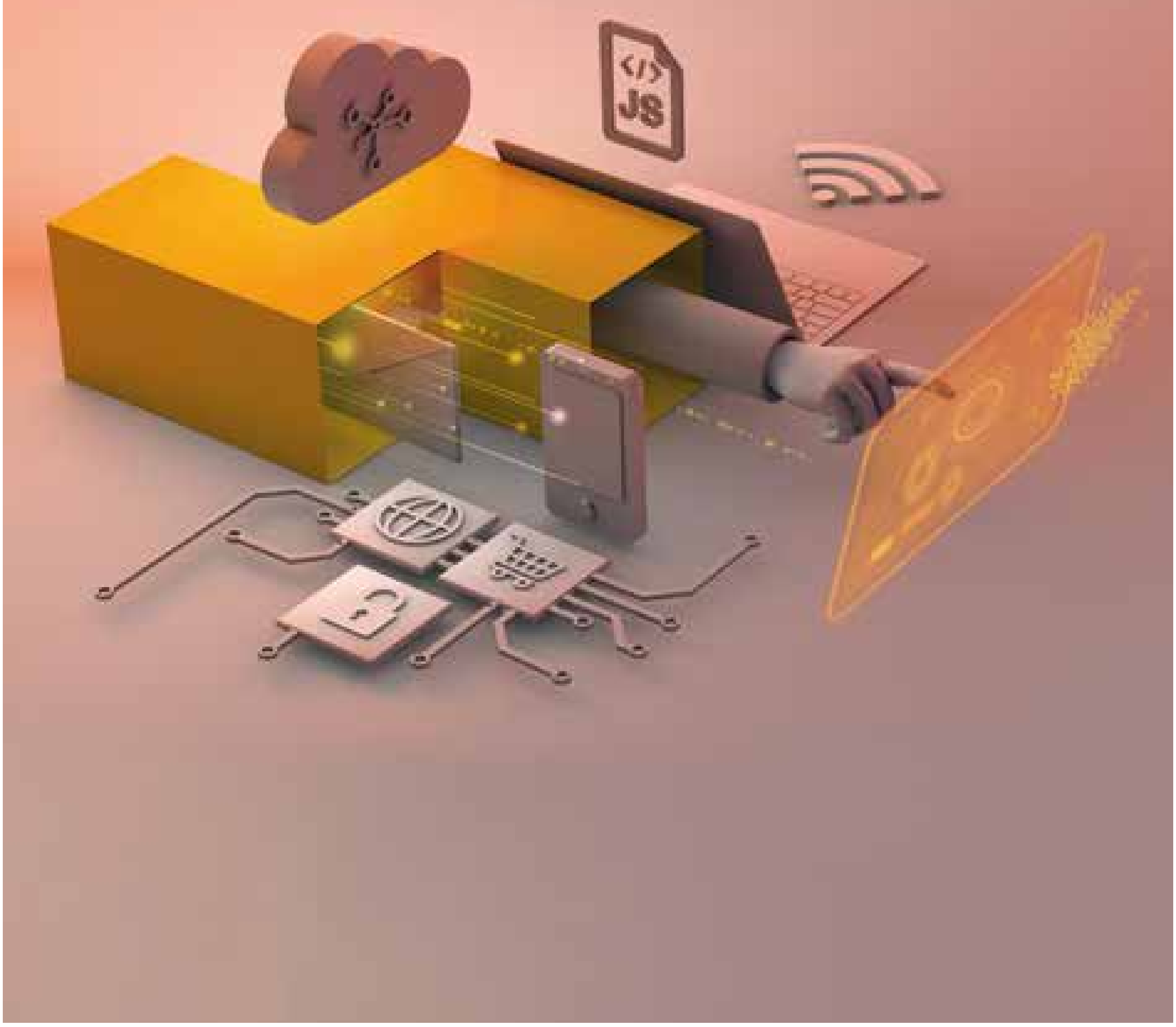
BRTA
BASQUE RESEARCH
& TECHNOLOGY
ALLIANCE

DIGITAL TECHNOLOGIES

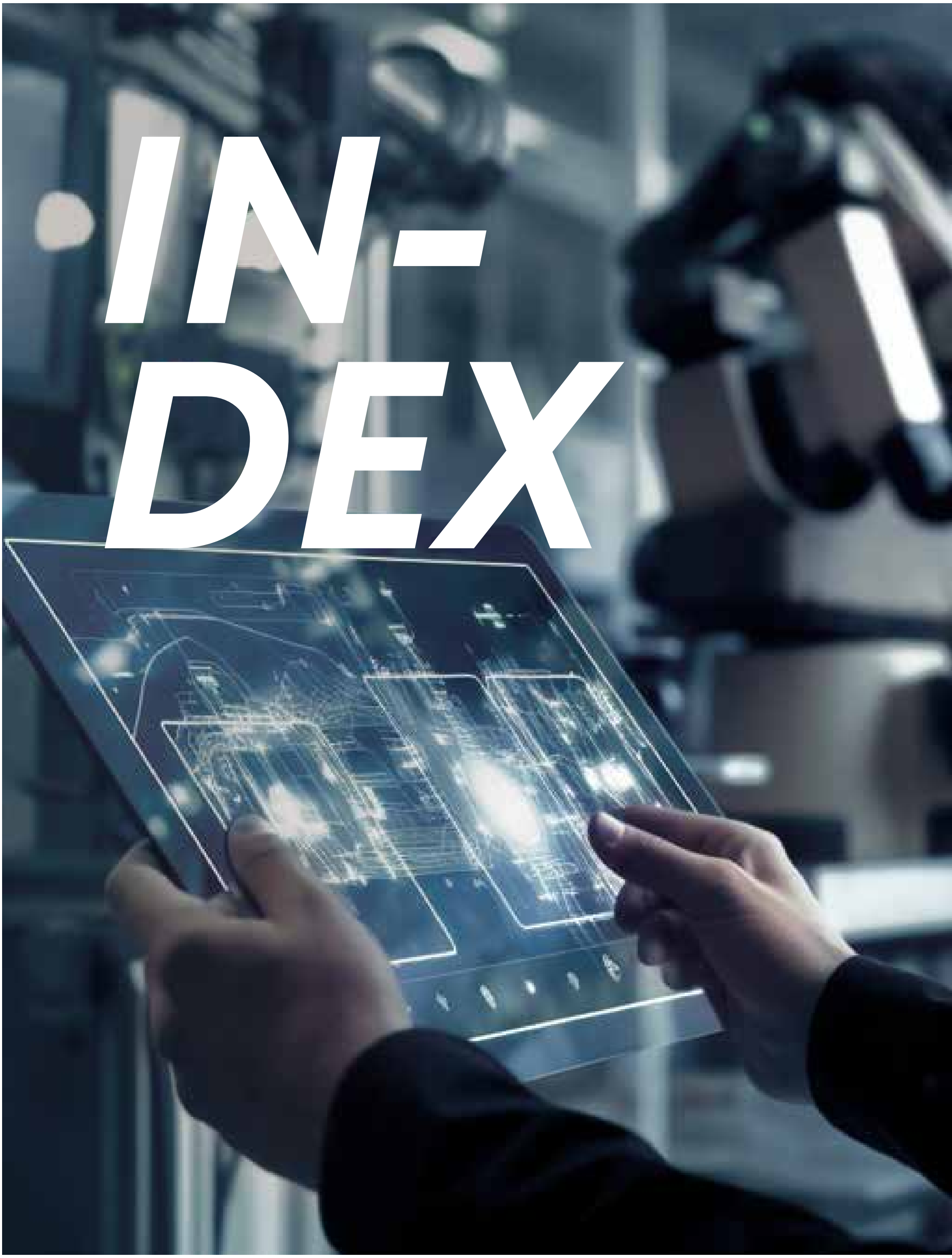


THE BRTA RESEARCH AGENDA

THE BRTA RESEARCH AGENDA

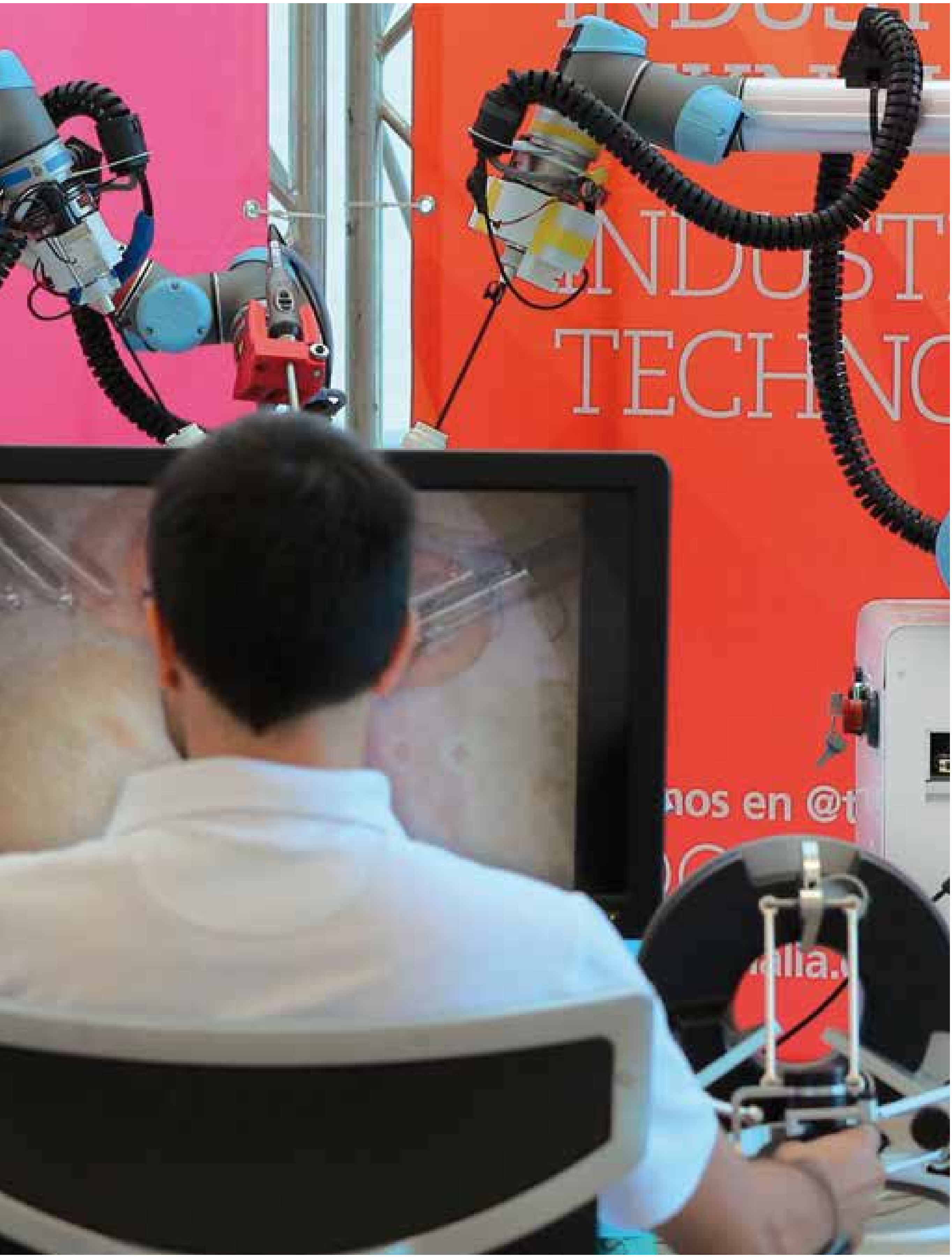
THE BRTA RESEARCH AGENDA

IN-DEX



BRTA
BASQUE RESEARCH
& TECHNOLOGY
ALLIANCE

01 INTRODUCTION



DIGITAL TECHNOLOGIES

01 INTRODUCTION

Digital technologies are changing people's lives, from the way we communicate to the way we live and work. Digital transformation is the integration of digital technologies in business and their impact on society. Digital platforms, the Internet of Things (IoT), cloud computing and Artificial Intelligence are part of the technologies affecting sectors ranging from transport to energy, agri-food, telecommunications, financial services, industrial production, healthcare, as well as the daily lives of citizens.

Digital is at the heart of EU policies, as it presents important opportunities for job creation, promoting education, increasing competitiveness and innovation, combating climate change and facilitating the ecological transition.

Digital is at the heart of EU policies, as it presents important opportunities for job creation, promoting education, increasing competitiveness and innovation, combating climate change and facilitating the ecological transition.

Europe aims to empower businesses and people for a sustainable, more prosperous and people-centred digital future. To this end, the "Roadmap to the Digital Decade" programme has been defined, with concrete goals and objectives for 2030, guiding Europe's digital transformation along the axes of skills (20 million ICT specialists and 80% of the population with digital skills), businesses (70% of companies using the cloud and AI, doubling unicorns), infrastructure (doubling the share of semiconductor production, quantum-accelerated computers) and digitisation of public services (100% online, digital identity).

The achievement of the digital goals is underpinned by the declaration on digital rights and principles for the Digital Decade. It aims to define citizens' rights in the digital space by putting people at the heart of the digital transformation[1-2].

To support this digital transformation, the EU is developing the following areas of action[3]:

Data economics

With the development of technology, more and more data is becoming available. The Council aims to create a single market for data, thus enabling greater exchange and re-use of data across sectors and across borders, in line with EU principles. It is a growing economy, from 2018 to 2025 the value of the data economy in the EU-27 is expected to grow from EUR 301 billion to EUR 829 billion; the number of data professionals will grow from 5.7 million to 10.9 million; the percentage of the EU population with basic skills will increase from 57% to 65%. To this end, the EC has proposed a European Data Strategy that will facilitate the digital transformation over the next five years, including the Data Governance Regulation, which aims to promote the availability of data for cross-sectoral and cross-border re-use.

Artificial Intelligence

Artificial Intelligence (AI) can contribute to a more innovative, efficient, sustainable and competitive economy, while improving security, education and healthcare for citizens. It also contributes to the fight against climate change. While supporting the development of AI technology, the Council recognises the potential risks and advocates an ethical and anthropocentric approach to AI technology. On employment, by 2025, AI and robotics could create 60 million new jobs worldwide. On the regulatory side, a Regulation for the harmonisation of rules on Artificial Intelligence has been published to ensure safe, lawful and reliable AI that respects fundamental rights.

Connectivity

Fast and ubiquitous connectivity across the EU is needed to give all Europeans access to digital technology. The EU has set connectivity targets for 2025, which are gigabit connectivity for all major socio-economic drivers, seamless 5G coverage in urban areas and on major land transport routes, and access to connectivity offering at least 100 Mbps for all European households.

Cybersecurity

As cyber threats and crimes increase in number and complexity, the EU is working to improve its response capacity and to protect the integrity, security and resilience **of electronic products**, digital infrastructures and communication networks and services. Central to this is providing a secure communication environment, and ensuring access to electronic data and evidence for law enforcement and judicial purposes4-5. [4-5].

--

1 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/shaping-europes-digital-future_es

2 https://www.consilium.europa.eu/es/press/press-releases/2022/11/14/declaration-on-digital-rights-and-principles-eu-values-and-citizens-at-the-centre-of digitaltransformation/

3 https://www.consilium.europa.eu/es/policies/a-digital-future-for-europe/)

4 https://www.consilium.europa.eu/es/policies/cybersecurity/

5 https://www.consilium.europa.eu/es/policies/e-evidence/

DIGITAL TECHNOLOGIES

01 INTRODUCTION

EU Member States recognise the need to enhance, modernise and clarify rules on digital services in order to ensure the safety of online users, and to enable innovative digital businesses to grow.

Digital services

Online platforms are an important part of the EU digital market and economy. EU Member States recognise the need to strengthen, modernise and clarify rules on digital services to ensure the safety of online users, and to enable innovative digital businesses to grow.

In line with European policies, at state level, the Digital Spain agenda6 is the roadmap for digital transformation, an ambitious strategy to take full advantage of new technologies and achieve economic growth that contributes to social cohesion. Digital Spain 2026 acts in three key dimensions: **infrastructures and technology, economy and people** with 10 strategic axes. In the infrastructures and technology dimension, the axes are digital connectivity, the promotion of 5G technology, cybersecurity and the data economy and Artificial Intelligence. In the area of the economy we have the digital transformation of the public sector, the digital transformation of business and digital entrepreneurship, sectoral and sustainable digital transformation and Spain, audiovisual hub. Finally, in the area of people, there are digital skills and digital rights.

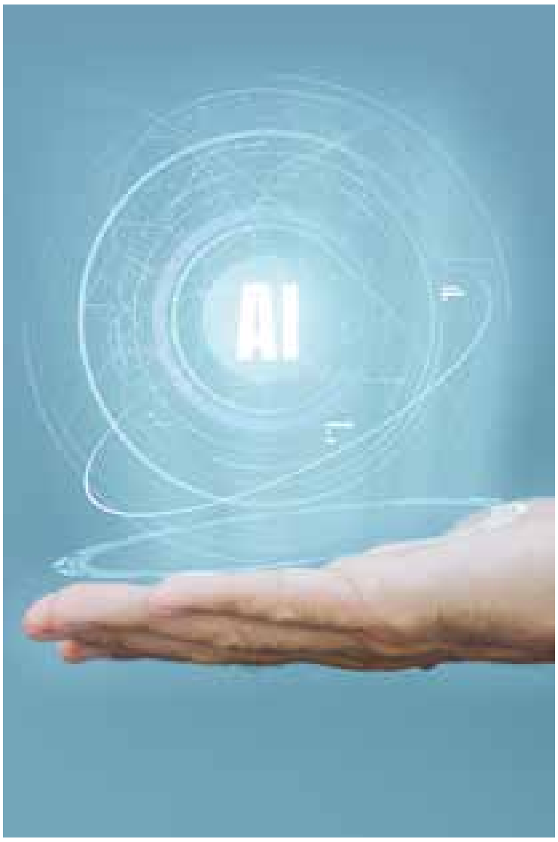
The Strategy for the Digital Transformation of the Basque Country 2025 (SDTBC2025)7 has been defined in the Basque Country and is structured in three dimensions: technological levers, enablers and areas of application that act as a system seeking to generate value for the Basque Country. The technological levers have been selected taking into account the disruptive role they are set to play in the short, medium and long term in the challenges posed by the three transitions (technological-digital, energy-environmental and social-health).

