us not limit the solution before we know what the best option is.

In the EU, we have just over €1 billion to fund projects in quantum computing and quantum communication. Sateliot is participating in one of them, called Quango, a €2.1 million secure information exchange scheme for banks, security agencies and governments worldwide.

These are significant sums that pale in comparison, however, to what both China and the United States are investing in order to lead this field. China has already spent €10 billion and is set to increase this investment by 7% year-on-year. The United States do not want to be left behind and have a budget of $29 billion to invest in quantum computing during the period from 2022 to 2026.

As we can see, the quantum race is on and the winner will get a big prize. If Spain and Europe do not press on, they will be left out of future applications, including satellite. We must all push forward with this: companies, universities, research centres, AMETIC, the Government of Spain and the EU, in order to be the protagonists of the so-called quantum revolution.


When it comes to industry in general, but more so to the automotive industry, incorporating new technologies and innovations in our processes and products is part of our DNA.

For years now, quantum computing has been observed from afar, primarily associated with the realms of research, academia, and science, rather than with industry. Lately, however, the industry has been showing significant interest in emerging quantum technology disciplines.

So, when this year (with the help of I3B Innovation Institute and Aitor Moreno Fernández de Leceta) Mercedes-Benz Spain was offered the opportunity to participate in a project to apply quantum computing to an industrial environment, our response was a resounding, “of course, let's do it”.

To put it very simply, we are talking about having a computational capacity that surpass the limitations of conventional computing. We can compare it to the difference between traditional physics and quantum physics. In industry, traditional limits are sufficient for many or almost all processes. And for those that require more computational capacity, we look for ways to execute them with the current capacity, simplifying them through programming and imaginative solutions.

We all use data centres, edge data centres and cloud capabilities, but using a quantum computer is currently not part of a company’s or an industrial consortium’s normal portfolio.

This last point has also meant that solutions originally designed from the outset for a quantum computing environment have not been developed.

Therefore, the fact that we have the chance to use a quantum computer to develop a proof of concept and test this technology for our manufacturing processes is a great opportunity that we cannot afford to miss.

We are aware that quantum computing will soon have an impact on all digital industrial processes, and Mercedes-Benz, given its innovative DNA, cannot allow itself to be a mere spectator to this change.

In our case, we have chosen the process for calculating the mountability of a car, taking into account that the variability of our products is gigantic.

I will try to explain this in a little more detail so that the complexity we are dealing with can be understood:

Based on the order placed according to the configurations chosen by a customer, we calculate the list of materials we need to be able to assemble it. This is like a kind of Meccano with over 4,000 pieces. But not only do we handle a large number of parts to be assembled, we also have to take into account possible constructive modifications, possible modification notices to parts, rare or less frequently requested configurations. In short, we handle thousands and thousands of possible vehicle variants. And our aim is to be able to calculate and confirm that a van will be assembled without any surprises before starting the logistical and production process.

Obviously, we have highly optimised tools to ensure this process works well. But we think it could be a good option for testing the capabilities of quantum computing and comparing its results with the current ones.

In Spain, we are fortunate to have talented innovation centres that are working on spreading the word about quantum computing and how it can help us with our business processes. In this field, innovative initiatives promoted by public administrations are always welcome. We are an enterprising, innovative society, we have many trained professionals and we know that our public administrations are also aligned with making Spain a leading technological country.

REPORT

# SPAIN QUANTUM INDUSTRY

AMETIC 2023 - ENGLISH VERSION

Ametic
LA VOZ DE LA INDUSTRIA DIGITAL

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# 04 QUANTUM ETHICS

# Quantum Ethics

More than ever, today's society is aware of the importance of ethics. Psychological safety and sustainability are part of the initiatives being pursued by societies all over the world.

In this context, companies cannot see ethics as an extra, as a *nice-to-have*: ethics are the basis of any long-term sustainable, profitable business. Indeed, those that do not put strong ethical principles at the core of all their activities will eventually disappear. Enron[1] or Lehman Brothers[2] are two paradigmatic examples.

The latest technological revolution, artificial intelligence, has shown us that disruptive technologies are particularly susceptible to being affected by ethical issues. On the one hand, they have brought us incredible benefits, such as providing assistance to people with functional diversity or searching for biases in different areas of HR in companies. However, they have also had unintended consequences, such as this Facebook[3]case, which had major repercussions.

Quantum technologies are rapidly evolving, and their immense impact and expected transformative power deserve to be described as breakthrough technologies. It is important to achieve *"quantum awareness"* in order to properly identify potential risks and establish a framework of ethical and legal sensitivity to support the development of such technologies.

Of the different quantum technologies, quantum computing is undoubtedly the one that generates the most media attention and is expected to have the greatest impact on many future applications and in terms of the boost it can give to current technologies, such as AI. Some even speak of super artificial intelligence and autonomous artificial beings. We do not know how long and what the final impact will be, but even if only half of what we can imagine can be realised, the need for responsible social control seems a necessity that we should not delay.

In this sense, and in connection with AI, we are not starting from scratch. Different academic and governmental institutions have conducted research and proposals in the area of AI ethics. And, in the case at hand, this could well be the elements on which to base the foundations of quantum ethics. The principles that should guide the ethical framework, and that should nurture the legal and regulatory system, include values such as Freedom, Justice, Dignity, Security, Sustainability, Privacy, Trust, Equal Access and Net Neutrality.

In the case of quantum technologies, we cannot wait and make the same mistakes; we have to be ahead of the curve. There is therefore an urgent need to define an ethical framework for quantum technologies, which will provide us with tools to prevent potential problems and help to maximise their development for the benefit of society as a whole.

Different organisations have already started to develop ethical frameworks, both globally in science and technology, such as UNESCO's *World Commission on the Ethics of Scientific Knowledge and Technology (COMEST)*[4], and focused on quantum technologies, such as the World Economic Forum's report on *Quantum Computing Governance Principles*[5].

An interesting compilation of guiding principles and identified risks can be found in this article[6]. The guiding principles include respect for human rights in relation to machines, respect for human autonomy and freedom, implementing technological developments in quantum technology and its synergies with other technologies according to ethical standards and universal moral values with cultural sensitivity, taking into account the

aforementioned values, applying quantum technology while ensuring the safety and integrity of people, guaranteeing these aspects through standards, audits and certifications, and many other areas that are worth reviewing and taking into account.

This reference also lists a series of risks, including imbalance, monopolisation of IP (Intellectual Property), potential impact on the economic and financial system, data privacy, data security and reliability, inappropriate use of encryption or visual technologies, environmental risk and even the extinction of the human race itself.

## Ethics and quantum: key issues

Quantum ethics asks humans to act in a morally correct manner, abiding by the standards of ethical practice and conduct established by the quantum community, and in order to ensure that these actions have desirable consequences, with the latter taking precedence if it conflicts with the former:

| 1 | 2 | 3 |
|---|---|---|
| Unforeseen risks and unintended consequences | Technological inclusion | Environmental, social and corporate governance |

## Unforeseen risks and unintended consequences

The main challenge for quantum ethics is establishing an ethical framework for a technology where we cannot yet foresee either its full potential or its applications. On the basis of current developments, we can identify risks in areas as varied as:

- Cybersecurity
- Artificial intelligence, data harvesting and privacy
- Military applications
- Gene editing
- Emerging materials

In other words, on the one hand, we would be running the risk of accentuating existing problems and, on the other, of not yet being able to identify what the new ethical challenges arising from quantum technology will be.

## Technological inclusion

In any technological revolution, an imbalance is created between those who have access to it and those who do not. And the more advanced the technology in question, as is the case with quantum technologies, the worse this imbalance becomes. On the other hand, greater accessibility and knowledge sharing are the fundamental basis for realising the full potential of any technology.

It is therefore necessary to democratise access to these new technologies to ensure maximum development and to bring the maximum social benefit. To this end, governments and companies must have a number of mechanisms at their disposal, such as regulations, subsidies, grants and other policies, which can accelerate accessibility.

## Environmental, social and corporate governance (ESG)

In this new context we are experiencing, which applies to companies and investors alike, profitability alone is no longer enough. ESG is an approach for assessing the inclusion of and responsibility for environmental and social values when developing and operating a company.

Generally, the objectives advocated within an ESG perspective include working towards a certain array of environmental goals, as well as a set of objectives that relate to supporting certain social movements, and a third range of aims associated with incorporating the issues of diversity, equity and inclusion in a coherent way.

## Ethics and quantum: key actions

The key issues detailed in this report are also a call to action. We need to ensure that governments, institutions and companies have the required impact.

| | | | |
|---|---|---|---|
| **1** Continuous study of risks and consequences | **2** Outreach and education | **3** Implementation of ESG principles | **4** Legal frameworks and regulations |

## Continuous study of risks and consequences

This action takes the form of the following activities:

- Monitoring and forecasting quantum technologies using internal and external sources (reports, news, experts, etc.).
- Identifying the main ethical implications and their risks, based on the results obtained from monitoring and forecasting.
- Putting mitigation measures in place to address identified risks.

## Outreach and education

The key actions relating to outreach and education are:

- Disseminating information about the importance of ethics in quantum technologies, with a focus on their implications, risks and unintended consequences.
- Producing materials for dissemination (white papers, articles, podcasts, etc.).
- Conducting training sessions on the intersection of ethics and quantum technologies.
- Participating in conferences, symposia, seminars, etc., through which ethical principles relating to quantum technologies can be conveyed, as well as case studies, practical examples, lessons learned, etc.

## Legal frameworks and regulations

The three key issues identified result in an urgent need to create legal and regulatory frameworks to ensure that quantum technologies reach their full potential for the benefit of society as a whole.

From a deontological point of view, defining a structured, standardised framework of standards would at least help us to consider all the ethical, legal, social and political implications (ELSPI framework).

Some might believe that we still have plenty of time to consider all these aspects, since the technology is still in its early stages of development, but this is precisely why this is the most effective time to take this action, before the new technology has reached its maturity. Thinking about and organising an ethical, legal and socially involved framework that orders and guides this maturation process will allow us to maximise its potential benefits and minimise, or even eliminate, the risks identified.

This implies the need to coordinate mechanisms at both public and private levels that address the issue of quantum ethics, and that mitigate the risks and consequences that we are not yet able to see. And, as we have said, the key will be not to lag behind the development of quantum technology, as has happened with so many other cases. We must lead the way.

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[1] Enron case: https://es.wikipedia.org/wiki/Enron
[2] Lehman Brothers case: https://en.wikipedia.org/wiki/Lehman_Brothers
[3] Facebook case: https://www.forbes.com/sites/edwardsegal/2021/09/04/facebook-apologizes-for-embarassing-mistake-caused-by-ai/?sh=c9a8c25846bd
[4] UNESCO Committee on Ethics in Science and Technology: https://en.unesco.org/themes/ethics-science-and-technology/comest
[5] World Economic Forum report on ethics and quantum: https://www3.weforum.org/docs/WEF_Quantum_Computing_2022.pdf
[6]: https://yjolt.org/blog/establishing-legal-ethical-framework-quantum-technology#_ftn39

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Other links of interest not directly referenced:
https://www.ey.com/en_uk/emerging-technologies/why-innovation-leaders-must-consider-quantum-ethics
https://physicsworld.com/a/why-we-need-to-consider-the-ethical-implications-of-quantum-technologies/

REPORT
# SPAIN QUANTUM INDUSTRY
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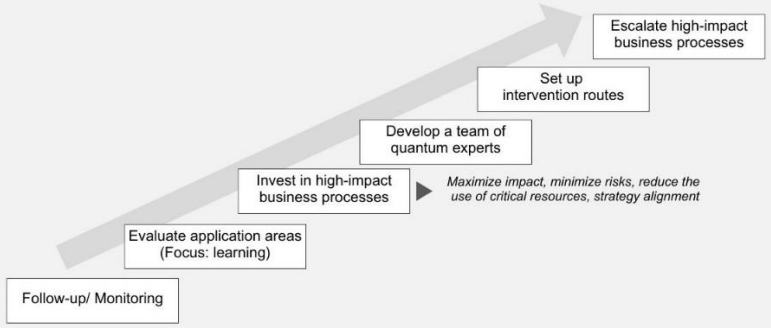
# 05 WHAT CAN MY COMPANY DO?

# What can my company do? What role can AMETIC play?

## Five particular recommendations for adopting quantum within organisations

The degree of development of the quantum market both from the perspective of products and services as well as the supply ecosystem is still in its infancy, so the capacity for adoption by organisations using these technologies is very limited. The five most significant specific recommendations for organisations considering adoption in the current context of these technologies are summarised below.

1) **Adoption roadmap.** Organisations must establish their ideal adoption path, covering the stages of monitoring and tracking, assessing areas of application following the greatest logic, investing in Business Cases that have an impact, developing their own quantum capabilities and paving the way for continuous progress.




2) **Acting on competence development.** The process of modernising the organisation with this type of technology has to take place simultaneously with developing the appropriate skills in its professionals, who are the ones who can embed the technologies in the specific business processes and differentially exploit their potential as they develop.

3) **Open cooperation.** Organisations can rely on local knowledge brokers and the ecosystem itself to accelerate this adoption process and to maximise impact on the organisation itself, minimise risk and reduce the use of critical resources and people in this process.

4) **Generosity for the sake of effectiveness and efficiency**. The effort and knowledge required in developing solutions with quantum impact is enormous. Some organisations have more means and resources, and can facilitate the sharing of knowledge, assets and experiences so that, progressively, the productive system as a whole can make progress, ultimately resulting in these approaches being improved for society as a whole. Participation in networks, associations and other similar instruments, as highly valued mechanisms for learning in the field, allow participating entities to benefit from the experiences and knowledge developed by the community as a whole.

5) **Without leadership, nothing can be done.** In an organisational context where technology is becoming increasingly prominent, the landscape of responsibilities and management of different disciplines and capabilities is becoming more complex. It is therefore vital to have the capacity within organisations to bring together the sometimes divergent interests of teams and business units and to ensure that joint efforts in technological innovation are sustainably driven towards the organisation's purpose or mission.

## Funding avenues for quantum technologies

In line with the actions envisaged in the Digital Spain 2025 Agenda and its extension, the Digital Spain 2026 Agenda, a series of specific funding mechanisms have recently been established and are already being coordinated in Spain for actions in the field of quantum computing and communication. It is a fact that both public and private investment is increasing significantly compared to the immediate past.

In Spain's European environment, including Member States and partner states, several countries also have specific support quantum programmes: Israel, the UK, Austria, Denmark, Germany, France, the Netherlands, to name but a few. However, in other countries, opportunities for quantum are reduced to more generalist programmes or bottom-up schemes, whereas in some cases, a specific support instrument for quantum RD&I is being considered.

Of particular note is the UK and its National Quantum Technologies Programme, which saw an investment of £400 million during the period from 2014 to 2019, and the next phase aimed at marketing these technologies is being planned.

With the aim of helping Spanish companies to access these funding mechanisms and develop projects in quantum technologies, the following is an index of national and international funding programmes dedicated to this area, or which could be used to fund projects in this field.

Further details on each of the different funding programmes can be found in the Annex.

### National opportunities

- RD&I projects
- Missions
- Neotec
- Aerospace technologies programme
- ERDF Interconecta
- Aerospace PERTE (Strategic Project for Economic Recovery and Transformation)
- Chip PERTE (Strategic Project for Economic Recovery and Transformation)
- Quantum Spain
- Gipuzkoa Quantum
- Supplementary plans
- IA networks + THDs
- Innovative Business Clusters
- RD&I projects in strategic lines
- Public-private partnership projects

### International opportunities

- QuantERA
- Quantum Flagship
- Digital Europe Programme
- Horizon Europe
- European partnerships
- Eureka
- Connecting Europe Facility
- European Defence Fund
- Erasmus

## AMETIC's role

AMETIC is the voice of the Digital Industry representing over 300 direct partners. Our structure is divided into Commissions and Working Groups covering multiple topics and sectors, such as Smart Cities, Cloud Computing, Artificial Intelligence and Big Data, Industry 4.0, Mobility, Microelectronics, Blockchain, Cybersecurity, Digital Skills and Talent, Agenda 2030, and more.

With the aim of leading the promotion and creation of the national quantum ecosystem, through the **Quantum Technologies Working Group**, under the umbrella of the Innovation Committee, AMETIC brings together the interest of leading companies in Spain with a clear focus on application, innovation, acceleration and transfer in use cases. This Working Group is made up of 50 entities, including private companies and supply and demand technology centres, and has the following objectives:

- Researching the use and application of quantum technologies to accelerate sustainable transformation and help achieve the European Green Deal and the 2030 Agenda for Sustainable Development Goals.
- Building a public-private consensus-based positioning of quantum technologies to be shared with industry and government at the national and European level.
- Supporting the participation of Spanish companies in the European Industrial Consortium QuIC and the QT Flagship, as well as other international initiatives.
- Positioning Europe as a world leader in quantum.
- Contributing to the expansion of the European quantum market: acting as a hub for quantum companies and their customers to adopt and promote markets and activate demand.
- Streamlining projects, standardisation and application of Spanish and European quantum technology in end markets, such as the automotive, banking and finance, cybersecurity, aeronautics and health/pharma industries, all of which are showing a growing interest in this technology.
- Leveraging Spanish capabilities in academia, research and quantum-related talent, and connecting these with the business fabric and markets.
- Launching activities to encourage and boost the national quantum market, e.g.by reissuing the report ***"La España cuántica: Una aproximación empresarial" ("Quantum Spain: a Business Approach").***
- Promoting initiatives to foster professional vocation and adequate training to respond to the upcoming employment and talent demands required in the field of quantum technologies.
- Raising awareness in society and administration of the importance, applications and benefits of quantum technologies.

AMETIC is the only business association participating in the European Commission's Strategic Advisory Board and is a member of the Quantum Industry Consortium (QuiC), an association at the European level, representing the national chapter. We have also recently joined the UNE CTN 071/SC14 "Quantum Technologies" working group.

At AMETIC, we believe that the quantum era is not only beginning, but that it is accelerating considerably, and we want to be the catalyst in Spain.

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# 06 BASES FOR A SPANISH STRATEGY ON QUANTUM TECHNOLOGIES

# Bases for a Spanish strategy on quantum technologies

Quantum is possibly the only scientific discipline currently in development that has the potential to radically transform many areas of our society. The promise of quantum technologies is to deliver supremacy in certain key fields of the Digital Transformation: Artificial Intelligence, optimisation, communications protection, hypersensitive sensing, ultra-precision metrology, etc. Their role in solving major challenges relating to health, environment, energy, transport, security or industry will be impressive. In an increasingly interconnected, automated and complex world, those who master these capabilities will exert powerful control over the market and shape the future. As the Quantum Flagship points out, "*sovereignty over these technologies will become the fundamental element for the future economic development and digital self-determination of societies*".

When all these capabilities start to be fully deployed, in about 5 years' time, it will be a complete game changer, so giving up is not an option. To be relevant then, the foundations need to be laid now. Organisations will need to develop a unique and complex mix of talent to set up impactful applications. The combination of knowledge and application skills required in these fields is very difficult to create and replicate, and requires even more intensive, sustained training and consolidation time than in other similar disciplines, such as, for example, AI.

Because of this vital importance, some twenty countries have launched specific national quantum strategies in recent years with extraordinary actions and investments[1].

Spain has developed capabilities in certain areas of digital transformation with a clear positive impact for industry, public administrations and, progressively, for society as a whole. It has the strengths and talent to seize new opportunities. However, in a context where developments are not linear but exponential, the challenges of maintaining momentum and relative competitive position are enormous. It is time to redouble efforts for developing and adopting new technologies like quantum technology, both with incremental measures as part of business as usual and with bolder actions that, as a country, will provide a differential impulse and overcome certain gaps that incremental approaches will not be able to cover.

The objective of a Spanish strategy on quantum technologies is to boost companies' and public entities' competitiveness and differentiation through the early and intensive incorporation, adoption and assimilation of quantum technologies – in combination with other technologies – in their products, services and internal processes, resulting in a positive social and environmental impact for society as a whole.

> *"The focus is not so much on specialising in what you are good at, but rather, and more so with technological change, being able to evolve in the things you are good at. The key is to search for these feasible transformations".*
>
> **- Ricardo Hausmann.**

The opportunity is twofold: to realise this transformation of the productive sectors (and of the institutions themselves) and to do so by taking advantage of the existing capacities in the territory and those that can be created.

While, in terms of establishing a strategy for the country, both an incremental and a bolder approach have the same objective, it is a matter of analysing key points and proposing complementary models to the current one that would create new favourable conditions and take advantage of these to achieve this objective even more effectively and efficiently. We believe that developing these conditions requires a new model, with new instruments and new ways of working among the stakeholders involved in quantum and

associated technologies, as these are conditions that would be difficult to achieve through a purely incremental improvement or progression on the current model. Doing the same things in the same way will not drive a differential quantum market, even if we increase the intensity and productivity under the current system by a significant percentage. Building these favourable conditions requires considerable effort in terms of investment, orchestration and leadership.

We can maximise the chances of success by intelligently leveraging opportunities from our assets and strengths, and by creating the favourable conditions for these.