The **technological levers** are innovative digital technologies in which the Basque Country must gain advanced knowledge for their application in public, productive and social activity. These levers include aspects such as 5G connectivity, Artificial Intelligence, quantum computing, cloud services, interoperability services and cybersecurity.

Enablers are the set of instruments promoted by Public Administrations and the private sector that make the territory more fertile and attractive for the proliferation of innovative initiatives based on the technological levers with the greatest potential for transformation. Enablers include digital skills, R&D, public procurement of innovation, broadband connectivity, entrepreneurship, a cohesive technological community, ...

The areas of application are the specific areas of public and private activity that are being affected by the irruption of digital technologies and that are entailing a whole process of transition to new ways of generating value, new models of social and productive relations or new business models. These areas include SMEs, Smart Industry, energy and environment, food industry, security, employment, education, mobility, e-Administration, ...

In this context at European, national and Basque level, BRTA is a crucial player in responding to the challenges presented by the technological-digital transition. To this purpose, this document presents the capabilities of the BRTA alliance classified into technological pillars, disruptive technologies and digital solutions. The technological pillars are 7 areas of technological development consolidated in BRTA: electronics and embedded systems, AI and data science, connectivity, digital platforms, cybersecurity, software engineering and interaction technologies. Disruptive technologies are emerging areas of development with high transformative potential and digital solutions are solutions that use several technology pillars.

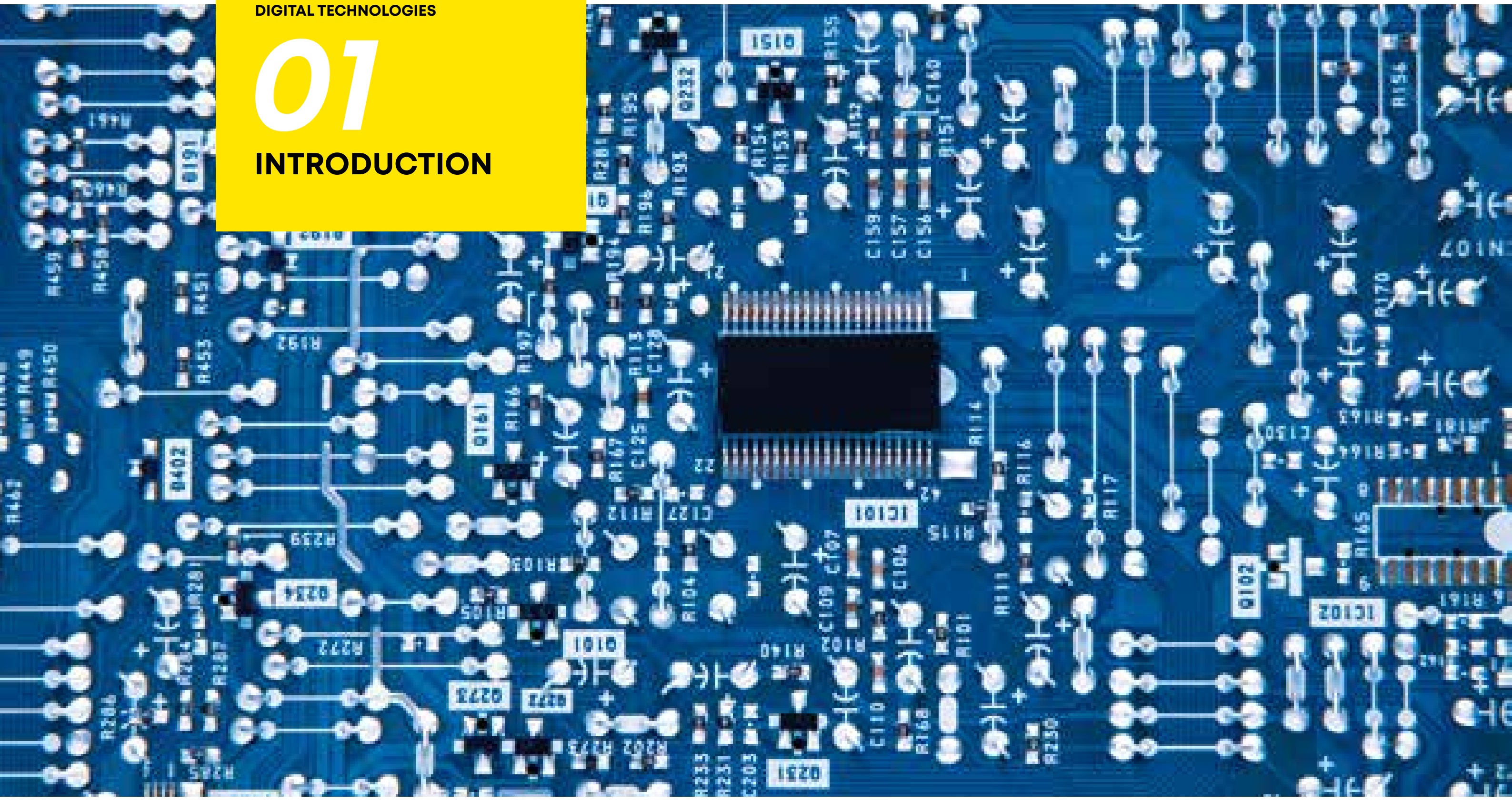


--

6 https://portal.mineco.gob.es/ca-es/ministerio/estrategias/Pagines/00_Espana_Digital.aspx
7 https://www.spri.eus/archivos/2021/10/pdf/etde2025_estrategia_es.pdf

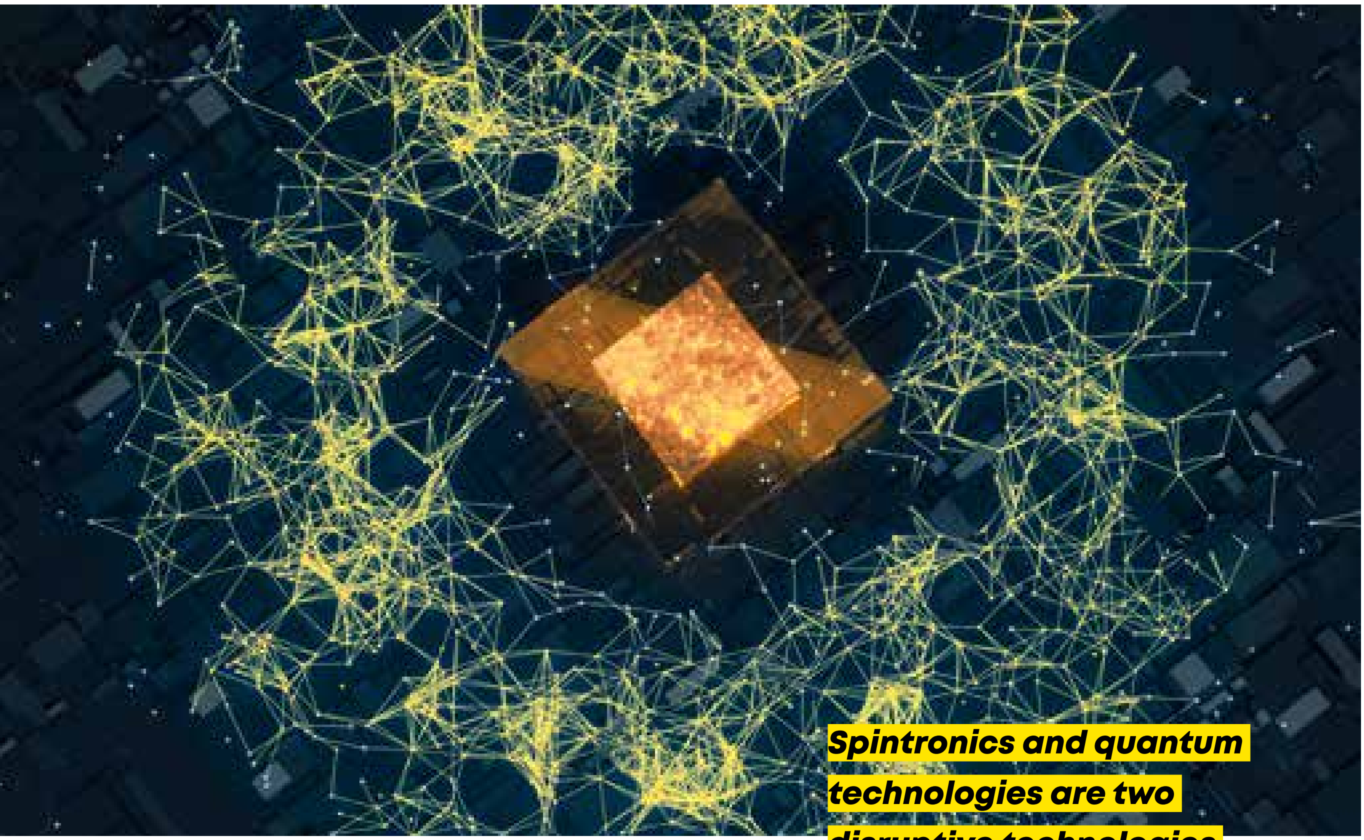
DIGITAL TECHNOLOGIES

01 INTRODUCTION



The document is structured as follows. Section 2 describes the technological pillars on which digital solutions are based in the different industrial sectors and activities. To do so, it analyses the positioning in the Basque Country, the main associated challenges and BRTA's capacities to face these challenges. Section 3 analyses two disruptive technologies that, although they still have a limited impact, can lead to real technological revolutions. These two disruptive technologies are spintronics and quantum technologies. Section 4 presents a set of Digital Solutions that are composed of the technological pillars already described in Section 2 and that have a high impact on today's industry. Finally, Section 5 shows a mapping of BRTA's capabilities on the set of Digital Technologies addressed throughout the document.

Technology pillars	Disruptive Technologies	Digital Solutions
• Electronics and embedded systems • AI and data science • Connectivity • Digital platforms • Cybersecurity • Software engineering • Interaction technologies	• Quantum technologies • Spintronics	• Digital Twin • Robotics • CPS and IoT Networks • Monitoring, Diagnostics and Prediction



Spintronics and quantum technologies are two disruptive technologies that, although they still have a small impact, could lead to real technological revolutions.

Shaping Europe's Digital Future / Priorities for the European Union

- https://www.digitales.es/publicacion/2030-digital-compass-the-european-way-for-the-digital-decade/
- https://www.digitales.es/wp-content/uploads/2021/07/kk0521014enn_002_double_paged_81E59A7C-C5D9-65D8-2BAFF66AFB1A4D54_75375.pdf
- https://digital-strategy.ec.europa.eu/en/policies/strategy-data
- https://www.consilium.europa.eu/es/policies/a-digitalfuture-for-europe/
- https://www.digitales.es/wp-content/uploads/2021/07/kk0521014enn_002_double_paged_81E59A7C-C5D9-65D8-2BAFF66AFB1A4D54_75375.pdf

02

TECHNOLOGICAL PILLARS

DIGITAL TECHNOLOGIES

02 TECHNOLOGICAL PILLARS

BRTA's work areas in the digital field are 7, and for each of them the following outline is developed: introduction, positioning of the Basque Country, technological challenges and R&D priorities.

2.1 Electronics and embedded systems

2.1.1 Introduction

Embedded electronics and systems refer to electronic devices and systems that are integrated into other products or equipment. These systems typically include a combination of hardware, such as microprocessors and sensors, and software, such as firmware and embedded software. Examples of embedded systems can be found in many industrial, automotive and even healthcare applications. In fact, electronic systems are one of the main enablers of digital transformation, enabling the development of many innovative products and services in all sectors of the economy.

The realisation of intelligent electronic components and systems for today's digitisation applications requires different elements, such as: digital electronics, analogue electronics, mixed-signal electronics, memories, power electronics, sensors, actuators, energy management circuits, etc. This heterogeneity of functionalities can be integrated monolithically on a single chip in a so-called system-on-chip (SoC). However, the increasing complexity of today's applications requires multi-chip components and the use of system-in-package (SiP) integration technologies. A system-in-package (SiP) integrates multiple integrated circuits (ICs) and other components, such as passive components, into a single package. These ICs and components are typically manufactured separately and then assembled to form a single package. The package may include a variety of different functions, such as microprocessors, memory and wireless communication. SiP technology enables the integration of multiple functions into a single package, which can reduce the size and cost of electronic devices and systems, and improve their performance and reliability.

The future of electronics is expected to be determined by several key trends and technologies, such as miniaturization, flexibility, or so-called green electronics. Miniaturization will enable the integration of electronics into smaller spaces. Flexible electronic components will adapt to different shapes and sizes. Green electronics will use sustainable materials and enable the development of more energy-efficient devices. Overall, the future of electronics and

Embedded electronics and systems refer to electronic devices and systems that are integrated into other products or equipment. These systems typically include a combination of hardware, such as microprocessors and sensors, and software, and embedded firmware and software.

embedded systems is expected to be determined by the integration of diverse technologies and the growing demand for connected devices and systems.

2.1.2 Positioning in the Basque Country

In the PCTI EUSKADI 2030, cyber-physical systems are identified as one of the base technologies for the technological-digital transition. These cyber-physical systems are electronic systems that are interconnected with each other forming a network of intelligent electronic components.

The Basque Country has an ecosystem of companies, technology centers and universities with great knowledge in electronics and embedded systems. The Association of Knowledge Industries and Applied Technology (GAIA) includes these agents.

In this way, we can find in the Basque Country companies that design and manufacture electronic components and assembled printed circuits (PCBs), such as, for example, IKOR Sistemas Electrónicos, IDK Elektronika, P4Q, Fagor Electrónica or Microelectrónica MASER; as well as companies that integrate different electronic components to design innovative electronic devices for very different applications, such as consumer electronics, telecommunications or telemedicine (ALCAD Electronics, Ikusi-Velatia, Copreci, Fagor Automation, etc). We can also find companies that offer engineering services for the software and hardware design of an electronic device (Ulma Embedded Solutions, Tinkoa Embedded Systems, etc).

It should be noted that GAIA has driven the **Basque Microlectronics Hub** (https://bmh.gaia.es/es/hub/), in collaboration with the Basque Alliance for R&D (BRTA) and eight technology and cooperative research centers (CEIT, GAIKER, CIC energigune, CIC nanoGUNE, IKERLAN, TECNALIA, TEKNIKER and VICOMTECH) that have specialization and solutions related to microelectronics and its technologies. The objective of the Basque Microlectronics Hub is to promote the microelectronics discipline, which encompasses the study and manufacture of very small electronic designs and components that are typically made of semiconductor materials.

At present, more than 80 Basque industrial companies have shown their support and commitment to this initiative.

BRTA entities drive basic research initiatives with the design of high-capacity and ultra-low power electronic systems and advanced sensorization systems (Elkartek µ4IIoT, ANDREA, IDEA II projects) **and also lead and participate in national or international projects** in this sense (WATEREYE, DRAGON, PolySensor).

The following is a list of the most representative national projects in electronics and embedded systems of BRTA members:

- **harshMop:** Continuous monitoring system for muti-use offshore platforms for early corrosion detection combined with corrosion protection systems (CPP2021-008523)(2022-2025).
- **MODITRANS:** Transformer modeling and diagnostics (CPP2021-008580) (2022- 2025), where advanced sensing technologies will be developed.
- **PolySensor** Piezoresistive Thermoplastic Matrix Materials for further Integration of Sensors in Injection Molding and Additive Manufacturing Products (AEI - 2021 - 2022).

Some of the most representative ELKARTEK projects in electronics and embedded systems of BRTA members are:

- **MICRO4FAB, µ4F, µ4INDUSTRY, µ4IIoT** (set of ELKARTEK projects from 2016-2022), where advanced sensing technologies have been developed, researched in high-capacity and ultra-low power electronic systems and advanced electronic manufacturing technologies.
- **IDEA II** Research and development in additive electronics 3D printing and integration (2021 - 2022).
- **ANDREA** (2022-2023): Digital transformation and efficient use of resources through non-destructive inspections.
- **INSPECTA** (2019-2020): An approach to critical joint and defect inspections by robust and automatable methods.
- **IN-SENSE** (2020-2021): Development of a new generation of “in-sense” landing gear that increases aeronautical safety.
- **ERTZEAN** (2021-2022) - Embedded architecture for new edge computing applications.

We highlight some significant European projects in which different entities of the Basque Country participate:

BRTA entities drive basic research initiatives with the design of high-capacity, ultra-low power electronic systems and advanced sensing systems, and also lead and participate in national and international projects.

- **WATEREYE** (O&M tools integrating accurate structural health in offshore energy) where corrosion sensing technologies and positioning systems have been developed (2019-2022).
- **DRAGON** (D-band radio 5G network technology), where research is being conducted on millimeter wave radio frequency design technologies (2020-2024).
- **FLASH-COMP**: Sustainable production of composites through a human centered digital approach (2022-2026).
- **FR8RAIL, FR8HUB, FR8RAIL II, FR8RAIL III, FR8RAIL IV** (set of European projects of the Shift2Rail program, period 2016-2023): where research has been carried out along the lines of digitalization of the freight train and technologies have been developed for its monitoring, positioning, etc.
- **NIMBLE-AI**, where neuromorphic computing architectures for chips oriented to vision applications are being investigated.

2.1.3 Technological Challenges / R&D Priorities

1) High-capacity, ultra-low-power electronic systems

One of the great challenges of the electronic systems of the future is to be able to develop smaller and smaller devices, with greater computational capacity, but with lower energy consumption. These devices must also be able to operate robustly in hostile environments. Increasingly, heterogeneous components and systems-on-chip (SoC) will be integrated. For this reason, the following lines of action have been identified:

- Design of high-performance and/or ultra-low-power integrated circuits (ASICs) and FPGA architectures.
- Integration of logic with power management devices, radio frequency (RF), optical, sensing or actuation technologies.
- New neuromorphic computing architectures .
- Improved compatibility of electronics in harsh environments (high temperature, vibration, EMI) for industrial, automotive or space applications.
- Design in ultra-low power technology.
- Low-power and sustainable printed electronics.

2) Advanced sensorization technologies

There is a need for sensors with lower energy consumption, capable of working in hostile environments and capable of better characterizing different key parameters of the applications in which they will be used. Thus, advances in the following lines of action are considered to be key to the electronic systems of the future:

- Design of new mechanical sensors (acceleration, gyroscopes, etc).
- Design of sensors for selective detection of environmental and respiratory gases (CO, CO_2, NOx, VOC, etc.).
- Design of electromagnetic or ultrasonic sensors to measure properties of the materials in which they are placed (corrosion, hardness, etc.).
- Transmitter/receiver technologies for applications such as LIDAR and Active Phased Array imaging.
- Biological and biochemical sensors.
- Positioning systems.

3) Advanced power electronics technologies

Significant new advances in the power electronics of electronic systems used in Internet of Things (IoT) applications are needed for optimal management of available energy. Progress must be made both in better energy collection and storage, as well as in better management of the available energy. Thus, the following lines of action are identified in which to advance in the design of power electronics:

- Higher power density and frequency, new materials for high-temperature electronics and new CMOS/IGBT processes.
- Energy harvesting and storage, microbatteries, supercapacitors and wireless power transfer.
- Energy-efficient components and systems.
- Stand-alone power systems for IoT applications.

4) Radio frequency design technologies

Cyber-physical systems usually communicate wirelessly, because they are often located in places that cannot be easily reached by a wired network. In addition, these communication links require higher and higher communication rates. Since the electromagnetic spectrum is becoming increasingly saturated, one of the trends in communication systems is to increase the working frequencies to work in bands that allow communication with large bandwidths, which imposes great challenges in the design of radio-frequency electronic devices. Thus, it is considered that the following lines of action will be key to the development of the cyber-physical systems of the future:

- Design of miniaturized high frequency solutions, working in millimeter wave (> 60 GHz) and THz (>100 GHz) bands.
- Design of low-power radio frequency electronics for ultra-wideband signals.
- Integration of additional functionalities such as antennas, passive devices and embedded power sources: Power-Source-in-Package (PSiP)/ Power-Source-on-Chip (PwrSoC).

5) Advanced hardware manufacturing technologies

The different electronic components are usually mounted on PCBs (printed circuit boards). As mentioned above, the current trend is to try to embed more functionality in less space, since the aim is to have smaller and lighter electronic devices. To achieve this, it is necessary to improve current hardware manufacturing techniques, both for PCBs and for the electronic components themselves. Listed below are the lines of action that are considered critical to achieve the objectives set out in this challenge:

Progress must be made in better energy harvesting and storage, as well as in better management of available energy.

- PCB design on flexible substrate
- 3D printing of IC components on PCB
- IC fabrication using new technologies and new materials: BiCMOS, GaN, SiC, SiGe, etc.

6) Software design technologies in electronic components and systems.

Proper design of the software running on an electronic system is key to obtaining a safe and energy-efficient device, whether it is firmware running on a microcontroller or software running on a microprocessor with an operating system. For this reason, further work is needed on the following lines of action:

- Secure and energy-efficient firmware design.
- Over-the-Air firmware update techniques.
- Real-time software implementation in operating systems.
- Efficient programming on coprocessors, GPUs and hardware accelerators.
- Distributed middleware programming.

7) Electronic Components and Systems Engineering (Virtual)

Virtual engineering or the design of digital twins of electronic components and systems is key to be able to model the operation of a system before its physical implementation, especially when it comes to safety-critical devices. These models should allow not only to verify the functionality of the electronic device before its manufacturing, but also to estimate its robustness, reliability and even its power consumption. For this reason, the following lines of action are considered key:

- Interoperable methods and tools for virtual prototyping of complex systems with a large number of components.
- Methods for hardware and software co-simulation of heterogeneous systems (co-simulation of software, hardware and sensors, hardware-in-the-loop, etc).
- Model-based verification, validation and testing methodologies, interoperable tools and platforms for critical systems.
- Procedures for the assessment of functional safety, robustness and reliability of safety-critical devices.
- Methods and tools for modeling and integration of heterogeneous subsystems (analog, digital, RF, antennas, power electronics, memories, buses, optical components, passive components, etc).

2.2 AI and data science

2.2.1 Introduction

Data science encompasses several disciplines, such as data engineering and preparation, data mining, descriptive and predictive analytics, data-driven learning techniques, data visualization, etc.

On the other hand, **Artificial Intelligence** is generally associated with software (and hardware) systems for which, given a complex goal, they (1) perceive the context through data (2) reason from both information extracted from the data and existing knowledge and (3) act in a physical or digital dimension to achieve the goal.

Artificial Intelligence can be understood as a set of technologies included in the broad concept of data science or not, in any case they are two closely linked concepts. **The data analytical process may end in the implementation of an AI algorithm** or not.

Data science and AI are **applied in a multitude of fields. In manufacturing and industrial production**, it contributes to a more efficient use of resources, energy and materials, through better design and manufacturing processes, improving their operation. Its contribution is relevant in other sectors, such as energy, health, logistics and e-commerce, agriculture and food production, marketing, entertainment and in service sectors, such as financial services, public services, etc..

It should be noted that, in general, the work is based on **structured and unstructured data** (text, audio, video, etc.), being very important the phase of capturing the data with the required accuracy, reliability and frequency.

The **process a data scientist follows to** answer questions posed to him can be summarized in these steps: 1) Obtaining the data; 2) Preprocessing of the data where data that do not meet the quality criteria or are not of interest for analysis are cleaned and filtered; 3) Transformation and integration to homogenize the data coming from multiple sources, so that they are comparable among them; 4) Analysis of the data using different methods and algorithms that answer the questions under analysis; 5) Validation of the data: see if these data are robust or change due to biases inherent in the data, if additional data are necessary; 6) visualize, present the results, implement the algorithm to embed it in the desired product/solution.

In 2021, the Basque Artificial Intelligence Centre (BAIC) is created with the aim of leading and promoting the development of Artificial Intelligence in the Basque Country.

2.2.2 Positioning of the Basque Country

The Basque Country's **"Science, Technology and Innovation Plan Euskadi 2030"** considers **Data Science and Artificial Intelligence as one of the key base technologies** in relation to the areas of specialization and their adaptation to the technological-digital, energy-climate and social/health transitions, and with the potential to trigger disruptive innovations in these areas. Its strategic priorities include:

- The **Smart Industry** and its challenge to valorize the use of data, providing intelligence and ultimately value to customers, which involves servitization and the development of new business models.
- **Cleaner energies**: Digitization, access to data, data sharing along value chains, as well as the transition to new data-driven business models.
- **Personalized health**: Access to large-scale data and advanced analytics, and new ways to manage data and extract knowledge from diverse and complex data, and to use such data to drive biomedical research and innovation and advance disease prevention, treatment and cure.

As part of this strategy, the **Basque Artificial Intelligence Center (BAIC)** was created in 2021 with the aim of leading and promoting the development of Artificial Intelligence in the Basque Country. BAIC was created to be a space for public-private collaboration to promote Artificial Intelligence (AI) in the Basque Country, an instrument for its rapid adoption by the industry, while serving as a laboratory for experimentation and acceleration of projects that serve as international positioning in one of the greatest technological and social challenges.

We have an ecosystem and shared objectives among different types of agents: AI providers (consolidated and startups), user companies, knowledge agents, training offer and public administrations.

DIGITAL TECHNOLOGIES

02 TECHNOLOGICAL PILLARS

In parallel, the **GAIA Cluster has created AI Basque**, whose scope is focused on fostering Artificial Intelligence in all economic and social fields, promoting collaboration with other sectors and fostering the development of new products/ services, technologies and markets. At the end of 2021, AI Basque was constituted by 21 companies of the ICTA sector, 3 technological centers, the GAIA Cluster and the UPV-EHU.

In terms of **alignment with the European strategy**, entities of the Basque Country are part of the ecosystem associated with the data spaces that are being established in Europe. We highlight the Basque presence in the "International Dada Spaces (IDSA)" association: The Spanish hub is piloted from the Basque Country (Baidata), TECNALIA is listed as "Competence Center" and TECNALIA as well as TEKNIKER and IKERLAN are "Implementation partners".

BRTA entities drive basic research initiatives related to the design and implementation of **reliable systems (robust, secure and ethical)** based on Artificial Intelligence (Elkartek 3KIA, SIIRSE projects) and also **lead European projects** in this sense (AIPROFICIENT, ARISE, AITHENA, DARROW).

Singular initiatives/projects (ELKARTEK):

. HODEI-X (Contribution of the Basque ecosystem to GAIA-X, European federated data and services infrastructure).
. 3KIA (Integral and Transversal Proposal for the Design and Implementation of Reliable Systems based on Artificial Intelligence).
. SIIRSE (Smart, Robust, Secure and Ethical Industrial Systems for Industry 5.0: advanced specification, design, evaluation and monitoring paradigms).
. EKODATA - Data Economy, value generation through analytical exploitation.
. RESTERIA (21-22): Development of a resonant induction platform for the optimization of inductive thermography testing through the application of Artificial Intelligence.

We underline some significant European projects in which different entities of the Basque Country participate:

. AI-PROFICIENT (Artificial Intelligence for the improvement of effiCienCy, quality and production maintenance).
. ARISE (23-26) Artificial intelligence in manufacturing for sustainable applications in SMEs.
. BEAM-IDL (22-23): Monitoring and identification of multiple laser beam shaping using deep learning algorithms. VEDLIOT Open call.
. DARROW (22-26) IA for the improvement of wastewater treatment.)
. AITHENA (22-25) AI-based TrustwortHy, explainable scene and motion prediction and Actions.
. KINAITICS (22-25) AI for cybersecurity reinforcement.

PSignificant national projects:

. ION-MAKE (AI acceleration of the optimization process in the manufacture of electrodes for new generation batteries - PROJECTS OF ECOLOGICAL TRANSITION AND DIGITAL TRANSITION 2021, MICINN).
. ION-SELF (Automation and autonomization through AI of the process of synthesis and characterization of new electrode materials for batteries - State Program for R&D&I Oriented to the Challenges of Society, MICINN).

The GAIA Cluster has created AI Basque, whose scope is focused on promoting Artificial Intelligence in all economic and social fields.

- Strategic positioning in virtual models and digital twins for an industry 4.0 - MIRAGED", use of AI for the generation of digital twins, Accreditation and granting of aid to Technological Centers of Excellence "Cervera", CDTI.
- IA4TES Artificial Intelligence for Sustainable Energy Transition. Research on the solutions that can provide the different Artificial Intelligence technologies, in the development of the electricity sector, thinking about the new paradigm of electricity system that is characterized by having a mostly renewable production, a mix of centralized and distributed, a digitized and automated, optimized network, capable of providing bidirectional services to all types of users.

2.2.3 Technological Challenges / R&D Priorities

. Sensing and perception

Sensing is concerned with the detection of an object or physical property and the conversion of those measurement principles into a signal that can be captured and processed. Perception is the organization, identification and interpretation of sensory information in order to understand the sensed information.

The ultimate goal of sensing and perception is to have information that can be communicated and processed. These technologies must be able to process different types of data: from real-time sensors, time series, text, sounds, images, videos, etc.

DIGITAL TECHNOLOGIES

02

TECHNOLOGICAL PILLARS

Sensing and perception are the starting point for any application related to AI and data science, which will depend on receiving timely, quality, meaningful and reliable data.

R&D priorities in this area are:

- Ensure **perception regardless of operational conditions**: different environmental, climatic, personal, etc. conditions.
- Improve the sensing **capacity in frequency and quality** while reducing the cost.
- Integration of **sensing and processing in a modular way**.

These priorities are closely related to those of the "Electronics and embedded systems" pillar and in particular to "Advanced sensing technologies".

. Data, knowledge and learning

This section includes the different technologies that allow the construction of models. This construction is carried out both from the data that, once filtered and conditioned, are received in a system and from the existing knowledge about it (organized for example in sets of rules, in physic-mathematical equations, or in ontologies). From these two elements, digital models (data only) or hybrid models are configured that will allow the subsequent processes of reasoning, optimization, action, etc. to be carried out.

Learning encompasses the set of technologies within AI that allows to generate or update a model from data. In machine learning the objective is to automate and generalize the induction of knowledge from data, where special attention is also paid to the computational complexity of the problems and their solution in adequate processing times. On the other hand, there is a wide range of techniques (e.g. probabilistic, by reinforcement) where the objective is to update the model from the information received (new data, results, ...) during its operation and exploitation.

R&D priorities in this area are:

- Methods capable of facilitating the **explainability of the models**, especially from technologies with low self-explanatory capacity, such as neural networks.
- The **'federation' of learning**, within scenarios where data are distributed in different spaces (e.g. due to privacy policies) and it is necessary to combine/compose the operation and results of simple models.
- The use of data **augmentation techniques** that can feed these learning systems, increasing both the quality and the number of training data.
- The incorporation from the design of **'reliability'** premises (from a triple **ethical, legal and robustness perspective**) to both learning systems and models to facilitate their inclusion and avoid rejection by society.

Reasoning and decision making is the ultimate goal of Artificial Intelligence. The complexity of decision making processes has grown hand in hand with the increase in complexity in a digital, hyper-connected and global world.

. Reasoning and decision support

Reasoning and decision making is the ultimate goal of Artificial Intelligence. The complexity of decision-making processes has grown hand in hand with the increase in complexity in a digital, hyperconnected and global world. The number of variables involved in a decision making process is increasing and response times are decreasing. Both factors mean that the human capacity for decision making is clearly reduced. The hyper-monitoring of an increasingly digital world opens up a huge range of possibilities for Artificial Intelligence to become the perfect complement to increase human capabilities in decision making.

The set of techniques included in this section would be aimed at **complementing the cognitive capacity of both models (knowledge and learning phases) and humans**, orienting these increased capacities towards decision-making (e.g. how to control a machine so that it minimises its consumption while satisfying production requirements while generating the least number of faults).

The R&D priorities in this area are:

. Decision-making is identified with prescription or action, whether we are talking about optimisation, planning, research or diagnosis. The reasoning goes more towards ensuring certainty, credibility and transparency in the decision-making process.

. Combination of classical emulation systems based on parametric physical equations with Machine Learning: Decision-making systems can **be carried out by humans, machines (Machine Decision Making), or a combination of both**. There is a novel concept called Physics Aware ML, **in which Machine Learning is combined with physical concepts** or laws that guarantee the credibility and certainty of the solutions provided; or the concept recently introduced by the Massachusetts Institute of Technology, Shared Interest, which allows for semantic interpretations of the behaviour of models.

. Human-machine interaction systems: In human-machine interaction there is usually a gap of understanding in the way both make decisions. For mixed systems there is no single human-machine interaction scheme, they can take different forms (the machine suggests and it is the human who decides by declining, modifying or accepting the suggestion; the human guides the machine in the process of finding the solution in an iterative and cooperative process, HMI schemes, Human Machine Interaction). Examples of such approaches are the combination of neural computation with symbolic representation, the inference of causal relationships .

DIGITAL TECHNOLOGIES

02

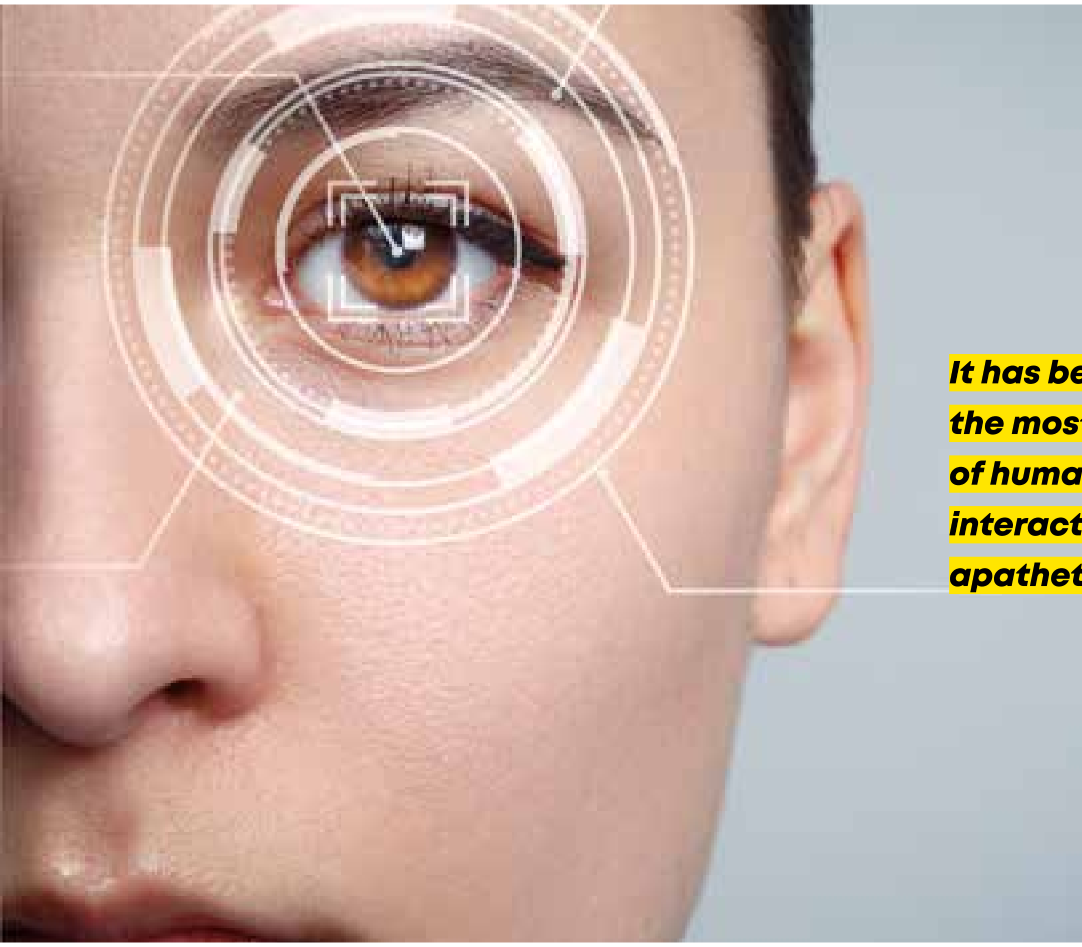
TECHNOLOGICAL PILLARS

. Interaction

Beyond the interaction techniques identified in the section “Interaction Technologies” where forms of human-machine interaction (language and/or speech) are expressed through AR/VR/RV/RX technologies, this section focuses on how AI can help to improve that interaction. Historically, but especially in the last decades, it has been shown that the most efficient form of human-machine interaction is through apathetic interaction.