## Favourable conditions

A quantum strategy requires new instruments and new ways of working between public and private stakeholders involved in quantum technologies to develop favourable conditions that would be difficult to achieve through a purely incremental improvement or progression on the current model. If we improve on the following, largely interrelated, elements, we will get on the quantum map:

- Visibility of the Spanish ecosystem on the global and, especially, the European stage.
- Coordination within this discipline between existing stakeholders in the territory.
- Awareness raising, demand creation and mobilisation.
- Acceleration of the supply-side entrepreneurial ecosystem.
- Creation of realistic experimental and piloting environments.
- Implementation of strategic projects.
- Support for deep, non-conclusive research.
- Quantum talent retention and development: ensuring access and developing quantum skills at the national level.
- Consolidation of open and well-connected networks.

## *Visibility of the Spanish ecosystem on the global stage*

Spain is a country with 47 million inhabitants in a world of 7.5 billion people, or in a Europe-27 of 500 million people. We need to concentrate and coordinate all our positioning efforts in this area or Spain will be weakened. A “country brand” and benchmarks are needed to make the quantum ecosystem visible in order to access the opportunities, some of them identified in this document (Quantum Flagship, Horizon Europe, Digital Europe) and new ones that will emerge.

**Recommendations:**

- Launching coordinated, high-impact initiatives.
- Promoting international collaboration to help grow and develop opportunities for Spanish industry, and to protect Spain's capabilities.
- Encouraging and facilitating Spanish participation in international forums, events and networks in this field.

## *Coordination between stakeholders*

There is a need to coordinate all the stakeholders active in the field of quantum technologies to guide, align and streamline activities, investments, etc., and exploit the synergies created by collaboration between them. On the other hand, the key to success lies in the optimal integration of quantum technical capabilities targeted at specific business processes for the end-application domains. Greater coordination would simultaneously allow for greater specialisation and diversity, enabling more hybridisations of quantum capabilities and facilitating their transfer to concrete application domains. Furthermore, the development of quantum applications requires common tools and practices for research, experimentation, development and implementation: platforms, laboratories, libraries, development environments, etc. A more coordinated scenario will enable sharing and reuse, increasing resource efficiency.

**Recommendations:**

- Development of frameworks, work programmes and long-term funding instruments to connect all stakeholders “end-to-end” (from knowledge to market) in order to strengthen value networks in the priority areas for Spanish industry.
- Developing a Research and Innovation Agenda specific to the context, strengths and opportunities of the national ecosystem, compatible with the RIS3 strategies for the Autonomous Communities.
- Promoting long-term coordinated actions among stakeholders, including public officials responsible for associated policies (RD&I, education, public procurement, etc.) at different levels of government.
- Strengthening mechanisms and stakeholders to bridge the gaps between knowledge generation and its commercial application in the market.

## *Awareness raising, demand creation and mobilisation*

A rigorous demand for products and solutions based on quantum technologies is what best contributes to generating excellent capabilities in the national ecosystem. Efforts for raising awareness and mobilising demand are needed to accelerate early adoption of quantum solutions. For this, the role of public officials is crucial. Mechanisms and instruments for public procurement of innovative technology by public bodies should be intensified and extended to support this new area, to compensate for the market deficit and to accelerate the creation of capacities in the supply ecosystem.

**Recommendations:**

- Extending innovative public procurement and public contracting mechanisms to favour early adopters in the public sector, its institutions and agencies, facilitating access to specialised SMEs and start-ups.
- Creating frameworks for promoting and devising early solutions that connect supply and demand.

## *Accelerating supply-side entrepreneurship within the Spanish quantum ecosystem*

To maximise the impact of these technologies on the economic fabric and society, an active industry is needed to exploit technological developments and to implement them in an industrialised way in the market. A business segment specialising in this work is essential, which may consist of established companies in the Information and Communications Technology supply side that incorporate this new value proposition, whether national or global, or of new companies or start-ups focused on this field. This is the core of the national quantum technology ecosystem. Developing this industry will enable quantum applications and solutions to be reproduced and disseminated to society as a whole.

**Recommendations:**

- Encouraging convergence between development companies in quantum and emerging technologies through key national priorities (RIS3) and developing opportunities for this convergence to take place.
- Supporting the development of key infrastructures and technologies for national sovereignty in this knowledge discipline.
- Accelerating the creation and facilitating the hybridisation of start-ups in the field with potential demanders of quantum technology products and solutions.

## *Implementation of attractor projects*

The coordination and creation of a dense network around quantum would facilitate external attractor projects and global initiatives being set up, which could be implemented in Spain. In addition, mechanisms to systematically search for and consolidate these projects must be triggered. Implementing relevant projects involving sophisticated demand has a direct impact on the excellence of the system. At the same time, they are another element for talent retention.

**Recommendations:**

- Ensuring effective collaboration around major initiatives or key driver projects for developing quantum technologies and solutions.
- Using emerging technology working groups, established within public-private partnership frameworks.

## *Experimental and piloting environments*

Any strategy to strengthen the quantum ecosystem must include access to experimental capabilities in their various forms, computing, communication or sensing and metrology. Work teams need this type of environment to validate algorithms, test devices, experiment with new approaches, etc. And because of the still limited academic and business context in this field of knowledge, both the features and access to experimental environments are scarce. There is a need to create these types of experimental environments that are easy to interconnect and provide adequate accessibility for piloting.

**Recommendations:**

- Facilitating access to relevant facilities, infrastructures and experimental environments. In particular, access to quantum should be encouraged for SMEs and start-ups to ensure that quantum technology is accessible.
- Reducing barriers to sharing and interconnecting experimental and piloting infrastructures.

## *Support for deep industrial research and innovation*

The existing systems and instruments for RD&I funding and technology adoption common in Spain are potentially valid for many projects within the context of quantum technologies. However, these existing mechanisms do not favour high-risk “deep tech” research approaches (for which there is not yet a clear demand). In a context of such dizzying developments as quantum, some of its potential is still uncertain. This means that proposals in this area cannot compete within the usual RD&I frameworks with those of other more mature, consolidated technologies. More open and flexible national mechanisms should be envisaged in quantum to allow for a focus on intensity and stability, to provide agility in exploratory and non-conclusive phases, and to facilitate scalability in an agile manner.

**Recommendations:**

- Developing specific instruments to support risk initiatives with their own excellence indicators.
- Paying special attention to the niche opportunities in Spain across all quantum disciplines: computing, simulation, ultra-secure communications, high-sensitivity sensorics or metrology, and across all the adjacent existing opportunities around all these technologies (machinery, instrumentation, auxiliary components, etc.).
- Ensuring friendly and agile conditions for industrial RD&I and innovation in deep quantum technologies.

## *Talent retention, attraction and development*

The availability of qualified quantum scientists is scarce, and there is a huge demand for quantum scientists all over the world, especially in those hubs with a magnetism for talent. A sufficiently attractive framework needs to be built to retain local talent, contribute to their skills and professional development and, as far as possible, also attract people from certain geographical areas.

**Recommendations:**

- Adapting training plans to add competences in quantum technologies, promoting the development of formulas, such as specific degrees, and formats, such as dual university-industry programmes, and covering all training cycles.
- Facilitating mobility between the academic and business worlds, and reducing restrictions, with the aim of facilitating the dissemination of knowledge.
- Creating training routes in companies for developing or retraining talent in quantum technologies, which are not only doctorate studies and which foster cross-cutting knowledge.
- Attracting the best international talent, enhancing administrative flexibility (such as visas) and promoting specific funding instruments.

## *Strengthening open and well-connected networks*

The national quantum system not only has to coordinate itself internally, but also within the European context, with which it largely shares priorities, in order to harness the joint power and combine this with its own efforts. Existing networks should be consolidated and new ones developed to exploit synergies.

**Recommendations:**

- Strengthening national associations and networks in the field, such as AMETIC.
- Promoting missions and other policies to bring national networks closer to international networks.
- Creating a specific team to uphold Spanish interests in international, especially European, financing or commercial frameworks, programmes and instruments.

[1] QURECA, Quantum Effort Worldwide: https://qureca.com/es/overview-on-quantum-initiatives-worldwide/

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# 07 ANNEX
# Financing channels (details)

# Annex. Financing channels (details)

The following is a breakdown of the different channels for public funding available, both at the Spanish and European level, for projects in quantum technologies. As far as possible, the programme and its description, the available budget, and the opening and closing dates have been included. In some cases, the latter is temporary, and is indicated as such.

## National opportunities

Recently, instruments are being developed in Spain that offer support, either directly or indirectly, to RD&I in Quantum Technologies, which is very positive for developing the ecosystem in Spain, its alignment and the use of available capacities on the scientific and business sides, both in terms of technological supply and demand, and for the potential for their application in key industries.

Within the current existing RD&I support instruments, there is room for a wide range of options, with different focuses and NRT ranking, which in any case, require a detailed study to ensure their suitability, of which we highlight the following:

### *CDTI R&D projects (PID)*

CDTI Centro para el Desarrollo Tecnológico Industrial

A business support instrument for R&D with a broad thematic spectrum, based on partially refundable credits, i.e. funded by a Non-Returnable Tranche (NRT), developed by companies and aimed at creating and significantly improving production processes, products or services.

For more information: Centre for the Development of Industrial Technology [Centro para el Desarrollo Tecnológico Industrial - CDTI] / RD&I aids / Research and development projects

## CDTI Misiones


The call for **Science and Innovation Missions** published by the CDTI aims to support pre-competitive research projects through cooperation, led by companies, in order to:

- Conduct relevant research that proposes solutions to cross-cutting and strategic challenges facing Spanish society.
- Improve the knowledge and technology base on which Spanish companies rely to compete.
- Stimulate public-private cooperation.

In its 2021 call, included among the actions foreseen in the National Recovery, Transformation and Resilience Plan, which received funding from the "NextGenerationEU" funds, including the Recovery and Resilience Mechanism, one of the Missions identified was the ***promoting high-performance computing***, which includes developments in both distributed computing and quantum computing to advance and strengthen capacities in high-performance computing to serve the business and industrial needs of the productive fabric, in particular:

- Technologies for developing solutions aimed at boosting quantum computing (simulators, development of specific SW, etc.).
- Technologies for developing hybrid architectures for classical and quantum computers.

2021 Resolution: Resolution of 20 July 2021 on the Presidency of the Centre for the Development of Industrial Technology E.P.E. (CDTI- Centro para el Desarrollo Tecnológico Industrial)

In the current 2022 edition, the call for the Science and Innovation Missions programme has included among its proposed Missions the *development and strengthening of the Resolution of 20 July 2021 on the Presidency of the Centre for the Development of Industrial Technology E.P.E. (CDTI- Centro para el Desarrollo Tecnológico Industrial), to benefit Spain's integrated photonics ecosystem*. The following areas of work have been established:

- Technologies applicable to developing tools for designing and programming photonic circuits.
- Technologies for Nano/micro chip production
- Research and development of new solutions

Projects should be clearly framed within the Programme's mission and should also set out objectives aimed at addressing one or more of the specific areas of improvement proposed in the mission. In addition, companies may propose additional complementary objectives in their project, provided that they are consistent with the selected mission.

**Application deadline**: From 22/06/2022 to 05/09/2022 at 12:00

**Funding:**€125 million

**Aid intensity:**

| Project typology | Maximum intensity | | |
|---|---|---|---|
| | Small enterprise | Medium-sized enterprise | Large company |
| Industrial research | 70% | 60% | 50% |
| a) Collaboration with companies or between a company and a research organisation; or<br>b) Wide dissemination of results | 80% | 75% | 65% |
| Experimental development | 45% | 35% | 25% |
| a) Collaboration with companies or between a company and a research organisation; or<br>b) Wide dissemination of results | 60% | 50% | 40% |

For more information: Centre for the Development of Industrial Technology [Centro para el Desarrollo Tecnológico Industrial - CDTI] / RD&I aids / Research and development projects

## *CDTI's NEOTEC*

An instrument aimed at recently created and highly technological start-ups, which offers very favourable financing conditions based on non-repayable grants.

The NEOTEC Programme aims to support the creation and consolidation of technology-based companies, where technology must be the company's competitive differentiating factor, and to this end, it offers funding for implementing new business projects that require the use of technologies or knowledge developed from research activity and in which the business strategy is based on developing technology.

The companies financed must therefore be technology-based enterprises (TBEs), i.e. companies whose activity is focused on applying products or services that require the use of technologies or knowledge developed from research activity. The EBTs base their business strategy or activity on intensive mastery of scientific and technical knowledge and therefore on creating their own RD&I lines.

NEOTEC is a well-established programme, which has been repeated annually since 2002.

**2022 call:**

**Application deadline:** From 20/05/2022 to 05/07/2022 at 12:00.
**Publication in the Spanish Official State Gazette**: Publication in the Spanish Official State Gazette
**Current status:** Closed
**Amount:** €35 million
**Aid:** Subsidy of up to 70% of the budget for the activity, with a maximum subsidy amount of €250,000 per beneficiary.
For more information: Centre for the Development of Industrial Technology / NEOTEC

As a new development, 2022 saw the publication of the first edition of the **NEOTEC Women Entrepreneurs** programme, specifically aimed at financing the start-up of innovative business projects led by women.

NEOTEC Women Entrepreneurs will promote new business projects that require the use of technologies or knowledge developed from research activity and in which the business strategy is based on developing technology. Projects running for one or two years, in any technological and industrial field, will be eligible for support. The company's management body must be made up of a majority of women and they must hold a majority of the company's share capital or a significant stake in the project to be supported.

**Application deadline:** From 17/02/2022 to 19/04/2022.
**Publication in the Spanish Official State Gazette**: Publication in the Spanish Official State Gazette
**Current status:** closed
**Amount:** €5 million
**Aid:** Subsidy of up to 70% of the budget for the activity, with a maximum subsidy amount of €250,000 per beneficiary.

For more information: Centre for the Development of Industrial Technology / NEOTEC - Women Entrepreneurs

## *Aeronautical Technologies Programme*

The Aeronautical Technology Programme (ATP) aims to finance R&D-intensive strategic initiatives carried out by a group of companies, with the objective of contributing to the development of relevant technologies for application in the aeronautics field.

In this way, the ATP supports all operators with aeronautical technological capabilities (companies, universities, technology centres, etc.) and is financed with NextGenerationEU funds, within the framework of the EU Recovery and Resilience Mechanism and Component 17 (institutional reform and strengthening of the capacities of the national science, technology and innovation system) under the Government of Spain's National Plan for Recovery, Transformation and Resilience.

In this sense, the aim is to significantly reduce the environmental impact of aeronautical technologies, increasing the efficiency of future aircraft and reducing polluting emissions from air transport, without forgetting other strategic technological challenges, such as systems, UAS or intelligent and advanced manufacturing.

Projects must address one of the identified technological challenges:

- Technologies focused on reducing emissions: zero-emission aircraft
- UAS
- Systems
- Intelligent and advanced manufacturing: Digitisation

It is also a non-repayable grant covering up to 80% of the eligible costs, which are as follows:

- Personnel costs.
- Costs of instruments and inventoriable material.
- Costs of contractual research, know-how and patents acquired or licensed from external sources on an arm's length basis, as well as the costs of consultancy and equivalent services exclusively for the project.
- Overheads and other additional operating expenses, including costs of materials, supplies and similar products, arising directly from the project.
- The cost of a report carried out by an auditor registered in the Official Register of Statutory Auditors, up to €1,500 per beneficiary per year.

The 2022 call is currently closed, but the 2023 call is expected to open at the end of Q1/Q2 next year.

For more information: Centre for the Development of Industrial Technology / RD&I aids / Aeronautical Technology Programme

## *ERDF Interconecta*

UNIÓN EUROPEA
Fondo Europeo de Desarrollo Regional

An instrument managed by CDTI, of a regional nature. It aims to foster the generation of innovative capacities in less developed regions by financing experimental development projects carried out by business consortia.

In addition to these and other funding instruments, support programmes for incorporating PhDs, such as the Torres Quevedo programme, are also of interest for quantum projects, which have high requirements for talent. On the other hand, tax deduction schemes for RD&I, as well as bonuses for research personnel applicable in Spain, are also an important pillar.

For more information: ERDF Interconecta

## *Aerospace PERTE (Strategic Project for Economic Recovery and Transformation)*


In March 2022, the Council of Ministers approved the Aerospace Strategic Project for Economic Recovery and Transformation (PERTE), a public-private collaboration instrument with the aim of boosting science and innovation in the aerospace field in order to respond to the challenges of the sector, such as climate change, global security and digital transition, funded by a public investment of €2.193 billion.

Thanks to this strategic project, public administrations, companies and RD&I centres will coordinate their work to strengthen the capabilities of the aeronautics and space industries, promoting the development and implementation of innovative technologies.

The specific objectives of the Aerospace PERTE are centred around three pillars:

- the aeronautical pillar
- the space pillar
- the cross-cutting pillar

For the space pillar, the specific objectives are to improve space industry capabilities in designing payloads relating to environmental monitoring, quantum communications and security for international collaboration, as well as to position the Spanish space industry on the European map for the commercial use of space.

In particular, activities relating to quantum communications are included in **ACTION 8 – Satellite and ground systems for quantum communications**, with the specific objectives of developing the necessary space technology capabilities for launching the first geostationary satellite with quantum keys for resilient institutional communications within the Spanish and European framework.

We propose that this action should be implemented through a dedicated programme (Third Party Programme) run by the European Space Agency (ESA), for developing and procuring the QKD quantum mission for the satellite and its associated ground segment, covering the remainder of the satellite development cost, i.e. innovative telecommunications payload, ground segment, launch, operations and other costs to be borne by the satellite operator promoting the system.

In addition, Spanish industry will also play an important role in the activities to set up the privately funded GEO telecommunications satellite, with a subsequent pull effect on the innovative ecosystem of space technologies and secure communications.

The GEO telecommunications satellite activities (innovative telecommunications payload, satellite platform, ground segment, launch, operations and other activities) will be carried out by the private sector and its development will require an expected investment of around €205 million.

The development of the satellite payload for the next generation QKD quantum mission and its associated ground segment will be funded with a total of €125 million from Component 15.I5 (€125 million), with the Ministry of Economic Affairs and Digital Transformation being the implementing agency for this element. Since Recovery Plan funds from different elements led by different ministries may converge in this measure, beyond the coordination actions to be promoted within the working group, an agreement will be formalised between the public administrations involved, for which the funds will be committed through an agreement with the European Space Agency (ESA).

In terms of the timetable for implementing satellite and ground-based systems for quantum communications, “opening soon” was indicated last June without any further details.

For more information: Aerospace PERTE | The Government of Spain’s Recovery, Transformation and Resilience Plan.

## *Chip PERTE (Strategic Project for Economic Recovery and Transformation)*


In May 2022, the Council of Ministers approved and published the technical report on the Chip for Microelectronics and Semiconductors Strategic Project for Economic Recovery and Transformation (PERTE), funded with a public investment of **€12.25 billion**, with the aim of strengthening the value chain for the Spanish microelectronics and semiconductor industry, from an integral perspective, covering all the phases involved in conceiving, designing and manufacturing chips.

In reference to this, the Chip PERTE sets out in its **first axis of action, Strengthening Scientific Capacity**, that, in the field of quantum computing, it is necessary to pave a continuous path together with the Quantum Spain initiative in order to take these actions to the next level. Firstly, this requires solving quantum computing optimisation problems in order to provide answers to scientific problems, which are inaccessible using classical computing and, secondly, supporting this by developing the necessary innovative hardware and software.

In particular, it specifies two actions:

**Action 2. RD&I development in integrated photonics.** The objective of this action is to accelerate research, development and innovation in the area of integrated photonics, relying on leading companies, research centres and universities in this field.

The action will have an estimated budget of €150 million for the period from 2022 to 2027.

**Action 3. RD&I activities in quantum chip development.** The objective of this action is to accelerate research, development and innovation in the area of quantum chips in order to forge ahead with the next generation of quantum chips in collaboration with leading companies, research centres and universities in this field.

The scope of this measure will cover those innovative activities that enable:

- The development of quantum annealers or quantum optimisers, as well as programmable quantum simulators.
- The development of quantum computing hardware and software to optimise the different technologies used in quantum computing and simulation platforms, resulting in more scalable circuits with longer coherence times and high qubit density.

The action will have an estimated budget of €40 million for the period from 2022 to 2027.

For more information: The Government approves the PERTE for microelectronics and semiconductors to position Spain as a benchmark country for designing and manufacturing chips.

## *Quantum Spain*


In relation to European initiatives, in October 2021, the Government of Spain approved the **Quantum Spain** plan for creating a quantum computing ecosystem for Artificial Intelligence (AI) based on a public-private collaboration model, with the aim of boosting quantum computing in Spain and strengthening the Spanish computing system through a series of actions structured along the following lines:

- Quantum algorithms
- Creating a production quantum computer based on superconducting currents
- Providing classic simulation computers
- Talent

A fundamental part of this plan consists of building quantum chips with increasing capacities over time, reaching 20 qbits in operation, and making these accessible in the cloud for the entire Spanish education and business system. For more details: The Government of Spain is promoting the creation of the first quantum computing ecosystem in southern Europe

At that time, a €22 million grant was approved to promote the creation of a quantum computing ecosystem in Spain, channelled through the Spanish Supercomputing Network (RES), in line with the strategy outlined in the Recovery, Transformation and Resilience Plan, with the Spain Digital 2025 agenda and the National Artificial Intelligence Strategy (ENIA).