The R&D priorities in this area are:

- The most widespread forms are through the use of language (NLP; Natural Language Processing and/or NLU Natural Language Understanding) and speech recognition (Speech Recognition) through the development of conversational agents. The trend for the future is the multimodal agent, i.e. one that is able to analyse, decide/suggest and reason by means of text, speech, gestures, emotions, spatial-temporal relations, among others.
- Interaction aimed at augmenting human capabilities is now known as **“augmented human”**, with research focusing on three main pillars: 1) perception (both human and machine); 2) interaction scheme; and 3) information and telecommunications.
- Improved interaction systems will make it easier for humans to use AI-based developments effectively and safely, while ensuring that their capabilities are enhanced in the scheme that the ethical pillars of AI dictate, which is **“human-centred automation”**. In this novel trend, the functionalities of the machine and the interaction medium (interface) are at the service of exploiting the human’s inference capabilities, needs and purpose in the decision-making process (which will be implemented following the provisions of the section on reasoning and decision support).



It has been shown that the most efficient form of human-machine interaction is through apathetic interaction.

. Architectures, methods and tools

The architectures, methods and tools needed to deploy digital solutions must guarantee both design aspects (reliability, reproducibility, interoperability, privacy and/or security) and technical aspects in operation (latency, energy consumption, communications resources, quality, among others). The **operationalisation of Artificial Intelligence throughout its life cycle as a product or service** involves aspects of software, hardware, engineering and integration, validation, testing and certification, as well as interoperability. All these elements must allow training, reusing and implementing models in reproducible steps, linking models, data and hyperparameters, allowing the entire life cycle to be monitored.

The R&D priorities in this area are:

- From the platform point of view, they are aimed at the operationalisation of AI-based products or services, offering **AI as SaaS** ("software as a service") or IaaS ("Infrastructure as a service") offering an ecosystem that guarantees interoperability and stability. All the big digital giants offer their reference platforms GoogleAI, Microsoft Azure ML, Amazon Web Services (AWS), IBM Watson, SAS, NVIDIA GPU Cloud, among others.
- From the point of view of methods, the key points will be more focused on the more technical aspects in the operation of these products or services (latency, energy consumption, etc.), with key aspects such as **Edge-cloud computing** (in relation to latency and communications needs) or the **GreenAI** concept that takes into account the energy cost of Artificial Intelligence models.

02
TECHNOLOGICAL PILLARS

Connectivity is presented as one of the main pillars of this process by offering ubiquitous and immediate access to information.

5G technologies as those enabling technologies that will allow massive data movement with ultra-low latency between end devices and Cloud Computing platforms.

2.3 Connectivity

2.3.1 Introduction

The rapid development of information and communication technologies (ICT) in recent years is leading to a major transformation in practically all sectors of activity. Connectivity is one of the main pillars of this process, offering ubiquitous and immediate access to information. Sectors such as entertainment and creative industries, transport and logistics, telemedicine and banking have undergone a clear transformation thanks to the connectivity of the elements or assets involved in their processes.

In the case of industrial processes such as energy or manufacturing, they increasingly rely on the combination of the interconnection of Cyber-Physical Systems (CPS) and the Internet of Things (IoT). In this type of industrial environment, several types of applications can be distinguished, with very different connectivity requirements: on the one hand, there are process automation applications, such as the monitoring of industrial plants, where physical quantities (e.g. temperature, pressure, etc.) from a large number of nodes and with very slow variation times are sensed. On the other hand, there are factory automation applications, such as robotic applications, where operations are performed that require very fast response times and very controlled latencies.

Such applications have traditionally been carried out using wired buses, as in the case of collaborative robotics; however, the advent of high capacity and high reliability wireless technologies is making possible the deployment of new industrial applications, such as the control and monitoring of high-speed rotating machines or the management of robots in highly mobile environments.

2.3.2 Positioning of the Basque Country

Connectivity technologies represent one of the cross-cutting pillars on which the “Basque Country Science, Technology and Innovation Plan 2030” is based. Specifically, this Plan points to the Internet of Things (“Internet of Things”, IoT) and 5G technologies as the enabling technologies that will make it possible to move data massively and with ultra-low latency between end devices and Cloud Computing platforms. These connectivity technologies will also enable computing tasks to be distributed between different points of the device-Cloud link, making it possible to divide these tasks between high-capacity remote servers (“Cloud Computing”) and devices close to the end node with lower response time (“Edge/Fog Computing”).

In this sense, BRTA entities lead several ELKARTEK research projects related to 5G technology (B-INDUSTRY5G), powerline communications (COM4RED, COM4RED2) and vehicular communications (AUTOLIB, AUTOEV@L), as well as various projects related to verticals such as rail transport and automotive, both at national (5G EUSKADI, OpenVerso) and European level (Safe4RAIL-3, X2RAIL-5, C-ROADS, 5G-IANA).

Some of the most representative ELKARTEK connectivity projects of BRTA members are:

- **B-INDUSTRY5G** (ELKARTEK 2021-2022), a project that has developed a cutting-edge 5G technology platform based on the coordination of a set of advanced 5G laboratories for Industry 4.0.
- **COM4RED, COM4RED2** (set of ELKARTEK projects in the 2017-2019 period), where Powerline communications for the electricity grid in new frequency bands were investigated.

- **AUTOLIB, AUTOEV@L** (set of ELKARTEK projects for the period 2019-2023), where ITS-G5 communications for cooperative ITS were investigated.
- **5G4BRIS3** (ELKARTEK 2020-2021), which aimed to establish the basis for a research strategy in key technologies for 5G networks, with a special focus on the main areas of the Basque Regional Innovation Strategy for Smart Specialisation (RIS3).

We would like to highlight some significant European projects on connectivity in which different entities in the Basque Country participate:

- **Safe4RAIL, Safe4RAIL-2, Safe4RAIL-3** (set of European projects of the Shift2Rail programme, period 2016-2023), where wireless communications have been developed for railway environments, both outside and inside the train.
- **X2RAIL-1, X2RAIL-3, X2RAIL-5** (set of European projects of the Shift2Rail programme, period 2016-2023), where work has been carried out on the train-to-ground communications technology of the future and tools have been developed to facilitate its deployment.
- **C-ROADS** (Connected Roads): where research has been carried out on the digitisation of roads by means of ITS-G5 communications.
- **5G-IANA**, 5G Intelligent Automotive Network Applications. European project for the design, development and testing of 5G services for the automobile.
- **5G Mobix**, Advanced Connected and Automated Mobility Services.

Finally, the most representative national connectivity projects of BRTA members are listed:

- **5G EUSKADI** (Red.Es Programme funded by the Ministry of Economy and Business in 2020-2022), where research was carried out into different applications of 5G technology for mobility, the industrial and energy sectors, among others.

- **OpenVerso** (Open Virtualised Technology Demonstrators for Smart Grids), Cervera Network of Excellence to accelerate the evolution of next generation 5G and future mobile communication networks.

2.3.3 Technology Challenges / R&D Priorities

The connectivity technologies of the future will have to respond to a number of challenges that will be set by the novel and advanced applications they will have to serve. These challenges include the following:

1. Large volumes of data

This is the case for the transmission of multimedia information, where the increase in the definition of images and the number of devices is causing data transmission volumes to increase exponentially in recent years. To accommodate this increase in information, both 5G cellular networks and IEEE 802.11-based WiFi standards are migrating towards more complex modulations and higher bandwidth communication channels, even moving to millimetre communication bands.

2. Consumption optimisation

There are many Machine-to-Machine (M2M) applications where the transmissions made are of very few bytes and the frequency of data transmission can be very low; however, access to them is complicated and they do not allow wiring. This is the case of applications in which physical variables such as deformation, temperature or pressure are monitored in large industrial facilities, critical infrastructures, etc. that follow the IIoT (“Industrial IoT”) paradigm. In these cases, it is essential to reduce energy consumption, and this is where LPWAN (“Low-Power Wide Area Network”) solutions are focused, which are wireless technologies for networks in large areas specialised in the interconnection of devices with low bandwidth and oriented towards long range and low consumption.

These technologies currently include proprietary LoRA™, RPMA (“Random Phase Multiple Access”) or Sigfox® systems, as well as licensed LPWAN technologies based on cellular networks such as LTE Cat-M1, NB-IoT and EC-GSM.

3. Ultra-low latency

In critical communications such as industrial communications, it is essential to have mechanisms that guarantee extremely low and limited communication latency/jitter parameters. This is the direction of 5G Ultra-Reliable and Low-Latency Communications (URLLC) services, as well as Time Sensitive Networking (TSN) technology. TSN consists of a set of standards within IEEE 802.1, which are designed for reliable, deterministic and low jitter communications over wired networks. There is currently a great deal of interest in extending TSN technology to the wireless environment, and it is expected to be included in the next versions of the WiFi standard and in future 5G releases where combined with latency control slicing techniques, wireless services will be able to satisfy critical communications services in terms of latency and jitter.

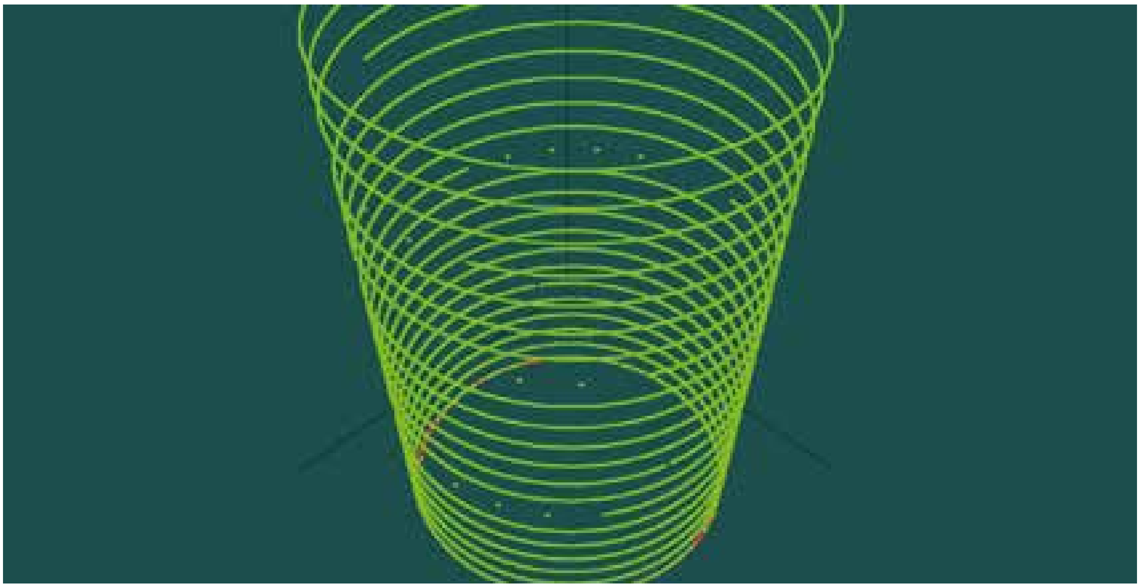
4. Reliability and availability

Reliability and availability are also two fundamental requirements in industrial applications such as Factory Automation and Process Automation. These factors become especially critical when moving industrial buses to the wireless world, where communication becomes more vulnerable to interference, both intentional and unintentional, as well as to variations in the propagation conditions of the wireless channel. In these cases the communication system must be able to guarantee the operation of the application below a residual error level defined by the Safey Integrity Level (SIL). This requires the application of different mitigation techniques such as spatial, temporal and frequency diversity, the use of redundant links (Multi-Link and Multi-Access Point techniques), as well as directive wireless links and frequency hopping and spread spectrum techniques.

5. High mobility

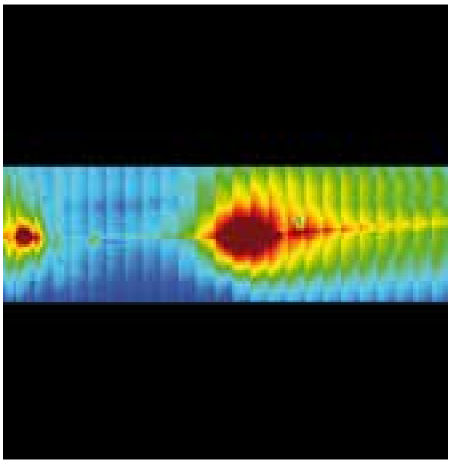
Another aspect of connectivity technologies that has undergone significant evolution in recent years is V2X ("Vehicle to Everything") vehicular communications. These technologies, which were initially based on WiFi technology in the IEEE 802.11p standard, have been incorporated by 3GPP in the roadmap for the development of 5G, proposing a standard based on LTE for V2X communications called C-V2X ("Cellular Vehicle to Everything"). In the first version of this standard, the basic mechanisms necessary to carry out vehicular communications were defined as V2V ("Vehicle to Vehicle") and V2I ("Vehicle to Infrastructure"), although it is in the latest versions (5G-V2X) where another series of mechanisms of greater impact have been included, with the aim of supporting the latency and/or reliability requirements that this type of communications require.

AI in the IoT can analyse data collected in real time to identify abnormal patterns. This can be done using machine learning and data mining techniques.



6. Data analytics

One of the areas where the technological development of communications is expected to grow the most is in the provision of Artificial Intelligence (AI) mechanisms in the field of IoT, and especially in Mobile Edge Computing (MEC). This makes it possible to execute real-time operations much closer to the source of the data, allowing decisions to be made and actions to be taken in very few milliseconds, as latency is reduced compared to working with intelligence only in the cloud and communications are optimised. This requires clear coordination between the devices on the edge and in the cloud, allowing dynamism to decide at any given moment where each of the actions should be executed. Machine Learning (ML) techniques are used in this area, where models are trained in the cloud with the vast amount of data produced by the devices, and then the trained models are deployed in nodes closer to the edge of the architecture to infer decision-making closer to where it is needed, reducing response time in critical systems.



Security and information protection are key challenges in today's communications, especially in the case of wireless communications, which are more vulnerable to attack than wired communications.

7. Security

Security and information protection are key challenges in today's communications, especially in the case of wireless communications, which are more vulnerable to attack than wired communications. The solution to this problem is to apply security enhancement techniques at all levels of the communications stack, from signal processing techniques at the physical layer to encryption techniques at higher levels. In addition, constant monitoring of these systems is required along with the implementation of ML-based methods to detect potential threats based on anomalous behaviour of the communications network.

2.4 Digital platforms

2.4.1 Introduction

A digital platform is the architecture on which the capture, storage, processing, analysis and visualisation of an ecosystem's data is deployed and is one of the main pillars for the digitisation of a company and the services it offers. These platforms enable the creation of new business models and interaction models with suppliers, customers and users that are more agile than traditional value chain networks. They also allow critical decisions to be made based on data.

There are currently a multitude of digital platforms focused on leisure, online shopping ("marketplace"), booking and sharing assets, etc. that have revolutionised the habits, culture and values of our modern society. In the social and industrial fields, platforms for capturing and managing data during the life cycle of a product, those focused on monitoring energy consumption and efficiency, those applied to production and logistics processes, platforms for health care and smart cities stand out. These platforms are often referred to as intelligent or smart.

Each platform is distinguished by a certain type of architecture and essential technical characteristics, which include:

1) The definition of the physical variables sensed and the type of data captured.
2) The type of sensors, connectors and communication protocols to capture and send data. Aspects related to embedded systems and connectivity.
3) The type of infrastructure on which data is received, stored, analysed and accessed either on local servers ('edge') or via the Internet ('cloud' or 'hybrid').
4) The software applications running on the platform, including Artificial Intelligence applications, and their typology (opensource, commercial software, proprietary software).
5) The deployment and scaling systems (orchestrators).
6) Data governance criteria.
7) Security and cybersecurity systems (encryption, authentication, blockchain).

These characteristics influence two concepts of vital importance for the implementation of digital platforms: scalability and flexibility. Thus, a single industrial digital platform can control several lines and different manufacturing processes (flexibility), and a single development can be implemented in SMEs with a "small" volume of data and in large companies with thousands of information nodes (scalability).

In terms of their evolution in industry, digital data platforms have evolved rapidly in recent years from isolated data silos on machines to interoperable servers and virtual data spaces ("datalakes") on which different operations based on multi-source data analytics can be performed. The latest evolution of industrial platforms is related to the rapid, continuous and high-quality deployment of applications and developments ("DevOps") and AI-based optimisation and prediction algorithms ("MLOps", "IAOps") on servers connected to multiple assets and machines.

According to the European Commission and as stated in its digital strategy, more than one million companies in Europe are currently using digital platforms to sell their products and offer advanced services, although the percentage of small and medium-sized enterprises that have integrated these solutions barely exceeds 50%.

On the other hand, the volume of data generated globally is growing exponentially, and it is estimated that from 33 zettabytes in 2018 it will reach 175 zettabytes by 2025. This presents a huge opportunity for businesses. In addition, the way they store and process data is going to change dramatically in the coming years. It is currently estimated that 80% of data processing and analysis is done in centralised computing and data centres and 20% in smart connected objects (vehicles, appliances, robots) and edge computing systems. In the coming years, it is very likely that these proportions will even out and may even be reversed.

On the other hand, it is estimated that more than 41.5 billion IoT devices will be connected and active by 2025, many of them in industrial sectors. Companies that are committed to managing the data generated by these devices on digital platforms will be able to offer new advanced services to automatically diagnose, anticipate and solve internal and customer needs and problems.

2.4.2 Positioning of the Basque Country

The EUSKADI 2030 PCTI identifies digital platforms as one of the basic digital technologies with the potential to contribute to the areas of smart specialisation and to the three transitions: technological-digital, energy-climate and social-health.