Of this investment, €14.5 million would be injected directly by RES entities to implement the project, while another €7.5 million will be transferred to non-RES entities through subcontracts or agreements, dividing the budget into three high-level areas:

- €10 million for hardware, as the most important aspect, in order to set up the new laboratory and produce quantum chips.
- €7 million for quantum software, with an emphasis on “Quantum Machine Learning”.
- €5 million for the platform to provide cloud access to quantum hardware.

It was also indicated that the initiative is expected to reach €60 million in total investment in the coming years through participation in different European initiatives.

The deployment of Quantum Spain will involve 25 centres in 14 Autonomous Communities, most of them belonging to the Spanish Supercomputing Network (RES), which will act as a channel for the grant. The network will be operational by the end of 2022 under the coordination of the BSC (Barcelona Supercomputing Center), with successive upgrades until it reaches 20 qubits in 2025.

For more information: Quantum Spain, BSC will coordinate Quantum Spain, the national quantum computing ecosystem | BSC-CNS

## Gipuzkoa Quantum

Gipuzkoa Quantum is part of the strategic plan developed by the Provincial Council of Gipuzkoa to apply this type of technology in its territory. The strategy incorporates a series of actions to make Gipuzkoa a benchmark for generating and applying knowledge in the sector. Gipuzkoa Quantum was created at the end of 2020 and, together with the MUBIL Hub for electromobility and energy storage and Gipuzkoa Advanced New Therapies Territory (GANTT) for advanced therapies, is one of the three initiatives included in the Strategic Projects for Economic Recovery and Transformation (PERTEs) proposed by Euskadi Next.

The aim of this grant is to boost the development of quantum technologies by supporting fundamental research, as well as industrial and experimental development projects. The total amount of grants to be awarded under this call will be €1,041,100. The beneficiaries of this subsidy will be:

- Companies operating in Gipuzkoa.
- The entities included in the Basque Science, Technology and Innovation Network (RVCTI), regulated by Decree 109/2015 of 23/06.

**Application deadline:** By the deadline.
**Deadline:** 31/10/2022.
**Amount:**

- **Aid:** From 25 to 100% of the eligible costs depending on the type of project and company.
- **Grant per project:** Collaboration: maximum of €120,000. Individual: €80,000.
- **Eligible expenditure:** Personnel, recruitment, instruments and equipment, consultancy and services, supplies.

For more information: GIPUZKOA QUANTUM - egoitza

## Supplementary Plans


The Supplementary Plans are an instrument aimed at establishing collaborations with the Autonomous Regions for RD&I actions that have common objectives based on interests reflected in the State and Autonomous Region's Smart Specialisation Strategy (RIS3).

The aim is to create synergies, align the implementation of funds and establish common priorities.

Eight areas of scientific-technical interest have been selected within the Spanish Science and Technology and Innovation Strategy lines: (1) Biotechnology applied to health, (2) Marine Sciences, (3) **Quantum Communication**, (4) Energy and renewable hydrogen, (5) Agrifood, (6) Astrophysics and high energy physics, (7) Advanced materials and (8) Biodiversity.

In order to build territorial synergies, the Supplementary Plans envisage the participation of several Autonomous Regions in a single programme, with the option of participating in several of them. This allows for the use of unique capacities and infrastructures, together with the possible participation of companies. The programmes will run for two or three years, with co-financing commitments and co-governance mechanisms, enhancing territorial economic transformation.

In total, €466 million is expected to be mobilised by 2025, of which €299 million will be financed by the Ministry of Science and Innovation and the rest co-financed by the Autonomous Communities.

On 08/11/2021, at the meeting of the Science, Technology and Innovation Policy Council, the framework agreements for 2021 were agreed in the areas of interest: Biotechnology in Health, Marine Science, Quantum Communication and Renewable Energy and Hydrogen.

In doing so, this programme aligns with key European initiatives in this area, both the Quantum Flagship and the European Quantum Communications Infrastructure (EuroQCI), by creating state-of-the-art infrastructures and acting as a driver for the European quantum industry. In particular, the parties express their willingness to identify, where appropriate, as areas of future collaboration for developing the programme, the following lines of action (LA):

- LA-1: EuroQCI – towards a European quantum communication infrastructure.
- LA-2: Hardware for quantum communications.
- LA-3: Software for quantum communications.
- LA-4: Quantum processing hardware.
- LA-5: Quantum processing software.
- LA-6: Human resources and training for innovation and entrepreneurship.
- LA-7: Innovation and industrial ecosystem, dissemination and leveraging of results.

The programme was initially launched with the Autonomous Communities of the Basque Country, Catalonia, Galicia, Madrid and Castile and Leon, with the participation of the CSIC, through the signing of a framework agreement with the Ministry of Science and Innovation.

For more information: Supplementary-plans-with-CCAA

## *Red.es IA + THDs*

The public business entity **Red.es**, attached to the Ministry of Economic Affairs and Digital Transformation through the **Secretary of State for Digitalisation and Artificial Intelligence**, is responsible for promoting and developing the information society in Spain.

In September 2021, Red.es published the call for grants for ***Research and Development Projects in Artificial Intelligence and other Digital Technologies and their Integration in Value Chains***, with funding of **€105 million** for industrial research projects (€50 million) and experimental development (€55 million), with a dual purpose:

On the one hand, to promote scientific research, technological development and innovation in artificial intelligence and, on the other, to foster technological development for the incorporation of artificial intelligence in value chains' production processes.

Despite the clear focus on AI, in addition to AI actions, the call included a number of other actions relating to different Digital Enabling Technologies including ***High Performance Computing***, thus providing an opportunity for funding quantum computing or quantum communication projects.

At the time of writing this report, it is expected that Red.es will publish a new edition of this call during the remaining months of 2022, which is expected to have a similar focus to that of the 2021 call.

For more information:
2021 CALL FOR GRANTS FOR RESEARCH AND DEVELOPMENT PROJECTS IN ARTIFICIAL INTELLIGENCE AND OTHER DIGITAL TECHNOLOGIES AND THEIR INTEGRATION INTO VALUE CHAINS | Headquarters

## *Innovative Business Clusters - IBCs*

The Ministry of Industry, Trade and Tourism's **support programme for Innovative Business Clusters (IBCs)** aims to improve the competitiveness of small and medium-sized enterprises. To this end, it plans to support with public resources the innovation and business

competitiveness strategies developed by the Innovative Business Clusters (IBCs), which are recognised as such as a result of their registration in the **Ministry's Register of Innovative Business Clusters**.

The types of actions and projects eligible for support under the programme are as follows:

**Line 1. Actions to support the operation of Innovative Business Clusters**

**Line 2. Technical feasibility studies**

Focused on establishing projects to be submitted in response to future calls for proposals under the following programmes:

- The Support Programme for Innovative Business Clusters through Line 3 "**Digital Technology Projects**".
- The EU's framework programme for research and innovation for the period from 2021 to 2027, "Horizon Europe".

**Line 3. Digital Technologies Projects**

Projects must incorporate knowledge and/or technologies that promote the digital transformation of the implementing companies under the following categories:

- Industrial research activities
- Experimental development activities
- Organisational innovation
- Process innovation

As the thematic scope of the projects is not restricted in the call, this call also offers an interesting funding framework for consortium projects in the quantum sector submitted by entities associated with Innovative Business Clusters whose strategic plan is directly related to promoting and developing quantum activities.

For more information:
Portal for Aid from the Ministry of Industry, Trade and Tourism – Innovative Business Clusters (IBCs)

## RD&I projects following strategic lines for 2022

The objective of the call for RD&I projects following strategic lines is to support industrial research projects in collaboration between companies and research organisations with the aim of responding to the challenges identified in the thematic priorities (topics), which are determined in the calls for proposals, and in which the overlap between disciplines at a methodological, conceptual or theoretical level is valued.

AGENCIA ESTATAL DE INVESTIGACIÓN

The aim is to give impetus to advances in the field of application targeted by the projects, both in the scientific field and in technological development and innovation.

In this regard, the 2022 call for proposals is closed, but is expected to re-open in Q2 2023.

For more information:
RD&I projects following strategic lines for 2022 | Spanish State Research Agency

## Public-private partnership projects


In December 2021, and under the direction of the Spanish State Research Agency for the Ministry of Science and Innovation, the regulatory bases were approved for granting public aid for **public-private collaboration projects**, for the State Programme to Promote Scientific-Technical Research and its Transfer, for the State Plan for Scientific, Technical and Innovation Research 2021-2023, within the framework of the Recovery, Transformation and Resilience Plan, and the call for early processing for this aid corresponding to the year 2021 was approved.

The purpose of the aid covered by these bases is to advance with incorporating scientific-technical knowledge and results that allow the validation and pre-competitive development of new technologies, products and services, creating the appropriate context that stimulates the creation of a critical mass in RD&I of an interdisciplinary nature for its application, transfer, search for solutions and generation of results both in the technological and innovation trajectories of companies and in the market, as well as facilitating the transfer of knowledge through actions that eliminate the existing barriers between the different stakeholders in the public and private spheres.

The thematic priorities described in the State Plan for Scientific, Technical and Innovation Research 2021-2023 include the *Digital World, Industry, Space and Defence*, which means that this call is likely to offer funding to projects involving actions of a quantum nature.

For more information:
Public-private partnership projects for 2021 | Spanish State Research Agency

# International opportunities

## *QuantERA and Quantum Flagship*

At the European level, the **QuantERA** network and the **Quantum Flagship** stand out as support instruments specifically aimed at quantum technologies.

The next call for proposals **is scheduled for 2023**, according to the biennial scheme (https://quantera.eu/quantera-funded-projects/). The European ERA-NET scheme is designed to foster cooperation and coordination between states in the field of research. Spain has participated and continues to participate in a good number of these schemes, covering very diverse fields: biodiversity, climate change, astronomy, Information and Communications Technology, biotechnology, health, materials, nuclear physics and many more). **QuantERA** is an ERA-NET formed by 31 countries (in the case of Spain, the State Research Agency on behalf of the Ministry of Science and Innovation) that supports international research projects in quantum technologies. QuantERA has launched three calls, which are already closed, but with further implementation in future, the first in 2017, the second in 2019, and the third in 2021.

For example, the first QuantERA call has funded 26 projects with a total amount of €32 million. Six of these projects involve Spanish participation.

The Future and Emerging Technologies Flagship Research Initiatives (FET Flagships) address large-scale, interdisciplinary, future-oriented science and technology challenges on a large scale and require the collaboration and participation of interdisciplinary research groups. The European Commission has launched FET Flagship initiatives relating to graphene, the human brain and, since the end of 2018, quantum technologies: the Quantum Flagship. This covers a time window of 10 years and foresees an investment of €1 billion. For example, the first call (in 2018) involved €132 million spread over 20 projects (link). With regard to the results of this first call, Spain is in fifth place, with a return of slightly over €8 million.

The following four priorities are included in its 6-10 year vision:

- Demonstrating and promoting functionalities achieved using technologies that cannot be achieved in a classical way and that meet the identified use cases.
- Developing schemes for assessing quantum technologies and continuously updating and improving benchmarks and KPIs.
- Promoting new enabling technologies and products that facilitate the development of quantum technologies and find applications outside the fields of quantum technologies.
- Assessing the impact of these products outside the field of quantum technologies and the progress of quantum technologies according to the NRT scale.

During the period from 2021 to 2027, quantum technologies will be supported by the Digital Europe programme, which will develop and strengthen Europe's strategic digital capabilities, as well as by the Commission's Horizon Europe programme, contributing to research applications.

For more information: Quantera and Quantum Flagship

## *Digital Europe Programme*

The Digital Europe Programme is a new EU funding programme focused on bringing digital technology to businesses, citizens and public administrations. With a budget of €7.6 billion, the programme is part of the EU's next long-term budget (the multiannual financial framework) and covers the period from 2021 to 2027. Digital Europe will provide funding to projects in five crucial areas:

- €2.2 billion for SUPERCOMPUTING and the following actions:
  - Developing and strengthening the EU's data processing and supercomputing capabilities by purchasing world-class exascale supercomputers by 2022/2023 (capable of performing at least a billion trillion or 1,018 calculations per second) and subsequent exascale facilities by 2026/2027.
  - Increasing accessibility and broadening the use of supercomputing in areas of public interest, such as health, environment and security, and in industry, including small and medium-sized enterprises.
- €2.1 billion for ARTIFICIAL INTELLIGENCE and the following actions:
  - Investing in and facilitating the use of artificial intelligence by businesses and public administrations.
  - Setting up a true European data space and facilitating secure access to and storage of large data sets and a reliable, energy-efficient cloud infrastructure.
  - Strengthening and supporting existing artificial intelligence experimentation and testing facilities in areas like health and mobility in the Member States and encouraging their cooperation.
- €1.6 billion for CYBER SECURITY and the following actions:
  - Strengthening the coordination of cybersecurity between Member States' tools and data infrastructures.
  - Supporting the broad deployment of cyber security capabilities across the economy.
- €580 million for ADVANCED DIGITAL SKILLS and the following actions:
  - Supporting the design and development of specialised programmes and internships for future experts in key capability areas, such as data and artificial intelligence, cybersecurity, **quantum** and HPC.
  - Supporting the upskilling of the existing workforce through short training courses that reflect the latest developments in key capacity areas.
- €1.1 billion to ENSURE THE WIDE USE OF DIGITAL TECHNOLOGIES IN THE ECONOMY AND SOCIETY and the following actions:
  - Supporting high-impact deployment in areas of public interest, such as health (complemented by the EU4Health programme), Green Deal, smart communities and the cultural sector.
  - Building and strengthening the European Digital Innovation Hubs Network with the aim of having a hub in each region to help businesses benefit from digital opportunities.
  - Supporting the adoption of advanced digital and associated technologies by industry, especially small and medium-sized enterprises.
  - Supporting European public administrations and industry in implementing and accessing cutting-edge digital technologies (such as Blockchain) and building trust in digital transformation.

This programme covered several topics relating to quantum communication infrastructures (already closed), and we will have to wait for its last and third call this year, as well as the launch of the 2023 work programme to see if similar topics will be included.

- Beneficiaries: minimum 3 entities from 3 different EU or partner countries (1 from the EU as a minimum).
- Type of grants: depends on the type of project (e.g. 100% for CSA or 50% for “simple grants”).
- Upcoming submission dates: 22/09/2022 (topic “Deploying advanced national quantum communication infrastructure (QCI) systems and networks”, topic budget: €20 million; maximum grant: €5 million).

For more information: The Digital Europe Programme

## Horizon Europe

Horizon Europe (HE) is the EU's main funding programme for research and innovation, with a budget of €95.5 billion. It addresses climate change, helps achieve the UN Sustainable Development Goals (SDGs) and boosts EU competitiveness and growth. The programme facilitates collaboration and strengthens the impact of research and innovation in developing, supporting and implementing EU policies. It supports the creation and better dissemination of excellent knowledge and technologies.

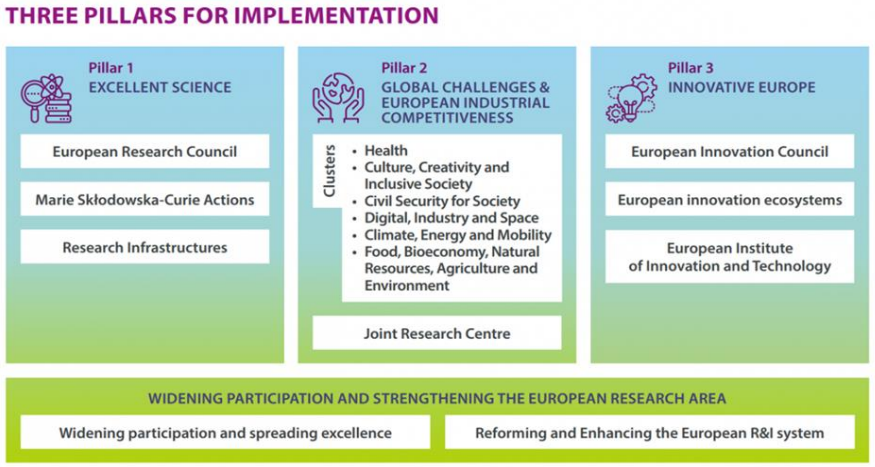


**Figure 1.** Structure of the Horizon Europe Programme

For more information: Horizon Europe Programme

The sub-programmes where Quantum Technologies projects could fit in, either with open themes (Pillar 1 and Pillar 3) or responding to specific themes (Pillar 2), are described below.

## Pillar 1 – Excellent Science

Pillar 1 of HE aims to increase the EU's global scientific competitiveness through three funding mechanisms:

- The European Research Council (ERC), which will fund frontier research projects designed and led by researchers themselves.
- The Marie Sklodowska-Curie (MSCA) programme, which will support the professional development and training of research staff through international and intersectoral mobility activities.
- Investment to improve and optimise transnational access to world-class research infrastructures.

The first two mechanisms (ERC and MSCA) can host Quantum Technologies projects and further details are provided below.

## European Research Council (ERC)

Objectives: ERC focuses on providing support to excellent researchers and their research teams to carry out innovative, high-risk, high-return research projects that lead to breakthroughs at the frontier of knowledge.

Beneficiaries: individual researchers or groups of researchers working for research organisations in the European Union or partners countries.

**Table 1.** *ERC-managed calls for 2023*

| | Requirements | Grants (*) | Submission deadlines |
|---|---|---|---|
| **Starting Grant** | 2-7 years' experience since PhD degree | Max. €1.5 million for 5 years | 12/07/2022 - **25/10/2022** |
| **Consolidator Grant** | 7-12 years' experience since PhD degree | Max. €2 million for 5 years | 28/09/2022 - **02/02/2023** |
| **Advanced Grant** | Principal investigators, leaders of a team, with 10 years' relevant professional research experience | Max. €2.5 million for 5 years | 08/12/2022 - **23/05/2023** |
| **Synergy Grant** | 2-4 principal investigators developing ground-breaking projects | Max. €10 million for 6 years | 13/07/2022 - **08/11/2022** |

(*) Additional grants may be awarded for relocating from third countries, purchasing large equipment, access to large facilities or other costs for experimental work (up to €1 million for Starting, Consolidator and Advanced Grants, and up to €4 million for Synergy Grants).

For more information: European Research Council

## *Marie Sklodowska-Curie Actions (MSCA)*

Objectives: MSCA Actions aim to enhance research careers among young people in Europe, attract the interest of top talent from around the world, retain its own researchers and reintegrate those working elsewhere. The following are details of the different calls included under MSCA (details of budgets and submission deadlines for 2023 and 2024, included in Table 2, are taken from unofficial draft programmes and are therefore not definitive information).

**Table 2.** *MSCA Actions for Quantum Technologies Projects*

**MSCA Doctoral Networks (DN):** implementation of PhD programmes by academic (universities, research organisations) and non-academic (companies) consortia, within one (*Industrial Doctorates*) or several European countries (***Joint Doctorates***).
Beneficiaries: minimum of 3 entities from 3 countries (European Union and partner countries; 1 from the EU as a minimum).
Type of grants: fixed costs with set monthly rates for the researcher's expenses (living expenses, mobility, family charges, etc.) as well as expenses incurred by the contracting entity (research, training, management, indirect costs, etc.).

| *Calls for applications* | *Budget (€ million)* | *Deadline for submission* |
|---|---|---|
| HORIZON-MSCA-2022-DN-01 | 427.30 | 12/05/2022 - **15/11/2022** |
| HORIZON-MSCA-2023-DN-01 | 431.83 | 30/05/2023 - 28/11/2023* |
| HORIZON-MSCA-2024-DN-01 | 450.01 | 29/05/2024 - 27/11/2024* |

**MSCA Postdoctoral Fellowships (PF)**: aimed at supporting the mobility of researchers (PhDs): i) of any nationality coming or moving within Europe (*European PF*); or ii) European researchers who want to carry out their projects inside and outside Europe (***Global PF***).
Beneficiaries: 1 legal entity incorporated in the European Union or partner countries.
Type of grants: fixed costs with set monthly rates for the researcher's expenses (living expenses, mobility, family charges, etc.) as well as expenses incurred by the contracting entity (research, training, management, indirect costs, etc.).

| *Calls for applications* | *Budget (€ million)* | *Deadline for submission* |
|---|---|---|
| HORIZON-MSCA-2022-PF-01 | 257.00 | 12/05/2022 - **14/09/2022** |
| HORIZON-MSCA-2023-PF-01 | 258.57 | 12/04/2023 - 13/09/2023* |
| HORIZON-MSCA-2024-PF-01 | 270.00 | 10/04/2024 - 11/09/2024* |

**MSCA Staff Exchanges (SE)**: aimed at developing an R&D project in which there is an exchange of staff (technical, research, administrative and managerial) across sectors, at international and/or interdisciplinary level.
Beneficiaries: minimum of 3 entities from 3 European Union countries and partner countries (minimum of 2 in different countries).
Type of grants: fixed costs with set monthly fees for the persons carrying out the exchange (travel, accommodation and subsistence), as well as expenses incurred by the contracting entity (research, training, management, indirect costs, etc.).

| *Calls for applications* | *Budget (€ million)* | *Deadline for submission* |
|---|---|---|
| | | |
| HORIZON-MSCA-2022-SE-01 | 77.50 | 06/10/2022 - **08/03/2023** |
| HORIZON-MSCA-2023-SE-01 | 77.92 | 05/10/2023 - 28/02/2024* |
| HORIZON-MSCA-2024-SE-01 | 81.00 | 10/10/2024 - 05/03/2025* |

*Provisional information

For more information: Marie Curie Actions

## *Pillar 2: Global Challenges and European Industrial Competitiveness*

The specific objectives of HE Pillar 2 are to generate knowledge, to increase the impact of research and innovation in developing and implementing EU policies and in support of these policies, and to foster access to and uptake of innovative solutions in European industry, in particular SMEs, and in society, to address global challenges, including climate change and the Sustainable Development Goals (SDGs).