The technological-digital transition in the Basque Country seeks a transition towards organisations based on digitalisation and which can benefit from the use of Artificial Intelligence and Big Data technologies. In this sense, digital platforms will make it possible to put technology at the service of citizens and promote a fairer and more competitive digital economy. Other key technologies such as the Internet of Things, 5G technologies and cybersecurity are enabling the development of these digital platforms with the highest standards of connectivity, security and trust.

BRTA's centres are pioneers in the development of digital platforms for different applications including data capture, visualisation and analysis platforms in industrial environments, smart grids, smart utilities, smart logistics, healthcare and smart cities.

The technological-digital transition in the Basque Country seeks a transition towards organisations based on digitalisation and which can benefit from the use of Artificial Intelligence and Big Data technologies.

Many industrial companies already rely on these solutions for the management of their process and business data and for the definition of new advanced services with greater added value that allow monitoring the capture and analysis of this data. The use of these platforms and data-based decision making is generating significant advantages for companies both internally (cost reduction, process optimisation, etc.) and for their customers.

The list of digital platforms developed by BRTA centres includes:

- KONNEKT by IKERLAN for transport, energy and industry 4.0.
- Datanext (VICOMTECH). Platform for connectivity, processing, prediction and optimisation of industrial process data.
- VIXION360, an industrial data monitoring platform created by TECNALIA and the company Spyro, and operated by the Vixion NEBT created for this purpose.
- BikiTT, BikiTT-Ind, BikiForge by CEIT, Process and product control platform with integration of digital twins for conventional heat treatments, induction and forging.
- MainRail, initially developed by CEIT and Inycom, is commercially operated by MainRail S.L., for railway infrastructure maintenance management.
- SAM by TEKNIKER aimed at increasing the performance of the facilities, optimising operations and predictive maintenance.
- SAVVY INDUSTRIAL CLOUD by Savvy Data Systems aimed at the industrial manufacturing, machining and metalworking sectors. Developed by Savvy Data Systems, a company in which DANOBATGROUP and IDEKO, IPF, FAGOR Automation and FAGOR Arrasate hold shares.
- Intelliweld platform developed by LORTEK for welding and inspection processes, eMenhir Welding industrial platform developed in collaboration with the company HISPAVISTA and HyperCog hyperconnected platform with cognitive capabilities for flexible manufacturing and development of cyber-physical systems.

On the other hand, BRTA entities play a relevant role in research projects related to the development of new concepts for the design, deployment and validation of digital platforms and their functionalities based on data analysis and Artificial Intelligence for different applications and environments. Among others, projects in the European framework (InterQ, HYPERCOG, DAWN, X2RAIL, LINX4RAIL, Cloud LSVA) and strategic projects at Basque Country level (Elkartek Projects: DIGITAL, EGIA) stand out.

2.4.3 Technological Challenges / R&D Priorities

Related to technologies:

1) Efficient deployment and scaling.

It is strongly believed that, in a high-speed world, no single application creates a long-term competitive advantage; rather, it is the platforms with the ability to develop, deploy and scale AI-driven applications that will make the difference the fastest. The same is true in the industrial world. From our perspective, the digital factory needs an agile and efficient software platform for application lifecycle management that includes development, testing, deployment and operations monitoring. To improve agility around application development, low-code capabilities, microservices architectures and container technology form the most relevant technical foundation.

The integration of Artificial Intelligence in digital platforms will provide an important competitive advantage and enable the development of new services with higher added value.

In fact, for efficient deployment, scaling and maintenance of industrial platforms, the use of virtual containers that package code, configuration files, libraries and application elements to run is recommended. The use of these virtual containers and containerisation and orchestration tools such as Docker, Kubernetes or Openshift presents a series of advantages such as the deployment of applications and portability to different environments, accelerating the development and deployment of new versions of applications or the reduction of computational resources.

Virtual containers are virtualisation systems capable of running separate parts of an application with a single guest operating system. Virtual containers are much lighter and more efficient than virtual machines or VMs that have their own operating system, CPU, memory, network interface and storage.

The main advantage of using containers is that it facilitates compatibility and facilitates the development and deployment of applications within the DevOps philosophy that promotes more efficient development of applications in less time and the rapid release of new features or revised versions of software to customers. This philosophy requires extensive version control, change tracking and coordination between developers, as well as the use of tools for building, testing and continuous software integration. Tools such as Git and Jenkins are common solutions to these challenges.

2) Secure and reliable architectures (edge-fog-cloud architectures)

Before cloud computing emerged, data processing only happened at the edge of the machine. It was a disconnected world. PLCs (programmable logic controllers) and IPCs (industrial PCs) are classic examples of sensor data processing directly at the machine edge. In these cases, software updates are usually performed manually on-premise.

Bringing cloud computing to the industrial world marked the beginning of the IIoT concept. This concept made it possible to move data processing and application lifecycle management to public cloud infrastructures. This stage essentially represents the birth of the 'industrial IoT'. With this step in the evolution, hyperscalers such as Microsoft, Amazon AWS, SAP, Adamos, Siemens Mindsphere, Forcam, Aveva, etc. emerged with offerings in the industrial domain. The great advantage of this concept is the fact that a holistic data lake can be established in the cloud, which provides transparency in production processes in multi-factory environments and enables the application of analytical capabilities for process optimisation.

There is currently a move towards a platform-centric IIoT at the edge, the Edge, of the machine. Container technology is leveraged to introduce new solutions in which application lifecycle management is moved to the cloud, while data processing remains on the machine. Examples in this context are the Siemens Industrial Edge, Phoenix Contact PLCNext, Bosch Rexroth CtrlX, Litmus, Savvy Edge, Beckhoff. This step has given rise to the beginning of the machine-centric IIoT concept.

The option of developing factory-centric edge platforms, also known as Factory Fog or Factory Edge, is a growing trend, starting in sectors with a high degree of protectionism (aeronautics and space) but which is expanding to other sectors. It is about consolidating IT infrastructure within the factory. It provides several advantages for customers, such as the ability to have more storage and computing capacity, the security of perimeter information control and the reduction of IT infrastructure costs through consolidation. Solutions range from proprietary solutions such as Siemens MindSphere On-premise, Savvy Fog, etc., to customised solutions such as Canonical, Edgeworx, Red Hat, VMware, Cloudera, etc. based on external providers.

3) AI integration

As mentioned above, the integration of Artificial Intelligence in digital platforms will provide an important competitive advantage and enable the development of new services with higher added value. Therefore, a challenge and a research and development priority is related to the efficient integration and deployment of Artificial Intelligence applications in digital platforms. In this sense, and based on the DevOps philosophy, IAOps, MLOps, model serving and monitoring, intelligent redeployment methodologies have been developed that include strategies for the supervised or automatic deployment of ML and DL models, the traceability of the data set or datasets, access to data from trained models or the comparison between prediction models, among others.

The fact that digital platforms have these features and that the integration and deployment of AI applications are designed based on these methodologies is essential to ensure their competitive advantage. BRTA centres have extensive experience in implementing these methodologies in different ecosystems.

4) Platforms for Big Data

The concept of big data refers to very large and complex data sets that require non-traditional processing software applications to manage them properly. Due to their volume and complexity, more sophisticated procedures and software are required to analyse and extract knowledge in the form of patterns, correlations, etc.

The challenge associated with managing large volumes of data includes ingesting and storing data, sizing systems, performing searches, sharing and analysis, real-time and delayed visualisation and interpretation. The need to handle large volumes of data is due to the generation of statistical reports and predictive models in very complex systems with many variables or degrees of freedom with non-linear relationships.

There are currently tools and applications specifically designed to work with large volumes of data, such as Hadoop (Big Data management), Spark ("streaming big data") or Hive (database).

5) 5G compatibility

This challenge is related to the connectivity pillar, where 5G and WiFi standards have been designed to respond to the ever-increasing volumes of data transmission. The fact that digital platforms are compatible with 5G networks and wireless communication systems with this protocol ensures that a high volume of data can be captured more efficiently and from a larger number of sensors and data acquisition systems. In such environments, this compatibility can make all the difference.

Data sharing is a fundamental enabler for competitive Artificial Intelligence (AI) solutions. An ecosystem of data platforms should support continuous and coordinated data flows, moving data seamlessly between intelligent systems.

6) Governance and data space

A data space is any ecosystem of data models, datasets, ontologies, data exchange contracts and specialised management services, together with software competencies around them. These competencies follow a data engineering approach to optimise data storage and sharing mechanisms, preserving, generating and sharing new knowledge.

Data sharing is a fundamental enabler for competitive Artificial Intelligence (AI) solutions. An ecosystem of data platforms should support continuous and coordinated data flows, moving data seamlessly between intelligent systems. Two conceptual solutions that introduce new approaches to address this particular need to regulate closed personal and proprietary data are Industrial Data Spaces (IDS) and Personal Data Spaces (PDS).

The IDS conceptual solution is oriented towards industrial proprietary data. Its realisation must guarantee a secure and reliable environment where participants can monetise and exchange their data assets securely and legally within a clear legal framework. A functional realisation of IDS connectors promises to significantly reduce the existing barriers for a free flow of data within an advanced data economy.

The concept of Personal Data Spaces (PDS) is seen as a valuable alternative to give individuals granular control over what data is captured about them and how this data is shared and used, but also as a means for organisations to more easily develop data-driven services. Companies currently bringing to market applications that support decentralised storage of personal information include OpenPDS and Solid.

2.5 Interaction Technologies

2.5.1 Introduction

The ability of digital systems to communicate and interact with people is a fundamental aspect for the development of valuable services in virtually all fields of application. The understanding of what is happening in the digital domain, the ability to control and convey the desired goals, encounters 2 main types of challenges in establishing a “natural” relationship between machines and people. The first type of barrier has to do with the communication channel (visual, speech, haptics). The second has to do with the more cognitive part of the interaction (what kind of visual representation is established and what it means, understanding and generation of natural language, etc.).

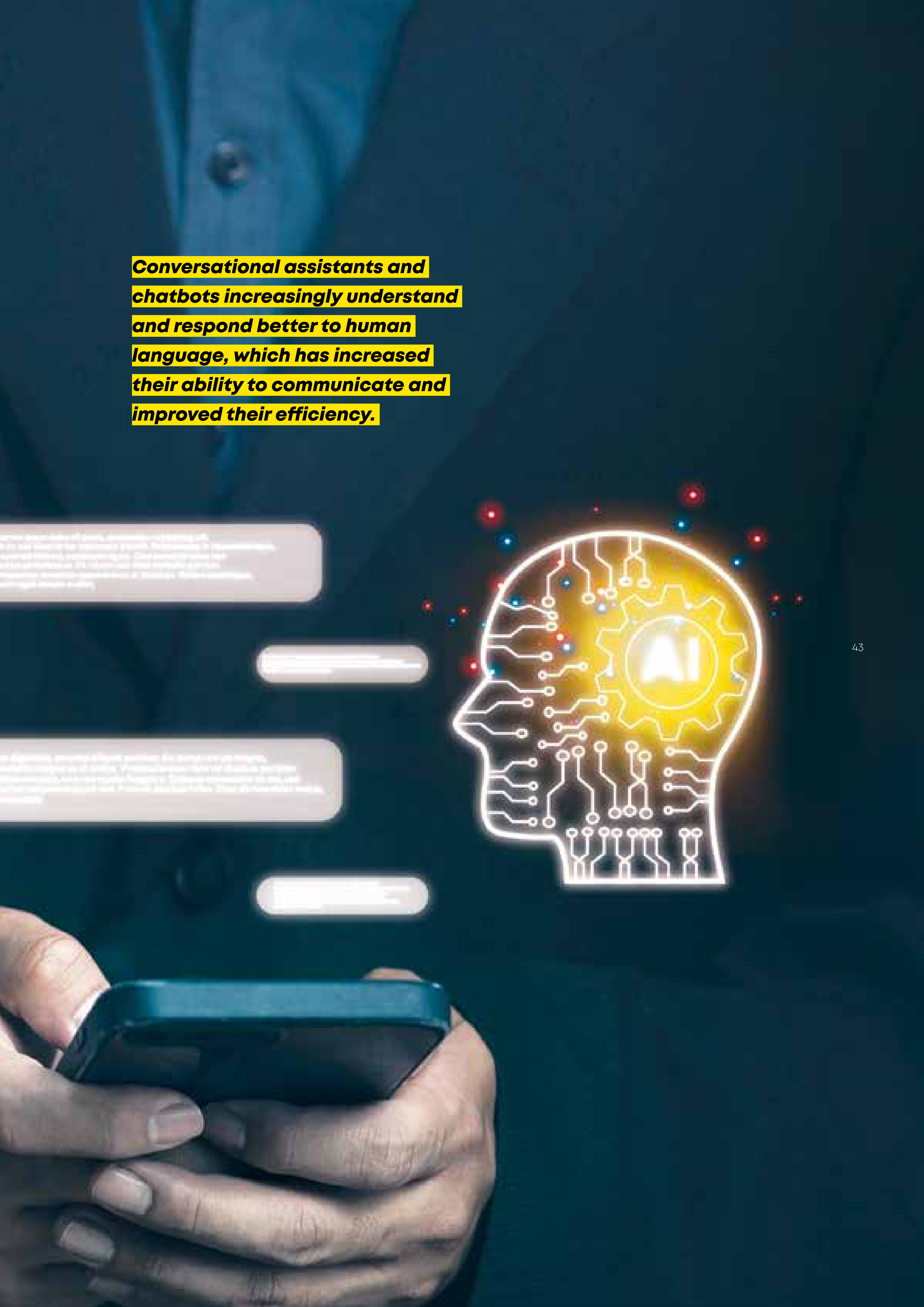
• eXtended Reality

Extended Reality (XR or eXtended Reality) is a term that refers to a range of technologies that allow people to experience and interact with digitally generated environments in a way that feels real. The current state of the art has come a long way in the generation and representation of virtual environments (VR, Virtual Reality or Virtual Reality) that nowadays have a strong industry in the field of immersive video games and even in the educational/training field.

• Speech and natural language technologies

Thanks to new neural architectures, together with the existence of large amounts of data and the availability of hardware infrastructure to process them, speech and natural language technologies have experienced an enormous advance in recent years.

Conversational assistants and chatbots increasingly understand and respond better to human language, which has increased their ability to communicate and improved their efficiency.



DIGITAL TECHNOLOGIES

02

TECHNOLOGICAL PILLARS

Current generic speech recognition systems perform similarly to humans in clean read speech, but still have room for improvement in noisy contexts or when speaking more spontaneously and require adaptation in domains with more specialised vocabularies and language.

Technology players in this field are competing to see who gets the best results for various applications: speech recognition and synthesis, classification and extraction of information from texts, automatic generation of texts and their summaries, automatic translation of both texts and speech-to-speech, or voice and/or natural language interaction systems, also known as conversational assistants and chatbots. The latter increasingly understand and respond better to human language, which has increased their communication capacity and improved their efficiency.

Conversational assistants include speech recognition, speech synthesis, understanding and natural language generation components.

• Speech recognition

Speech recognition technology has evolved from supervised systems based on component pipelines to end-to-end neural architectures that simplify training, tuning and inference. Pre-trained acoustic models have also emerged with unsupervised learning methods and a large amount of unlabeled data such as Wav2Vec2.0, HuBERT or the Conformers, which when tuned to the task outperform many benchmark results especially for languages and data-poor tasks. Recently, Whisper, a supervised model trained on 680,000 hours of audio in multiple languages capable of performing various speech processing tasks such as recognition, language identification, speech activity detection and translation, has been published.

Current generic speech recognition systems perform similarly to humans in clean read speech, but still have room for improvement in noisy

contexts or when speaking more spontaneously and require adaptation in domains with more specialised vocabularies and language (e.g. industrial manufacturing, health, energy, justice, etc.).

• Speech synthesis

Recent years have also seen the development of a wide range of neural architectures for speech synthesis, greatly increasing the quality and naturalness of today's synthetic voices. Generative neural systems such as Tacotron, which generate intermediate representations called spectrograms and use vocoders such as Griffin-Lim or WaveNet to transform these representations into waveforms, have become the standard. There are also end-to-end architectures such as DeepVoice or FastSpeech that allow waveforms to be generated directly from text.

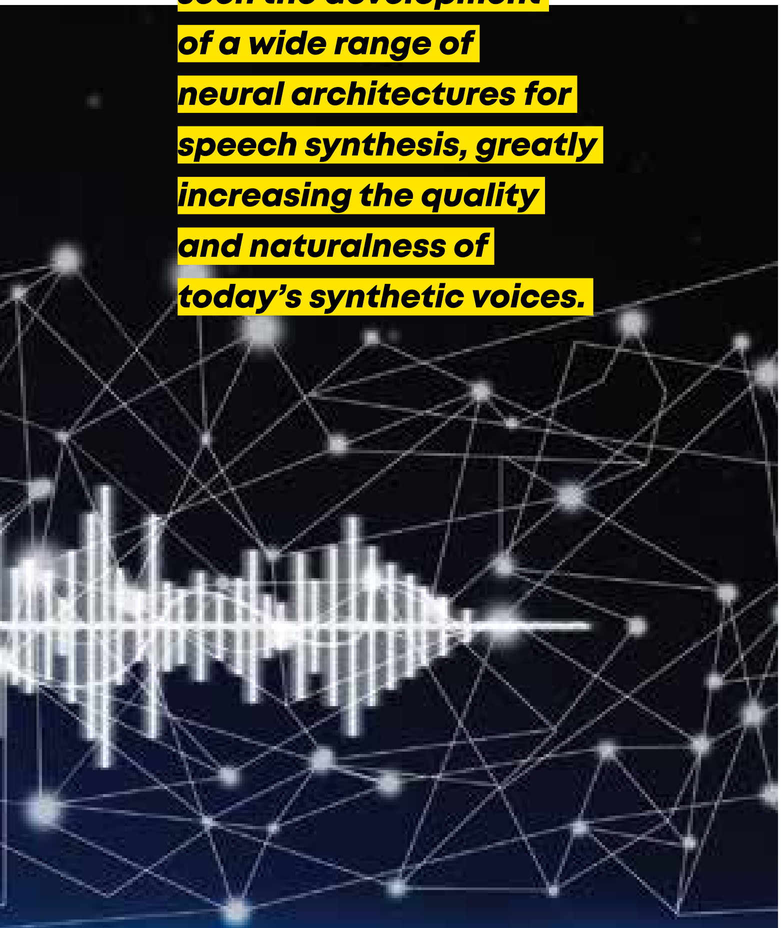
In addition, it is now possible to customise existing synthetic voices by using audio recordings to clone one's own voice.