Beneficiaries: entities established in the eligible countries (European Union and partner countries), consortia: minimum of 3 entities from 3 countries (except where otherwise indicated).

Type of grants: Subsidy in which the percentage of European support depends on the type of Action:

- RIA (Research and Innovation Actions): 100%
- IA (Innovation Actions): 70% except for non-profit organisations, which receive 100%.

## *Cluster 4. Digitalisation, Industry and Space*

This cluster includes enabling technologies that are strategic for Europe's industrial future, which are expected to achieve:

- Global leadership in “clean” and climate-neutral industrial value chains, circular economy and climate-neutral digital systems and infrastructures (networks, data centres).
- Industrial leadership and greater autonomy in strategic value chains, with guaranteed supply of raw materials.
- Sovereignty in digital technologies and future emerging enabling technologies.
- An agile, secure and attractive global data economy, developing and enabling the adoption of next generation computing, data technologies and infrastructures.
- Strategic autonomy in designing, developing, deploying and using global space-based infrastructures, services, applications and data.
- Ethical and people-centred development of digital and industrial technologies, through two-way engagement in developing technologies, empowering end-users and workers, and supporting social innovation.

The information on the topics listed in Table 3 is taken from **unofficial** draft programmes and is therefore not definitive.

**Table 3.** *HE Cluster 4 Topics for Quantum Technologies*

| **Destination 4. Digital & Emerging Technologies for Competitiveness and Fit for the Green Deal**<br>Objectives: Achieving strategic autonomy in digital technologies and future enabling technologies, strengthening European capabilities in key digital aspects of future supply chains, fostering agile responses to urgent needs, and investing in the discovery and industrial application of new technologies. | | | | |
|---|---|---|---|---|
| ***Topic*** | ***Deadline*** | ***Topic budget (€ million)*** | ***Subsidy (€ million)*** | ***Action type*** |
| HORIZON-CL4-2023-DIGITAL-EMERGING-01-40: Quantum Photonic Integrated Circuit technologies | 22/12/2022 - 28/03/2023* | 12 | 4-6 | RIA |
| HORIZON-CL4-2023-DIGITAL-EMERGING-01-41: Investing in alternative quantum computation and simulation platform technologies | 22/12/2022 - 28/03/2023* | 20 | 7-12 | RIA |
| HORIZON-CL4-2023-DIGITAL-EMERGING-01-43: Framework Partnership Agreement for developing large-scale quantum Computing platform technologies | 22/12/2022 - 28/03/2023* | no budget | - | FPA |
| HORIZON-CL4-2023-DIGITAL-EMERGING-01-50: Next generation quantum sensing and metrology technologies | 22/12/2022 - 28/03/2023* | 10 | 2-3 | RIA |
| HORIZON-CL4-2024-DIGITAL-EMERGING-01-42: Stimulating transnational research and development of next generation quantum technologies, including basic theories and components (Cascading grant with FSTP) | 15/11/2023 - 19/03/2024* | 15 | 15 | RIA |
| HORIZON-CL4-2024-DIGITAL-EMERGING-01-45: Quantum sensing and metrology for market uptake | | 15 | 4-5 | IA |

*Provisional information

| Destination 5. Open Strategic Autonomy in Developing, Deploying and Using Global Space-Based Infrastructures, Services, Applications and Data<br><br>Objectives: Achieving strategic autonomy in developing and implementing global space infrastructures, services and data applications, including strengthening European capabilities to access space, ensuring the autonomy of supply for critical technologies and equipment, and fostering the competitiveness of the European Union space industry. | | | | |
|---|---|---|---|---|
| ***Topic*** | ***Deadline*** | ***Topic budget (€ million)*** | ***Subsidy (€ million)*** | ***Action type*** |
| HORIZON-CL4-2023-SPACE-01-62: Quantum Communication Technologies for space systems | 22/12/2022 - 28/03/2023* | 5 | 2-2.5 | RIA |
| HORIZON-CL4-2023-SPACE-01-63: Quantum Space Gravimetry Phase-A Study | | 3 | 1-1.5 | RIA |
| HORIZON-CL4-2024-SPACE-01-64: Quantum Space Gravimetry Phase-B study & Technology Maturation | 21/11/2023 - 20/02/2024* | 14.2 | 14 | RIA |

*Provisional information

## Pillar 3: Innovative Europe

This pillar includes the European Innovation Council (EIC), which will primarily promote innovative and disruptive technologies with a focus on market-creating innovation, while supporting all types of innovations, including incremental ones, especially in SMEs and start-ups, with rapid European and global market scaling potential. Pillar 3 also encompasses support for European Innovation Ecosystems and the activities carried out within the framework of the European Institute of Innovation and Technology (EIT).

## European Innovation Council (EIC)

The European Innovation Council Accelerator acts as a catalyst to attract other investors needed to amplify the scale of innovations. A unique funding model offers start-ups and SMEs grants of up to €2.5 million, combined with equity investments made through the European Innovation Council Fund, ranging from €500,000 to €15 million. The EIC is structured around 3 different lines:

- **EIC Pathfinder** for advanced research projects aimed at developing the scientific basis for cutting-edge technologies (TRL 1-4).
- **EIC Transition** to validate technologies previously developed as part of other projects (approved in European calls: EIC Pathfinder, ERC, FET) and develop business plans for specific applications (TRL 4 to 5-6).
- **EIC Accelerator** to support companies (SMEs, start-ups, spin-outs, and in exceptional cases, small companies) to bring their innovations to the market (TRL 5-6 to 9).

For each of these EIC lines, open calls are published (EIC Open) and others in which specific challenges must be met (EIC Challenges). The type of beneficiaries and grants for those calls in which quantum technology projects could be eligible are detailed below.

| 2022 calls | Beneficiaries | Budget (€ million) | Grants | Submission date |
|---|---|---|---|---|
| **EIC Pathfinder Open** | consortia of at least 3 entities (SMEs, universities, start-ups, research centres, large companies, etc.) from 3 different countries. | 183 | 100% grant of up to €3 million and advice on business acceleration services. | 03/05/2022 |
| **EIC Pathfinder Challenges** Alternative approaches to Quantum Information Processing, Communication, and Sensing | individual entities (medium-sized and large companies are not eligible) or consortia of at least 2 independent entities (SMEs, universities, start-ups, research centres). | 167 | 100% grant of up to €4 million and advice on business acceleration services. | 19/10/2022 |
| **EIC Transition Open** | individual entities (SMEs or research entities; large companies are not eligible), or consortia of 2-5 independent entities (large companies are eligible). | 70.9 | 100% subsidy up to a maximum of €2.5 million. | 28/09/2022 |
| **EIC Accelerator Open** | individual entities (SMEs, small mid-cap (<500 employees), entrepreneurs intending to formalise an SME or small mid-cap). | 630.9 | mixed financing: - Investment component: in the form of equity (€0.5 - €15 million) - 70% subsidy up to a maximum of €2.5 million. | 05/10/2022 |
| **EIC Accelerator Challenges** Technologies for Open Strategic Autonomy[1] | | 536.9 | | |

[1] New applications of quantum technologies on the ground and in space building on Europe's research strengths including the Quantum Flagship to put EU at the forefront of the second quantum revolution and leader in the deployment of such technologies as well as to support the EU Secure Connectivity initiative

For more information: European Innovation Council

## *European partnerships*

European Partnerships (EPs) are initiatives in which the European Union, together with private and/or public partners (industry, public bodies or foundations) commit to jointly supporting the development and implementation of an integrated programme of research and innovation activities. The objective of the EPs is to enhance and accelerate the implementation of new innovative solutions in different industries, mobilising public and private resources, contributing significantly to achieving EU policy priorities.

## Key Digital Technologies Joint Undertaking (KDT JU)

Objectives: KDT JU supports RD&I projects relating to electronic and photonic components and the software that defines how these function as part of a system. KDT JU publishes two open topics to develop Innovation (IA) projects and one for Research (RIA) projects covering the challenges identified in its Strategic Innovation Agenda. In the 2022 Agenda, there is a challenge that includes quantum issues: *Major Challenge 1 - Advanced computing, memory and in-memory computing concepts: Materials and substrates, process modules and integration technology for novel devices and circuits for advanced computing, memory and in-memory computing concepts based on nanoelectronic, photonic or* ***quantum technology****.*

Beneficiaries: consortia consisting of a maximum of 50 participants for RIA projects and a maximum of 70 for IA (any type of entity from EU and/or partner countries).

Type of grants: according to the type of project:

- Up to €12 million per RIA project
- Up to €25 million per IA project

The percentages of aid per type of enterprise are as follows for both types of project: 25% large companies, 35% SMEs, 35% universities/other. The full amount of support comes from KDT JU funds, on the one hand, and, on the other hand, from national funding. In the case of Spain, there are 2 bodies that manage these funds:

- **Ministry of Economic Affairs and Digital Transformation (Ministerio de Asuntos Económicos y Transformación Digital - MAETD)**: supports companies and other private entities. The following table reflects the maximum aid rates covered by MAETD based on the eligible costs for the KDT call:

| Type of activity | Large enterprise / RTO | Medium enterprise / RTO | Small enterprise / RTO |
|---|---|---|---|
| ***RIA (EPS) Research and Innovation Actions*** | Up to 65% - JU% | Up to 75% - JU% | Up to 80% - JU% |
| ***IA (EPS) Innovation Action*** | Up to 40% - JU% | Up to 50% - JU% | Up to 60% - JU% |

- **Spanish State Research Agency (AEI) for the Ministry of Science and Innovation**: supports public entities (Public Universities and Public Research Bodies). The maximum grant per participant is €350,000 or 40% of the total costs of the Spanish part of the project (whichever is lower). These amounts are increased for Spanish coordinators up to €500,000 or 50% of the total costs of the Spanish part (whichever is lower).

Submission date: 21/09/2022.
For more information: KDT JU

## European High Performance Computing Joint Undertaking (EuroHPC JU)

Objectives: to make Europe a world leader in supercomputing, the HPC JU aims to:

- Develop, deploy, scale-up and sustain a world-leading, federated, secure and hyper-connected ecosystem of supercomputing, quantum computing, data infrastructure and services in the EU.
- Support the development and take-up of an innovative and competitive demand- and user-driven supercomputing system, based on a supply chain that provides components, technologies and know-how that limit the risk of disruption and the development of a wide range of optimised applications for these systems.
- Extend the use of this supercomputing infrastructure to a large number of public and private users and support the development of key HPC skills for European science and industry.

There are currently 29 projects under this initiative, and EuroHPC JU has acquired seven supercomputers, spread across Europe. To date, it is possible to apply for funding under various calls for proposals, although there are currently no open calls relating to quantum technologies.

For more information: EuroHPC JU

## *EUREKA*

Within the Eureka framework, we can find three typologies of opportunities, **Eureka Network**, the **Celtic-Next Cluster and Eurostars**, whereby all of these offer a programme label and not a grant, which will be managed at the national level according to each Eureka Country.

## EUREKA Network

This is an intergovernmental network for international cooperation that supports market-oriented R&D projects. It is possible to submit projects at any time of the year, collaborating with the Programme's member countries, although the CDTI participates in specific Eureka projects of various types:

- Bilateral: aiming to optimise synchronisation between dedicated funding tools at the national level for Eureka projects.
- Multilateral: seeking to set up projects on a specific topic of interest to a group of countries or with a country outside Eureka in order to promote cooperation beyond the countries in the Programme.

For more information: EUREKA Network

## Celtic-Next Cluster

This cluster is an industry-driven initiative, involving all major players in the Information and Communications Technology industry, as well as many SMEs, service providers and research institutions. Project consortia must have at least two different partners from two different EUREKA countries (one must be a EUREKA member country and one must be a EUREKA member country or a EUREKA partner country). Funding is typically between €1 million and up to over €70 million in terms of total project budget, and include from two to more than 50 partners.

In Spain, in the case of Eureka Network and Celtic-Next, through the EUREKA label, the Spanish company or companies in the international consortium will have to request their own co-financing from the CDTI, which provides for a loan of up to 85% of the Spanish budget, with a Non-Refundable Tranche of up to 33% of a maximum 75% of the loan.

For more information: Celtic-Next

## Eurostars

Eurostars is a programme to support innovative SMEs with developing collaborative and market-oriented transnational projects. These projects must represent a break with the technical state of the art and a commercial challenge, so as to enable these companies to make a significant qualitative leap in their market position.

Beneficiaries: consortia (minimum of 2 entities from 2 Eurostars countries) that must be led by SMEs. The type of entities that are eligible for funding depends on the entity's country of origin (see the Eurostars website; example link for Spain).

Type of grants: This is a programme of centralised and independent evaluation, managed by the Eureka Secretariat, and decentralised and coordinated funding, in which the partners for the approved projects receive the funds directly from their national funding body (the CDTI in the case of Spain, through the Interempresas Internacional call, grants subsidies of up to 60% for small companies and up to 50% for medium-sized companies, considering a maximum of €400,000 per entity).

Upcoming closing dates: 15 September 2022.

For more information: Eurostars

## *CEF (Connecting Europe Facility) Digital*

Objectives: CEF Digital's objective is to contribute to developing projects relating to the deployment of high-performance, secure and sustainable infrastructures, including Gigabit and 5G networks. CEF Digital will also contribute to increasing the capacity and resilience of digital backbone infrastructures in all EU territories, as well as to digitising transport and energy networks.

Among the actions planned within the context of CEF Digital is the EuroQCI (quantum communication infrastructure) initiative for **quantum communication infrastructures**. This programme will co-fund components of the terrestrial backbone, being complementary to what has been developed under Digital Europe, and will focus on cross-border links between two or more national quantum communication networks in the Member States and/or on connecting the terrestrial and space segments of the EuroQCI.

Of the total CEF Digital funding for the EuroQCI, the sum of €110 million will be applied to indirect management and will cover procuring the satellite infrastructure segment for the initiative (a constellation of EU satellites).

For more information: CEF Digital

## *European Defence Fund*

The objective of the EDF is to promote competitiveness, efficiency and European Defence Industrial and Innovation Capacity (EDTIB) across the EU. This objective is pursued by encouraging collaborative actions and cross-border cooperation between entities throughout the EU (in particular SMEs and MIDCAPS). Under the EDF, two types of projects are being implemented:

- Collaborative research projects (research action), with the objective of maximising innovation and introducing new defence products and technologies (budget of €2.7 billion).
- Collaborative development of defence products and technologies (development action), ultimately leading to increased standardisation of defence systems and greater interoperability between Member States (budget of €5.3 billion).

The EDF is being implemented through annual work programmes during the period from 2021 to 2027. The priorities identified in the annual work programme are in line with the Union's priorities and the selected themes are classified as follows:

**a) Thematic categories**

1. Defence medical support, Chemical, Biological, Radiological and Nuclear defence (CBRN), biotechnology and human factors
2. Information superiority
3. Advanced passive and active sensors
4. Cybernetics
5. Space
6. Digital transformation
7. Materials and components
8. Energy resilience and environmental transition
9. Air combat
10. Air and missile defence
11. Ground combat
12. Strength and mobility protection
13. Naval combat
14. Submarine warfare
15. Simulation and training

**(b) Non-thematic categories:**

1. Disruptive technologies
2. Open calls for innovative and forward-looking defence solutions

Beneficiaries: With the exception of funding projects on disruptive technologies, **only collaborative projects involving at least three eligible entities from at least three Member States or partner countries shall be eligible for funding**.

Type of grants: between 20% and 100% depending on the type of activity.

Upcoming closing dates: 24/11/2022. €924 million in funding will be allocated to tackle the organisation around 33 themes structured over 8 calls for proposals. In particular:

- Two critical domains will be put in the spotlight to support capability development, space and naval combat.
- €70 million will be allocated to R&D efforts in each of the following two categories: Cyber, to improve European capabilities in terms of cyber situational awareness, cyber security and resilience, and to develop a cyber warfare and defence information toolbox, and Information Superiority, for projects contributing to the development of a European Command and Control System and a deployable Special Operations Command Post. interoperability and data exchange between civil and military control centres in the context of the Single European Sky.
- Actions to support innovative entrepreneurs, start-ups and SMEs and bring them into the defence industrial ecosystem, i.e. a Defence Equity Mechanism, a Technology Challenge and a Chemical, Biological, Radiological and Nuclear (CBRN) Framework Partnership Agreement.

For more information: European Defence Fund

## *ERASMUS+*

Erasmus+ is the EU programme engaged in the fields of education, training, youth and sport for the period from 2021 to 2027. Through three Key Actions, Erasmus+ offers mobility and cooperation opportunities in the fields of higher education, vocational education and training, adult education and school education (including early childhood care and education), youth and sports staff. It pays particular attention to social inclusion, ecological and digital transitions, as well as to promoting the participation of young people in democratic life.

- **KEY ACTION 1.** Educational mobility of people
- **KEY ACTION 2.** Cooperation between organisations and institutions
- **KEY ACTION 3.** Support for policy development and cooperation

Calls can be managed by the EACEA (centralised actions) or by the National Agencies for each Programme Country (decentralised actions). In Spain, the National Agency is SEPIE (Spanish Service for the Internationalisation of Education) for the field of education and INJUVE for the field of youth.

The calls under Key Action 2 are described below.

## Cooperation partnerships in the fields of education, training and youth

Objectives:

- Improving the quality of the work, activities and practices of the organisations and institutions involved.
- Developing the capacity of organisations to work transnationally and across sectors.
- Addressing common priorities and needs in the fields of education, training, youth and sport
- Enabling transformation and change that leads to improvements and new approaches in a way that is commensurate with the context of each organisation.

Beneficiaries: Minimum of 3 organisations (in the fields of education, training, youth, sport or other socio-economic sectors) from 3 EU or partner countries.

Type of grants:

- ❖ Submitted by any organisation except NGOs (managed by SEPIE): between €100,000 and €400,000.
- ❖ Submitted by a European NGO (managed by EACEA): fixed amount of €120,000, €250,000 or €400,000.

## Small-scale partnerships in the fields of education, training, and youth

Objectives:

- Attracting and expanding access to the programme to new entrants, less experienced organisations and small-scale stakeholders.
- Supporting the inclusion of target groups with fewer opportunities.
- Supporting active European citizenship and bringing the European dimension closer to the local level.

Beneficiaries: Minimum of 2 organisations (in the fields of education, training, youth, sport or other socio-economic sectors) from 2 Programme Countries.

Type of grants: Fixed amount of €30,000 or €60,000.

## Partnerships for innovation

Objectives: Strengthening Europe's innovation capacity by boosting innovation through collaboration and knowledge flow between higher education, vocational education and training and the wider socio-economic environment, including research. It also aims to strengthen the teaching of new skills and address skills mismatches by designing and creating new curricula for higher education and vocational education and training (VET), supporting the development of initiative and entrepreneurial mindsets in the EU. 2 lines of action:

- **Lot 1. Education and Business Partnerships**: Transnational, structured and results-oriented projects where partners share common goals and work together to foster innovation, new skills, a sense of initiative and entrepreneurial mindsets.
- **Lot 2. Partnerships for Sectoral Cooperation on Capacities:** Creating new strategic approaches and cooperation models to develop concrete capacity building solutions in specific economic sectors or areas that implement one of the key actions of the European Skills Agenda for sustainable competitiveness, social equity and resilience, and the Skills Pact. These Alliances will be implemented in one of the **14 identified industrial ecosystems** (see the Erasmus+ Programme Guide).

Beneficiaries: Any public or private organisation:

- **Lot 1:** at least 4 Programme Countries and involving a minimum of 8 partners, including at least 3 labour market stakeholders and 3 education and training providers.
- **Lot 2:** at least 8 Programme Countries and involving at least 12, including at least 5 labour market stakeholders and 5 education and training providers

Type of grants:

- **Lot 1:** €1 million (2-year projects) or €1.5 million (3-year projects)
- **Lot 2:** €4 million (4-year projects)

## Erasmus Mundus Actions

Objectives: to promote excellence and internationalisation of higher education institutions worldwide through study programmes – at Master's level – jointly delivered and recognised by higher education institutions established in Europe and open to institutions in other countries across the world. It includes 2 lines of action:

- **Lot 1:** Erasmus Mundus joint masters (designing and implementing joint masters programmes).
- **Lot 2:** Erasmus Mundus design measures (designing joint master's programmes)

Beneficiaries:

- **Lot 1:** minimum of 3 higher education institutions from 3 different countries (at least 2 from Programme Countries).
- **Lot 2:** Any higher education institution.

Type of grants:

- **Lot 1:** amount calculated on the basis of institutional costs, maximum number of student grants, supplementary amount for students with disabilities (maximum of €5 million).
- **Lot 2:** €55,000.

For more information: Erasmus+

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# REPORT
# SPAIN QUANTUM INDUSTRY

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