• Natural language understanding and generation

Pre-trained language models and transfer learning have revolutionised natural language processing and pushed the boundaries of automatic language understanding and generation. These models exploit the large amount of available textual data (e.g. Wikipedia dumps, news compilations and web crawls) and Transformer-like neural architectures, to train models in an unsupervised way that are then tuned to specific language processing tasks in a supervised way with smaller sets of annotated data. Some well-known examples include BART, GPT-3, GPT-4, PALM, BLOOM, Megatron Turing NLG or Wu Dao 2.0.

In the field of human-machine interaction, two fundamental tasks for natural language understanding are intention detection and entity recognition, which allow the user's goal to be identified and the most relevant information to be extracted from the conversation. In addition, question-answer systems have also

Recent years have also seen the development of a wide range of neural architectures for speech synthesis, greatly increasing the quality and naturalness of today's synthetic voices.



been shown to be able to match user questions with answers from collections of natural language documents. Pre-trained, task-tuned language models perform well for the specific application domain for which they are developed, but are still far from the general, flexible and robust language understanding capabilities of humans.

For natural language generation, text-to-text systems are able to take existing texts as input and automatically produce new, coherent texts as output, in applications such as automatic summary generation, machine translation or dialogical interaction with users.

For machine translation in particular, Transformer architectures have achieved increasingly accurate results that are sensitive to the subtleties and ambiguities of human language, where minority languages such as Basque also now have high-quality neural machine translators.

At the conversational level, several pre-trained language models have recently been adjusted to generate responses to open user dialogues, giving rise to revolutionary systems such as LAMDA or ChatGPT. Despite this remarkable progress, challenges remain, as the responses of such conversational models are not yet able to maintain coherence across multiple conversational turns, return empathic responses or understand figurative language well, among other limitations.

At the same time, there is controversy in the scientific community regarding the size of increasingly large pre-trained language models. Many experts believe that obtaining state-of-the-art results simply by using more data and computational power is not research news and, moreover, their scaling requires large computational resources that increase their energy consumption, harming the environment. Progress in this area should prioritise the discovery of ingenious ways to make models lighter without sacrificing high performance. Finally, it is worth noting that many languages have few digital resources to develop such models compared to English, resulting in lower performance. It is expected that technology will be developed in the coming years to mitigate this challenge.

• Multi-sensory interaction

Multi-sensory interaction is a central element of the XR extended reality concept, which goes beyond volumetric video and spatial audio representation to include interaction through other senses, such as tactile (haptic), smell or taste. The concept of "tactile internet" was introduced in 2014 and is still being developed today.

The sense that currently accompanies visual and sound the most is haptic, where there are already solutions that include hardware and software for rich interaction for various domains. However, the fidelity and quality of the technology remains a major challenge and relies on proprietary hardware and development kits.

User interfaces must provide large amounts of information from different sources that must be coordinated and synchronised.

- **Orchestration of immersive interactive experiences**

User interfaces must provide large amounts of information from different sources that must be coordinated and synchronised. In addition, the existence of multiple types of communication networks and requirements for creating collaborative environments - where multiple users collaborate simultaneously - introduce strong challenges in the management and orchestration of data flows.

The concept of orchestration emerged in 1992 as the need to coordinate multiple streams of multimedia content in order to present them in a coherent manner. With the advent of the concept of object-based media, what began as a challenge of synchronising multiple data sources for representation has extended to adapting and making representation responsive through the optimisation of the communications network.

The trend towards virtualisation of networks is one of the main technological challenges in designing the best topologies and configurations to ensure quality of service (QoS) and quality of experience (QoE) of interfaces.

The major challenges in the orchestration of immersive interactive experiences are:

1. Synchronisation of multimedia objects. This is a very relevant challenge, where the interoperability of the Web is providing increasingly mature solutions.
2. The adaptation and "responsive" presentation of immersive interactive experiences. Just as the Web offers HTML5 tools for adapting interfaces using CSS Media Queries, it is a challenge to extend this adaptability to new immersive devices (VR cases, AR glasses, or

an environment of multiple devices and users interacting at the same time) in order to achieve an effective visualisation of information.

3. Generation of efficient flows. To coordinate the distribution and all multimedia objects across a heterogeneous network, the challenge of creating a flexible, dynamic and adaptable network architecture is very relevant, being able to distribute the computation to processors (CPUs and GPUs) throughout the network.
4. Machine-machine interfaces, the transmission of media data (images, signals, etc.) for processing e.g. by AI models also present similar QoS requirements that remain a clear technological challenge today.

2.5.2 Positioning in the Basque Country

The Basque industrial fabric has companies from the ICT world (represented by the Gaia cluster) with capabilities in the different aspects related to interaction technologies. From the language perspective, there is a strong activity related to the Basque language with agents such as Ixa Taldea or Elhuyar. There are also companies with a good position in the development of virtual reality services for both industry and education, where there is also the presence of DigiPen, which offers a University Degree in Computer Engineering in Real-Time Interactive Simulation. Companies such as Virtualware and Innovae also stand out.

As industry is one of the main sectors of activity in the Basque Country, it is important to mention the alignment of Basque companies with international trends related to the Industry 4.0 concept, where concepts such as “virtual commissioning” or the use of virtual environments for training tasks, maintenance, etc. are gradually being put into practice. In this field we can mention companies such as Ingemat or Lander Simulation.

From BRTA, centres such as CEIT, IKERLAN, TECNALIA, TEKNIKER and VICOMTECH have groups specialised in R&D&I and solutions related to interaction technologies.

1. **BRTA entities drive basic research initiatives** in natural language processing, with a special focus on the promotion of Basque. In addition, they lead and participate in different national and international projects related to both language technologies and other forms of interaction (extended reality, visual analytics, interactive and multi-device distribution of digital content, etc.), including projects such as Rescuer, Arete, Simfal, etc.Singular Initiatives/ Projects (Elkartek)

. ADAPT-IA: Towards Adaptive AI in Language Technologies applied to RIS3 industrial sectors.

. Advanced technologies for learning (IKASI) by demonstration in smart production environments.

2. Significant European projects:

. Rescuer (primer conjunto de herramientas de RESponder-Centered Support para operar en entornos adversos y sin infraestructuras). https://rescuerproject.eu/

. Infinito . INTERACT. INVESTIGAR: https://h2020-infinity.eu/

. Sistema educativo interactivo de realidad aumentada Arete: https://www.areteproject.eu/

. Traction: Opera co-creación para una transformación social https://www.traction-project.eu/ resources/ .

. SIMFAL (2017-2020). “Planificación del montaje y simulación de una línea de montaje final (FAL) de aeronaves” (H2020-UE.3.4.5.1, GA 737881). Desarrollo de herramientas de test basados en Realidad Virtual para planificar y evaluar diferentes alternativas de ensamblaje en aeronáutica.

. ASSASSINN (2020-2022). “Desarrollo de una célula multifuncional de ensamblaje de aeroestructuras complejas, asistido por red neuronal” (H2020 CleanSky, GA 886977). Desarrollo de una célula de ensamblaje multifuncional para aeronáutica mediante tecnologías de redes neuronales, robótica colaborativa y Realidad Aumentada y Mixta.

3. Significant national projects:

- New injection moulded products with touch-enabled surfaces - Touchsensor (AEI - 2022)

2.5.3 Technological Challenges / R&D Priorities

The main technological challenges of interaction technologies can be classified as follows:

• Language technologies

Speech technologies are constantly evolving and improving in quality. In this sense, speech recognition systems still have limitations mainly related to spontaneous speech and noisy environments or those requiring separation of background signals (music, etc.). Improving the robustness of such systems is still a technological challenge where case-specific approaches (channel modelling, etc.) must be combined with generalist approaches that are able to improve transcription rates in less controlled and a priori unknown situations. On the other hand, speech synthesis systems already have high quality timbres and prosodies where the next big challenge is to make the generative neural networks already being used in audio generation more expressive. At the same time, large language models have undergone a major revolution thanks to the combination of huge amounts of data, new neural architectures and major advances in processing and computational power.

In the case of virtual reality technologies, 3D rendering and processing capabilities in general already allow access to high quality virtual experiences that can be interactive.

In addition, translation systems benefit greatly from new technological approaches based on Transformers. The adaptation of these models to minority languages such as Basque requires the creation of quality corpora in which the great challenge consists precisely in generalising models comparable to other widely-used languages. The technological adaptation of large language models for both niche applications and minority languages is also a major challenge, especially in terms of comprehension.

Despite these advances, neural speech synthesis systems still fail with single letters, misspellings, numbers, long sentences, etc. leading to inconsistent quality depending on the input. And most generated voices tend to be monotonous and flat, unless a dataset is available that includes a variety of emotional expressions and multiple speakers. In relation to voice cloning, the next challenge is to provide systems capable of detecting possible associated fraud.

On the other hand, natural language generation has undergone an enormous improvement and has recently been successfully applied to the automatic generation of responses to open user dialogues.

• eXtended Reality (XR) technologies

In the case of virtual reality technologies, 3D rendering and processing capabilities in general already allow access to high quality virtual experiences that can be interactive, i.e. react in real time. However, the costs of creating such environments still present serious limitations, as they still require large amounts of manual work in modelling, attribute definition, physical simulations, semantic and interaction properties of objects, etc.

XR's main challenges can be summarised as follows:

1. Hardware: One of the biggest challenges with XR technologies is the need for specialised hardware, such as VR headsets and Augmented Reality (AR) glasses. These devices can be expensive and bulky, and can lead to problems with ergonomics, motion sickness, etc.
2. User experience: Another challenge with XR technologies is creating a smooth and intuitive user experience. These technologies are still relatively new and it can be difficult to design systems that are easy to use and understand. At present, it does not seem feasible for a worker to spend an 8-hour working day using a VR or AR headset.
3. Content creation: Creating high quality content for XR technologies can be challenging, especially in those aspects related to the merging of the real and virtual world, as this requires a precise understanding of the real scene into which virtual elements are to be introduced.
4. Latency: Latency, or the delay between user action and system response, is a major challenge in XR technologies. However, VR or AR headsets have limited computational capacity, requiring hybrid computing between the device itself and network elements (edge, MEC, Cloud). Therefore, achieving lower latencies is key to maintaining a consistent XR experience.

Digitalisation has in many cases been adopted without regard for security, which is precisely why many companies have suffered attacks and extortion that were unthinkable only a couple of decades ago.

5. Interoperability: XR technologies are still under development and there is not yet a standardised approach to creating and sharing content across different platforms and devices. Generally, an XR experience is developed and conceived for a particular hardware: mobile devices, a VR case, AR glasses. The interoperability to define an experience, and for it to adapt to any user context, is still something that technology does not easily solve. Furthermore, although there are initiatives and web standards to promote interoperability, such as WebXR or OpenXR, proprietary development environments, such as Unreal or Unity, are still popular.

2.6 Cybersecurity

2.6.1 Introduction

Digitalisation is one of today's most global phenomena. All economic sectors are becoming digitised without exception. Strategic sectors such as manufacturing, energy or healthcare have substantially improved their processes and performance in recent years thanks to digitisation. Thus, movements such as Industry 4.0 or the deployment of the smart grid have made it possible to create a much more optimised and sustainable industry.

Interoperability, access to data and automation are direct consequences of digitalisation that have marked a clear change of trend in many sectors. However, digitisation has in many cases been adopted without security in mind, and precisely because of this many companies have suffered attacks and extortion that were unthinkable only a couple of decades ago.

Digitalisation entails a global responsibility for the entire supply chain. The level of digitisation and interdependence present in today's major economic sectors requires global commitment and actions for the coordination and proper management of the security of digital systems.

This is why cybersecurity is increasingly critical to ensure business continuity, but also to guarantee the economic and environmental sustainability of our environment. Without adequate protection measures for our infrastructures, as well as for the products and services offered by the companies in our fabric, our sustainability will be at risk, and our business fabric will suffer continuous attacks that in some cases will have serious economic and environmental consequences.

2.6.2 Positioning of the Basque Country

The Basque Country has a long history in the field of cybersecurity with emblematic companies such as PANDA and S212SEC that originated here. Since then, this field has continued to grow with new companies and startups such as ORBIK and significant institutional support that has led international companies such as WATCHGUARD to decide to bring one of their cybersecurity R&D centres to the Basque Country in 2023. It can be said that the Basque Country aspires to become a relevant Industrial Cybersecurity hub at international level, driven by Cyberzaintza as a public entity, Cybasque as part of the private initiative and the Basque Network of Science, Technology and Innovation doing R&D&I in Industrial Cybersecurity.

Cyberzaintza, the Basque Cybersecurity Agency, is a public body created to combat, in a comprehensive and transversal manner, the threats derived from the use of the Internet and new technologies in the Basque Country. Its aim is to position the Basque Country as a benchmark in cybersecurity in a digital Europe, to contribute to breaking the technological dependence on other economies and to promote STEAM training for the next generations to ensure the generational change in the Basque digital sector.

CYBASQUE is the Basque Cybersecurity Cluster, representing a private and independent association, whose objective is the technical, commercial and economic promotion of the Cybersecurity industries it represents, thereby contributing to the development and progress of the Basque Country. CYBASQUE is an approved entity for the issuing of the Cybersecurity Made in Europe certificate promoted by ECSO. As members of the Basque Science, Technology and Innovation Network, BCAM, IKERLAN, TECNALIA and VICOMTECH are the technology centres that form part of the Cyberzaintza Standing Committee.

Some of the most representative cybersecurity projects of BRTA members are:

- **SPARTA** (Strategic programs for advanced research and technology in Europe), Horizon 2020 2019-2022, European network of centres of excellence in cybersecurity for the development of the strategic agenda, technological capabilities and demonstration cases for European R&D in cybersecurity.
- **SEKUTEK** (Sekurtasun Teknologiak), Elkartek 2017-2018, which marks the start of the coordination of research activity in industrial cybersecurity in the RVCTI, with a focus on technologies for protecting the ICT (Electronics, Information and Communication Technologies) chain from the sensor to the cloud.
- **CYBERPREST** (Cybersegurtasunerako gaitasun osoa), Elkartek 2018-2019, which broadens the focus, boosting the generation of knowledge in all the activities necessary to achieve a comprehensive cybersecurity framework.
- **SENDAI** (SEgurtasun integrala iNDustria AdImentsurako), Elkartek 2019-2020, focuses more on improving the resilience of Basque Industry in the face of cyber-attacks.

CYBASQUE's mission is to promote cybersecurity in all private areas of the territory, promoting collaboration with other sectors and fostering the development of new products/services, technologies and markets.

- **TRUSTIND** (Creating Trust in the Industrial Digital Transformation), Elkartek 2020-2021 focused on technologies that enable Security and Privacy to be reinforced from design and by default, throughout the supply chain, in an assessable and verifiable manner.
- **REMEDY** (REal tiME control and embeddeD securitY), Elkartek 2021-2022, focused on the generation of tools that enable the management of industrial equipment from the point of view of Cybersecurity.
- **TITANIUM** Tools for the Investigation of Transactions in Underground Markets. Methods and Solutions for the Investigation and Mitigation of Illicit Activities in Transactional Resources.
- **ATLANTIS**: Improved resilience of Critical Infratsructures AgainsT LArge scale transNational and sysTemic rISks. European research and development project for the protection and resilience of critical infrastructures against intentional incidents and attacks.
- **BEACON** (Cybersecure Industry Computing Continuum), Elkartek 2023-2024, which focuses on the field of industrial cybersecurity through the application of the Secure Computing Continuum.

Other European Cybersecurity projects in which BRTA participates: MEDINA, ASGARD, NOTIONES, AI4CYBER, DYNABIC, KINAITICS, IDUNN.

Other national cybersecurity projects in which BRTA participates: SLISE, SEGRES, NCIS, EGIDA.

The incursion of new technologies to protect continually presents new cyber security challenges and requires constant investment.

2.6.3 Technology Challenges / R&D Priorities

Cybersecurity is a continually evolving discipline, a long-distance race in which the industry tries to incorporate tactics, techniques and procedures to protect our industry's products, services and infrastructures. However, the continuous evolution of attack methods, as well as the incursion of new technologies to protect, continually present new cybersecurity challenges and require ongoing investment. The following highlights the main cybersecurity challenges and R&D priorities for the coming years.

1. **IoT/Edge/Cloud Security ("Secure Computing Continuum")**

Today's digital systems are spread across IoT, Edge, Cloud and Data Spaces in complex ecosystems where security and privacy must be provided at all levels and throughout the entire lifecycle.

The adoption of IoT technologies comes with a number of cybersecurity challenges. This is especially critical in industrial systems (IIoT), medical devices (robots, implants), or even vehicles. In any of these examples, it is easy to see the social and economic impact that an attacker can have. IoT devices are **in many cases designed without taking into account protection and monitoring measures, especially industrial legacy** equipment that will still be operating for many years to come in our industry and energy system. In other cases, despite having protection measures in place, these are insufficient or cannot be fully activated due to potential incompatibilities with other infrastructure equipment. This is why these systems will require **new monitoring techniques** that, thanks to the use of Artificial Intelligence, detect any type of anomaly and intrusion, **and even act by applying infrastructure protection measures following** the SOAR ("Security orchestration, automation, and response") philosophy.

The advent of **5G and edge computing** present new challenges in terms of cybersecurity that will need to be addressed in the coming years in order to properly protect edge computing and the numerous use cases that the advent of 5G will make possible thanks to its characteristics.

Finally, the growing trend towards **virtualisation of industrial equipment** will require new techniques for protecting this virtual equipment, as well as monitoring and controlling its behaviour, ensuring that this virtual equipment does not interfere with other virtualised systems on the same device.

2. Information security

The value of data is increasing, both at industrial, business and personal level, and even more so with the rise of Artificial Intelligence, whose main driver is precisely data. It is not possible to train Artificial Intelligence models without a good dataset, however, AI experts do not have at their disposal the necessary dataset to be able to go further with AI techniques, or to be able to continue improving systems. Initiatives such as IDSA, Gaia-X and similar initiatives aim to enable the **secure exchange of data** and the data economy to break down the barriers that currently exist. However, to make data exchange and data sovereignty a reality, a major effort will have to be made over the next few years in terms of reference architectures, advanced cryptography for secure computing, governance and data management policies, etc.

It is worth highlighting the need to develop techniques and procedures to **avoid data poisoning attacks** used to train AI models by mislabelling data or creating confusing data that can even be used as a backdoor trigger in the model.

In the case of sensitive data linked to individuals, e.g. health and social data, **new zero-trust solutions** for accessing and processing sensitive data need to be investigated. Cryptography and secure computing are two of the main answers to this need.

3. Secure SW and HW development

Initiatives such as the Cyber Resillence Act set the guidelines for how digital systems should evolve in the field of cybersecurity in the coming years. Such regulations, in parallel with standards such as IEC 62443, will help to raise awareness and encourage the introduction of **cybersecurity throughout the development cycle of digital systems and products**. It is expected that new challenges will arise, and that research and innovation will facilitate compliance with cybersecurity norms, standards and regulations in an agile manner and without a substantial increase in the cost of developing and maintaining this type of asset.

The use and evolution of **HW security technologies** such as TPM ('Trusted Platform Module') or TEE ('Trusted Execution Environment') will allow the incorporation of HW cybersecurity technologies in products, thus offering a higher level of security and reliability. Some specific challenges in this section would be:

- Security of connected vehicles and robots: Although **autonomous and connected vehicles**, as well as industrial and medical robotics, are often considered as IoT devices, their particular characteristics and protocols will require specific research for this type of equipment, as well as benefiting from advances in general IoT protection and monitoring technologies.
- Special attention should also be paid to **supply chains**, developing new techniques and procedures to detect supply chain attacks that compromise the final product or system.

4. Privacy and Identity Technologies

The development of Big Data and Artificial Intelligence offer new opportunities and also new challenges linked to privacy and how to preserve it properly in these new contexts. How to manage the identity of people and machines, their privacy at the appropriate levels while allowing the necessary analytics on them remains a challenge, as technologies such as homomorphic encryption, Secure Multiparty Computation and others can solve these challenges, but progress is needed in their application to real-world and industrial scenarios.

DIGITAL TECHNOLOGIES

02 TECHNOLOGICAL PILLARS

There is still some way to go to facilitate the migration of existing cryptographic systems towards quantum-resistant cryptographic systems.

5. Transition to post-quantum cryptography

With the advent of quantum computers, current cryptography may be compromised and although recommendations already exist to address them, there is still some way to go to facilitate the migration of current cryptographic systems to quantum-resistant cryptographic systems. Promising technologies to address this challenge include lattice-based cryptography, code-based cryptography, hash-based cryptography, multivariate equation system-based cryptography and isogeny-based cryptography.

Section 3 discusses some new emerging mechanisms for secure cryptographic key exchange based on quantum technologies, such as quantum entanglement, which is under investigation.

2.7 Software Engineering

2.7.1 Introduction

Software engineering of the future will be a **technical conversation between people** and machines rather than a manual iterative process of specifications and code. Multidisciplinary teams of domain engineers (aeronautical engineers, industrial engineers, etc.), users (pilots, operators, etc.) and software engineers will jointly design the next product/system (aircraft, robot, etc.) by presenting ideas that they turn into feasible designs based on existing knowledge in the organisations and the physical constraints of the solution if any. The designs are shown in real time and the multidisciplinary team compares different options using real-time simulations based on the option that best balances cost, capabilities, safety and time.

Future software development will become an **expression of capabilities** rather than a programming or layout of algorithms. Software engineers will have to become adept at expressing intentions in a way that allows computers to **learn from experience**. Elegant software will no longer be about well-implemented programming, but will be the result of **people working with automated systems and Artificial Intelligence** to implement the best ideas that teams can imagine in the most timely, affordable, ethical and secure way.

Conversations with computers will take place in the language of the domain; for example, with doctors developing software capabilities by talking about sequencing and genetic, protein or metabolic biomarkers, not by learning Java, Python or C#.

The use of simulation can turn the entire **current verification and validation process into an immersive experience** so that a new configuration of a complex system can be viewed from any point of view and not just a visual range, allowing engineers to make changes immediately and analyse their impact on the spatial environment with all available data and metadata.

Finally, **compliance with quality standards** will also be ensured from design as part of sophisticated software development frameworks that are implemented by expert engineers, but remain hidden from programmers who do not need to worry about these aspects of design. There will be no need to understand the ripple effects caused by changes in increasingly complex systems. Problems will be identified and corrected before implementation. Ensuring that proposed changes do not break the system will be done automatically by analysing the effects that a change could have on the assurance and evolution of a system.

Conversations with computers will take place in the language of the domain; for example, with doctors developing software capabilities by talking about sequencing and genetic, protein or metabolic biomarkers, not by learning Java, Python or C#.

2.7.2 Positioning of the Basque Country

Advances in artificial intelligence, computer vision and machine learning are driving the development of increasingly sophisticated and accurate systems for monitoring vehicle interior and driver status.

Some of the BRTA centres are also involved in cutting-edge research projects related to the software engineering of Artificial Intelligence systems, to the application of AI and other digital technologies to software development, and to continuous quality assurance. Some of the most representative projects in this field are:

- **ULTIMATE** (mUlti-Level Trustworthiness to IMprove the Adoption of hybrid artificial intelligence), Horizon Europe 2022-2025.
- **TRUSTIND** (Creating Trust in the Industrial Digital Transformation), Elkartek 2020-2022.
- **SIIRSE** (Smart, Robust, Secure and Ethical Industrial Systems for Industry 5.0: Advanced Specification, Design, Evaluation and Monitoring Paradigms), Elkartek 2022-2023.
- **SOLSTICIA** (Construction of Cybersecure and Intelligent Software Systems by Design based on AI), CDTI Missions 2021-2024.
- **PARAVASIS** (New paradigm for personalised and advanced design of industrial systems of the future), CDTI Missions 2022-2025.

In addition, some of the BRTA centres are involved in cutting-edge research projects related to the software engineering of Artificial Intelligence systems, to the application of AI and other digital technologies to software development, and to continuous quality assurance.

2.7.3 Technology Challenges / R&D Priorities

The technological areas of research for the coming years are as follows:

1. **Artificial Intelligence Engineering**

Software systems incorporating AI (non-deterministic) and non-AI (deterministic) components have different characteristics from those without AI. This research area focuses on exploring what existing software engineering practices can reliably support the development of AI systems, as well as identifying and augmenting software engineering techniques for the specification, design, architecture, analysis, implementation and maintenance of systems with AI components. Within AI engineering, **robustness** and **security**, **scalability** and **ethical human-centred design** are specific lines of work to address this technological challenge.

Some specific lines of research within Artificial Intelligence Engineering are:

- Quality attributes and architectures of IA systems such as explainability, data centricity, verifiability, monitoring and fault tolerance, as well as cross-cutting ethical aspects.
- Techniques for analysing and managing change in ML systems due to cross-dependencies that are difficult to track in the face of changes in certain parts of the code.
- Testing, deployment and maintenance of IA systems. Data science, software engineering and operations are different perspectives to be considered in the development and deployment of AI systems. Improved automation to identify inconsistencies, MLOps flows and testing techniques for AI components are needed.

Software systems are constantly evolving and this requires continuous quality assurance, including security, in the face of changes in the code, whether due to enhancements or bug fixes.

2. Artificial Intelligence for Software Development

Artificial Intelligence is a transversal technology that is used in business processes* in different sectors (logistics, energy, finance, etc.) to obtain competitive advantages, either in terms of optimisation or improved decision-making. The **software development process** is a manufacturing process where AI is also likely to play a differential role in **building safer and/or lower cost software**. In this research area, AI techniques (NLP, ML, DL, etc.) are applied in different phases of the life cycle, from requirements to maintenance and operation.

Some specific lines of research within AI for software development are:

- Automatic analysis of requirements and their relationship with standards and regulations.
- Automatic code generation from complex system designs.
- Automatic code repair and safe coding suggestions for developers.
- Automatic test case generation.
- Project estimation based on historical data.

3. Continuous Quality Assurance

Software systems are **constantly evolving and this requires continuous quality assurance**, including security, in the face of changes that occur in the code, whether for improvements or error correction; even more so when these systems must be certified by international standards or certification schemes and the cost of certification is high in the face of any change.

Some specific lines of research within continuous quality assurance are:

- Analysis and combination of different life cycle evidences resulting from testing, verification, simulation, etc. to meet the requirements and ensure the quality of the system.
- Automatic detection of changes in the assurance if there have been any changes in the system that produce new faults or vulnerabilities.
- Recommendations for changes to the system based on data collected when the system is in operation.

4. Quantum Software Engineering

Quantum software, like any other software, needs to be planned, designed, implemented, estimated, tested, security and quality assured, evolved and maintained among other things. This means that quantum software engineering needs to be developed as a new discipline, both academically and industrially, throughout the new quantum software lifecycle.

This new computing paradigm involves adapting and creating new processes, methods, techniques, practices and software engineering principles for quantum software development.

Some specific lines of research within quantum software engineering are:

- Automatic migration and modernisation of classical software to quantum software. Reverse re-engineering, abstraction and software modernisation techniques will be needed to automate the migration from classical to quantum software, in many cases being hybrid information systems.
- Quantum software testing. Classical software is deterministic under certain conditions, while quantum software is not. New verification and validation methods and techniques are needed to be investigated in the coming years.
- Quantum software programming. New programming paradigms need to be investigated in the coming years.
- Methodologies for quantum software development. Classical software development methodologies must be revised to adapt them to the characteristics of quantum software.

03

DISRUPTIVE TECHNOLOGIES

03 DISRUPTIVE TECHNOLOGIES

This section looks at quantum technologies and spintronics, two disruptive technologies that are still at an early stage of development but have the potential to bring about real technological revolutions.

3.1 Quantum technologies

3.1.1 Introduction

Quantum technologies are used in a wide range of application areas that exploit the quantum properties of matter at the particle level, such as superposition and entanglement, to gain differential advantages over classical technologies.

Quantum technologies are set to revolutionise global industrial value chains. As many products and services will be developed on the basis of these technologies that will be able to address existing and future challenges that are impossible or very difficult to solve by traditional means, their early mastery may prove to be a key competitive enabler for companies and a way to ensure the future prosperity of regions. As a result, the sector's growth is being driven by governments, large companies and start-ups alike, with many tens of billions of euros in funding and investment.

The main application areas where extensive research and investment is being carried out are as follows:

There are now several manufacturers worldwide of quantum computers using different technologies, many of which can be accessed in the cloud for applications that are still in the research field.

• Quantum Computing and Simulation

There are currently several manufacturers of quantum computers worldwide using different technologies. Many of them can be accessed in the cloud for applications that are still in the field of research or, at most, for proof of concept: optimisation, simulation, machine learning... Current technologies for creating qbits (the unit of quantum information) have clear limitations in terms of scalability (number of qbits), decoherence time (the time during which a quantum computer can function as such) and noise, but progress is being made at breakneck speed. The technology to overcome these limitations of quantum computers of this era, which has been dubbed NISQ (Noisy Intermediate-Scale Quantum), has probably yet to be discovered. It is important to stress that quantum computing is not a substitute for classical computing: it has advantages for solving certain problems, and therefore both classical and quantum computing will coexist and complement each other. Thus, in addition to transferring the concepts of classical SW engineering to quantum, there are new challenges arising from the coexistence in the same system of quantum and classical sections, and from the integration and automation of development and deployment cycles on information infrastructures (Quantum DevOps, or QDevOps).

• Cybersecurity and Quantum Communications

At the same time that quantum computing is beginning to threaten cybersecurity systems based on cryptographic algorithms, phenomena such as quantum entanglement will allow the development of new mechanisms for the secure exchange of cryptographic keys. On the one hand, research in this field is focusing on the development of encryption algorithms resistant to attack by a quantum computer, or Post-Quantum Encryption algorithms. NIST (National Institute of Standards and Technology) has an active standardisation process to select a set of algorithms for international standardisation, which is in its final stages. On the other hand, new methods for secure communications, such as QKD (Quantum Key Distribution), are also being actively developed, and there is a European initiative for the creation of a secure communications infrastructure using quantum technologies: EuroQCI (European Quantum Communication Infrastructure

(EuroQCI). In the somewhat more distant future, properties such as quantum entanglement and quantum teleportation open up possibilities for the deployment of an intrinsically secure future Internet.

The University of the Basque Country has created the EHU Quantum Center, a centre that integrates fundamental quantum research, the training of research personnel and the transfer of knowledge to society and companies.

• Sensorics and Quantum Metrology

Since the energies involved in quantum processes at the particle level are almost infinitesimal, quantum sensing is enabling substantial advances in terms of sensitivity compared to classical sensors. Quantum sensors can improve measurement accuracy, and enable applications in industry, healthcare and diagnostics, oil and gas, defence, defence, automotive, civil engineering, construction, space and telecommunications. Although quantum technologies used in sensing and metrology are very broad, and new ones will certainly continue to emerge, it is considered to be the most developed area of application of quantum technologies, which will be the first to have a major impact on the market.

3.1.2 Positioning in the Basque Country

The 'Basque Country Science, Technology and Innovation Plan 2030' distinguishes between digital or virtual technologies (Artificial Intelligence and Big Data / Data Science, Internet of Things and 5G Technologies, Cybersecurity, Cyberphysical Systems) and physical, biological, chemical or materials technologies. Within the latter, quantum and neutronics technologies are explicitly identified, encompassing quantum clocks and synchronisation, optical-quantum metrology, simulation and design of materials and molecules in quantum computers and neutronics.

Bilbao is one of the three nodes of the Quantum Flagship network in Spain, together with Madrid and Barcelona. Quantum Flagship is one of the largest research initiatives funded by the EU executive to put Europe at the forefront of progress.

Aware of the importance that quantum technologies are going to play in the future competitiveness of companies and in the economy of the Basque Country in general, the different administrations are making a strong commitment and generating different initiatives around quantum technology that aim to dynamise and strengthen the ecosystem:

Among these initiatives it is worth highlighting:

- **Industry-focused quantum ecosystem**

It has been created by the Provincial Council of Bizkaia, with a strategy aimed at consolidating the region's international position in the field of quantum technologies and becoming a pole of reference in knowledge and future quantum developments. The Provincial Council of Bizkaia is the second hub to join the IBM Quantum Network in Spain after the CSIC, and the fifth in the European Union. As part of this initiative, the Quantum Ecosystem provides special access so that all universities in the region can research and experiment with IBM quantum computers in the cloud. In fact, the UPV-EHU already plays a very important role in the region's ecosystem and enjoys international prestige in this field. It is one of the leading universities in basic (pure) and basic-applied research. It also has one of the few master's degrees in quantum science in the world and the first in Spain. And it is one of the ten European universities in the OpenSuperQ consortium, a European FPA (Framework Partnership Agreement) initiative to achieve a quantum computer with open specifications (open source model).

The University of the Basque Country has created the EHU Quantum Center, a centre that integrates fundamental quantum research, the training of research personnel and the transfer of knowledge to society and companies. The centre aims to discover and study quantum phenomena and systems; to disseminate knowledge about Quantum Science and Technology; and to develop technological applications. It does this through the interaction of research, training and transfer, with the clear vocation of projecting them both locally and internationally.

The **Ikur 2030 strategy** is an initiative launched by the Basque Government's Department of Education in the field of research excellence in 2021. Quantum technologies are one of the four strategic niches or areas that are part of this strategy, along with neurosciences, neutrionics, supercomputing and Artificial Intelligence.

In line with this strategy, the Department of Education and the Provincial Council of Gipuzkoa signed a collaboration agreement last September to jointly promote the development of a **Quantum Technologies Hub in Gipuzkoa**. Both institutions share the aim of positioning Gipuzkoa and the Basque Country as a benchmark in a field of enormous potential, which will enable the generation of highly disruptive technologies with a great impact on society, and from whose development many sectors will be able to benefit, especially those that handle a large amount of data.

DIGITAL TECHNOLOGIES

03 DISRUPTIVE TECHNOLOGIES

Quantum Teknologiak - QUANTEK' has had the objective of developing a knowledge base around quantum technologies as the driving force behind a quantum ecosystem in the Basque Country.

Singular initiatives/projects

Fundamental research and applied research projects:

- **QUANTEK** has been the first project focused on quantum technologies between 2021 and 2022. Funded by the Elkartek programme in 2021, 'Quantum Teknologiak - QUANTEK' aimed to develop a knowledge base around quantum technologies as the driving force behind a quantum ecosystem in the Basque Country. To this end, it has developed four lines of work: quantum computing and simulation, quantum software engineering, quantum security and communications and the delimitation of use cases for strengthening the quantum ecosystem. It has 4 partners: TECNALIA (coordinator), I3B, UPV/EHU and UNIV. DEUSTO.

- The **QFirst** project, funded by the ELKARTEK 2022 program of the Basque Government, addresses the development of quantum hardware for ultra-resolution sensors based on Vacant Nitrogen in diamond technology. Through this technology it is possible to achieve unprecedented performance and precision for devices used in physical and chemical property detection systems, identification and traceability, secure industrial communication, metrology or inertial positioning. It has 5 partners: TECNALIA (coordinator), UPV/EHU, MATERIALS PHYSICS CENTER, TEKNIKER and AVS NEXT.

- The **BRTA-Q** project is funded by the ELKARTEK 2022 program of the Basque Government and aims at structuring, ordering, coordinating and directing the strategy of BRTA centers in quantum technology. BRTA Quantum is also a subject (working group) that represents BRTA in the "quantum community". BRTA_Q has on the one hand a coordination component consisting of dissemination, awareness and communication actions, networking, coordination or support services, exercises and mutual learning studies, including design studies of new infrastructures.

  Coordinated by BRTA, with the participation of TECNALIA, CIC NANOGUNE, VICOMTECH, TEKNIKER and IKERLAN as partners.

Laboratories:

- In 2021 the QKD laboratory is installed in TECNALIA. This laboratory is based on IDQuantique communications equipment. It is an experimental QKD platform at all levels, with fiber rings up to 70km, for the optimization of classical quantum algorithms and development of new QKD algorithms.
- Within the AZPITEK program, the Basque Government has funded the creation of the **Q-eNVy** quantum sensing laboratory. This collaborative laboratory is focused on the engineering of Vacant Nitrogen centers, which is a field in which there is a remarkable knowledge in the Basque Country, distributed over several agents of the RVCTi. This laboratory responds to the need to approach the so-called deep tech as the fundamental element for the future economic development and digital self-determination of societies. Quantum sensing is a field in which the Basque Country aspires to become an international benchmark, not only in terms of the advancement of the technology itself, but also in the promotion of its most advanced applications in the most developed local value chains.

Others:

- The Ministry of Science and Innovation has deployed a research program in the framework of the Complementary Plans with the Autonomous Regions of the PERTE component 17, funded by the European Union, Next Generation EU. Under this scheme, the Ministry and the Basque Government have specifically funded the complementary action "Quantum Communication" to support between 2022 and 2024 the creation of a high security communication infrastructure in Spain, boost the quantum industry and promote a new industrial sector with new companies in the digital and cybersecurity fields. It targets a strategic sector within second-generation quantum technologies, which is based on the ability to manipulate quantum systems individually, thus aligning itself with some of the European Union's most ambitious R&D&I initiatives, such as the Quantum Flagship and the creation of a pan-European quantum network (EuroQCI). The action has involved direct support to TECNALIA and DIPC - DONOSTIA INTERNATIONAL PHYSICS CENTER, in which also participate: I3B, UPV/EHU and UNIV. DEUSTO.

3.1.3 Technology Challenges / R&D Priorities

- Develop new hardware technologies that allow to **evolve from the NISQ era to the Fault Tolerant Large Scale Quantum era**. Currently there are multiple technological bases with which qbits are developed (superconductors, trapped ions, optics, diamond defects…), and all of them have

many limitations, in terms of scalability in the number of qbits, noise, decoherence time... While it is necessary to continue advancing in the development of these technologies (which are evolving rapidly) it is necessary to investigate new mechanisms to trap and interact with particles to minimize these drawbacks.

- **Improving error correction algorithms** While the limitations of the NISQ era persist, it is necessary to implement algorithms to correct the errors produced by quantum noise. These algorithms are implemented in the quantum computers themselves, and require the dedication of a significant portion of the available qbits, such that there is a significant difference between the number of physical qbits and the number of logical qbits available, i.e., the number of qbits that can actually be used to perform the computational operations. Therefore, advancing the efficiency of error correction algorithms is as much as increasing the number of physical qbits.

• Develop new hardware technologies that will enable the evolution from the NISQ era to the Fault Tolerant Large Scale Quantum era.

- **Research on new quantum algorithms**, which exploit the quantum advantage in specific applications. To date, a limited number of quantum algorithms have been developed. There is a need to develop algorithms that help in solving new problems, as well as algorithms that eventually improve the performance of other existing quantum algorithms. An example of this is the recent publication of an algorithm that substantially improves the performance of Shor's algorithm, which even without being widely accepted by the international scientific community, could compromise the security of RSA in a much shorter time than expected.

- Develop tools that address the **entire SW lifecycle on hybrid systems**. The fact that quantum computers are nondeterministic by nature leads to the need, probably enduring in time, for the coexistence of classical and quantum processing within the same systems. This represents a source of innumerable challenges in the field of SW engineering aimed at these hybrid systems, from the fragmentation of problems and their distribution between the classical and the quantum part in an optimal way, to the validation of hybrid systems for security applications, which can hardly admit nondeterministic results.

. **Develop the QDevOps concept.**
Bringing the concepts of classical DevOps to quantum is not obvious, especially because of the limitations of the NISQ era, the fact that the systems will generally be hybrid, and that the quantum part will be deployed in the network, with the possibility of using any of the different existing quantum technologies. According to the DevOps scheme, it is necessary to perform an evaluation and testing of the platform during programming. In addition, before extensive computation, the current susceptibility to errors and the stability of the available quantum computing instances, generally accessible through the cloud, are evaluated before choosing the most suitable instance. This ensures that the **quantum platform that ensures the best results for the algorithms used is used**.

. **Deployment of quantum-inspired algorithms on embedded systems.**
It is becoming increasingly necessary to implement complex algorithms on the Edge, for example, for the development of real-time systems that could not withstand the latency of a cloud access. But the resources available on these embedded devices could limit the power of operations that can be executed locally. Quantum-inspired algorithms can improve the performance of operations, so that more computational power can be available on the same hardware, or simplify the hardware for the same computational power. Methods need to be developed to implement on FPGAs tensor networks that allow these quantum-inspired algorithms to be deployed in an efficient manner.

. **Quantum Simulation Systems**
Quantum simulation can refer to numerical approximations to complicated mathematical formulations (e.g., systems of differential equations) that describe a given physical phenomenon, or also to quantum systems that replicate the behavior of other quantum systems, for example, the processes of synthesis of new molecules, which are too costly to simulate on classical computers. In both cases, quantum simulation is still an emerging field of quantum technologies, but it has a wide potential for impact, so research is needed to bring it to states closer to its real application.

• QUANTUM COMMUNICATIONS

. **Overcome current QKD barriers,** for example, in terms of distance.
There are mainly two variants of QKD technology, discrete variable QKD (DV-QKD) which is based on the use of single photon detectors and continuous variable QKD (CV-QKD) which is based on coherent detection. Although experiments have been published in which much greater distances have been achieved, these technologies do not allow their use at distances much greater than 100 km over optical fibers, since the resulting attenuations cause the photons to lose their quantum states. This limitation in the maximum usable distance hinders the use of QKD in long-range metropolitan networks (e.g., inter-city links), or passive multi-user optical access networks. Further research is needed to develop systems that relax these restrictions on QKD systems.

. **Advancing new photonics technologies for QKD**

QKD technologies are considerably mature and products from different manufacturers can be found on the market that can be integrated into any data center. But these are expensive products, which can hardly justify their use in enterprises beyond government agencies or large corporations that handle highly critical information. In addition to lowering costs so that QKD can be used extensively, it is necessary to advance in the development of devices to explore the possibility of bringing QKD to the world of machines, for example for securing industrial communications. At present, there are many libraries to be integrated into photonic chips, but they often fall short of the performance required by QKD. For example, further research is needed in the generation of interleaved photon pairs before they can be included in industrializable integrated circuits.

- **Security challenges within the integration to classic infrastructures.**

  The advantages of quantum mechanics apply to the generation and exchange of quantum keys, but once these keys have been exchanged, classic IT cybersecurity challenges apply. Some of the most common attacks are multi-stage attacks, which target highly critical information. These attacks usually involve multiple stages over a long period of time. Secret keys are a common target, as they can unlock access to much more critical information. Countermeasures are based on various security monitoring mechanisms, and these should also be taken into account for quantum security devices.

- **Extending QKD capillarity to complex networks.**

  State-of-the-art QKD technology only enables communication (the exchange of secure keys) between two nodes, in a point-to-point manner, sometimes with trusted intermediaries. Normal operation will require this QKD exchange to take place between multiple nodes, like a complex multipoint network. Progress is needed not only to compact the QKD devices themselves but also to develop the necessary mechanisms to manage the structure of networks with complex configurations and topologies.

- **Developing the future Quantum Internet**

  Quantum mechanics offers very interesting possibilities based on the possible exploitation of phenomena such as quantum entanglement and teleportation, which would allow the development of intrinsically secure communications systems, since information could be transmitted from one place to another without necessarily having to travel over a communications line. Such phenomena have raised so many expectations that they have led to widespread misconceptions that quantum communications allow instantaneous transmission of information. Beyond these misconceptions, quantum phenomena offer possibilities that point to the development of intrinsically secure communications, although technology is still far from being able to exploit them.

- **Advances in the implementation of QNRGs**

  QRNGs, Quantum Number Random Generation, are a specific type of random number generators that are based on the measurement of a quantum physical process. The fundamental advantage of QRNGs is that they take advantage of one of the most basic features of quantum physics: quantum indeterminacy. This makes them the most robust technical solution to the challenge of producing unpredictable digits. There are a multitude of manufacturers of QNRGs that are used, for example, in commercial off-the-shelf QKD equipment. However, advances in technology are needed to improve performance in terms of size, cost and performance - for example, with random number generation speeds in the tens of Gb/s. There is also a lack of standards applicable to QRNGs.

- **QUANTUM SENSING**

- To **develop new sensor technologies**, more sensitive to new parameters. The energies involved in quantum phenomena at the particle level are tiny, so a correct functionalization of these sensors must necessarily lead to a substantial increase in sensitivity with respect to classical technologies. Today there is a rich set of technologies that are beginning to be used to implement quantum sensors, but research is still needed in the development of new families of technologies. For example, in the case of defects in diamond crystals there are wide fields to be explored related to the spatial distribution of the centers and the use of impurities other than nitrogen, which is the most widely used at present.

- **Evolving from quantum basis to chip.** The technological basis on which the detection operation is implemented in quantum sensors, in gases or in solid state, currently presents artisanal configurations, which makes them difficult to replicate (with similar characteristics) at a competitive cost. It is necessary to develop the associated industrialization and integration processes. A significant example would be, in the case of sensors based on NV centers, the evolution from diamond crystal to chip, integrating optical components, photodetectors, interfaces to microwave antennas.

- **Progress in TRL and sensor functionalization.** Quantum sensing is the quantum technology that is at the most advanced stage of maturity, but even the practical sensors available need to be developed to enable their use in real applications. For example, in the case of diamond defect-based sensors, the sensor readout systems are sophisticated, and progress needs to be made in the simplification and miniaturization of the necessary microwave sources and antennas, laser sources and photoluminescence detectors.

- **To advance in the development of practical sensors**, specifically oriented to certain applications where the quantum advantage can be an important differential to achieve market impact, such as inertial navigation, gravitometers, high-precision atomic clocks, diagnosis of certain diseases and metrology.

It is necessary to advance in the development of devices to explore the possibility of bringing QKD to the machine world, for the security of industrial communications.

3.2. Spintronics

3.2.1Introduction

Spintronics is a field of electronics in which the spin of electrons is used specifically for the operation of electronic devices, such as electronic logic or data storage. One of the main opportunities of spintronics is spin state memory in magnetic materials, in which logic or memory states are kept stable without the need for any power supply (non-volatile memory). This makes possible large energy savings in spintronic devices and is therefore a viable path to sustain ever-increasing electronic and computing capabilities without being limited by the looming energy catastrophe of today's unsustainable increases in energy consumption. Current projections expect a massive increase in the energy required to run the electronic infrastructure of up to 15% by 2050 of total global energy consumption. Therefore, if relevant technological breakthroughs can be achieved, the adaptation of spintronics on a large scale will have a disruptive effect.

3.2.2 Technological relevance and fields of application

- **Hard disk drive (HDD) technology**

  The fundamental aspects of spintronics are associated with physical interactions between spins or between spins and charge currents, producing new collective effects that can then be used in devices. The breakthrough discovery was the observation of the Giant Magnetoresistance (GMR) effect in 1988, which occurred independently by the groups led by Prof. Peter Grünberg and Prof. Albert Fert, who jointly received the Nobel Prize in Physics (2007) for this seminal discovery. The technological relevance of their discovery was appreciated with its rapid application, and, as early as 1997, IBM began selling commercial hard disk drives (HDD) with GMR-based readout sensors. This early use of spintronics enabled huge increases in HDD data capacity that exceeded Moore's Law by more than a decade. It also made HDDs the most relevant product in data storage technology, a position it has held ever since.

  Despite its huge commercial success, the spintronics technology used in HDD read heads is a fairly simple application, as it uses only a change in electrical resistance due to different magnetic configurations in a magnetic multilayer, which are generated by the magnetic field pattern of the bits. No actual spin manipulation is used in these devices. Therefore, HDD read heads are a first generation application, although the associated nanofabrication and material science capabilities are extremely advanced. Therefore, HDD readhead technology will not be a disruptive technology in spintronics in the future, although it may maintain its commercial leadership position among spintronics technologies for a few more years.

- **Magnetic Random Access Memory (MRAM)**

  Since the early 2000s, MRAM has been a commercial technology that combines non-volatile storage with high-speed access. The read process of these devices is also based on tunneling magnetoresistance (TMR), an effect closely related to GMR and discovered in 1995. As in the case of commercial HDD read heads, commercial MRAM devices also used only the simplest aspects of spintronics until 2016, because the only spintronic component was the spin-state induced resistance change. Data writing was done through an external magnetic field induced by electric currents (Oersted fields). This limited the commercial success of MRAM technology, as only chips with a rather low data capacity could be produced with this technology, limited to very special applications, such as the storage of some specific data in commercial airplanes due to their high radiation resilience.

  However, since 2016, spin-transfer torque (STT) MRAM devices have been in use, where the memory state is directly manipulated by a spin-polarized current, i.e. true spintronic manipulation. This has enabled a breakthrough in storage capacity scaling and, with these improved prospects, major electronics manufacturers have initiated or strengthened their research activities and pilot plants to move into commercial manufacturing of MRAM devices. Of the commercial technologies that exist today, MRAM technology is the most likely field in which new disruptive technologies (such as the use of spin-orbit torque, SOT) will be developed and its first commercial applications will be found, although its long-term competitive vision will also require new disruptive materials and new nanotechnologies. This will have a major impact on data storage technologies and has the potential to make MRAM not only a key component, but also the main component of mass data storage in the future.

- **Spintronic sensors**

  Since the rapid development and advancement of GMR sensors for the HDD industry, GMR-based sensors have been developed for other application fields, such as steering angle sensor for automotive applications. With the future vision of autonomous driving, more use of spintronic sensors can be expected in automotive applications and other industrial fields, which will expand the commercial portfolio of spintronic devices. In addition, more advanced spintronic technologies are also likely to enter these sensor applications for active control of sensitivity, linearity, and other performance aspects of these sensors. However, it is unlikely that major disruptive technologies will be developed in the industries, and will only use sensors in supporting functions.

- **Other device technologies**

  There are other technological approaches using spintronics, but their large-scale feasibility is not guaranteed at present, although they could be the predominant spintronics technologies in the future. One such technology is spintronics designed for three-dimensional data storage, which would completely change data storage technologies, because current technologies are basically two-dimensional and use surface storage devices. True three-dimensional data storage uses the third dimension, the depth of a device in a natural way, such as the racetrack data storage concept proposed in 2008 by IBM that uses STT-based spintronics for its operation. The potential of these technologies is enormous, but they will also require truly disruptive materials and other (nano)manufacturing advances to become a viable technology.

  In addition to new data storage applications, there are several spintronics technologies for data processing applications, such as spin transistors or other multiterminal devices that perform processing operations, based on spin-spin, current-spin or voltage-spin type interaction. These technologies are at a preliminary stage, although basic operations and functionalities have been demonstrated for several device designs. In many cases their efficiency and scalability are not sufficiently demonstrated, but they certainly have great potential, as they can in principle combine data processing and storage in a single spintronic device. In addition, their energy efficiency would be a major breakthrough, especially in devices operated by voltage-spin interaction, which do not depend on current flow for their fundamental processes. An example of the latter case is the MESO technology recently proposed by Intel.

  A recently demonstrated computational approach using spintronics technology is probabilistic computing, which is similar in its radical change of computer technology to the quantum computer approach, because it is not based on the classical von Neumann computational scheme. Recently, 8-bit (p-bit) probabilistic devices, based on STT-MRAM technology, have been demonstrated, achieving integer factorisation. This approach is in its infancy, but may have truly disruptive potential in terms of computational capabilities in line with quantum computing approaches.

3.2.3 Positioning in the Basque Country

Materials, Processes and Nanotechnology are key cross-cutting technologies identified in the PCTI Euskadi 2030 and, based on previous strategic decisions, the Basque Country is well positioned in the field of spintronics with expertise, infrastructures and very relevant R&D activity, although there is currently no strategic spintronics initiative. There is extensive activity including some BRTA centres with a portfolio of projects on all the core topics needed to facilitate a disruptive transformation through spintronics, including work on new materials and metamaterials, new device concepts and associated manufacturing methodologies. Key ongoing projects include:

• **EC Project: QuESTech (2018-2022)**

The overall objective of the scientific and technological activities of the QuESTech project is to build, study and qualify quantum electronic devices through research in the sub-fields of spintronics, electronics and quantum thermodynamics. The research sub-projects include technological developments such as nanomaterial growth, nanostructuring, microscopy, electron transport under extreme conditions and theoretical calculations. Several QuESTech results are already identified as breakthroughs relevant to the emerging quantum electronics industry.

• **EC Project: SPEAR (2021-2025)**

The overall scientific and technological objective of the SPEAR project is to study materials with strong spin-orbit coupling, novel phenomena in these materials and to build devices based on these phenomena for the next generation of memories, such as magnetic random access memory (MRAM), and beyond CMOS technology, such as spintronics-based logic or neuromorphic computing. SPEAR includes highly relevant research in spin-orbit interaction physics, spin-to-charge conversion, two-dimensional magnetic materials, spin-Hall-effect nano-oscillators, voltage control of magnetic anisotropy and skyrmions.

• **EC Project: INTERFAST (2021-2024)**

The INTERFAST project develops a novel technology platform for the electrical control of interfacial magnetism. The core idea of this technology is to manipulate hybrid electronic states at the interface between a magnetic material and an organic layer, in the form of spin-orbit coupling at the interface. This will allow active control of interfacial magnetism for a wide range of magnetic compounds. INTERFAST's plan is to demonstrate the applicability of this technology to a variety of key functions in spintronics, such as electrical reversal of magnetisation at an energy cost of only 1 fJ/bit, drastic reduction of currents to realise spintronic effects, and ultra-fast information processing in metallic spintronic devices.

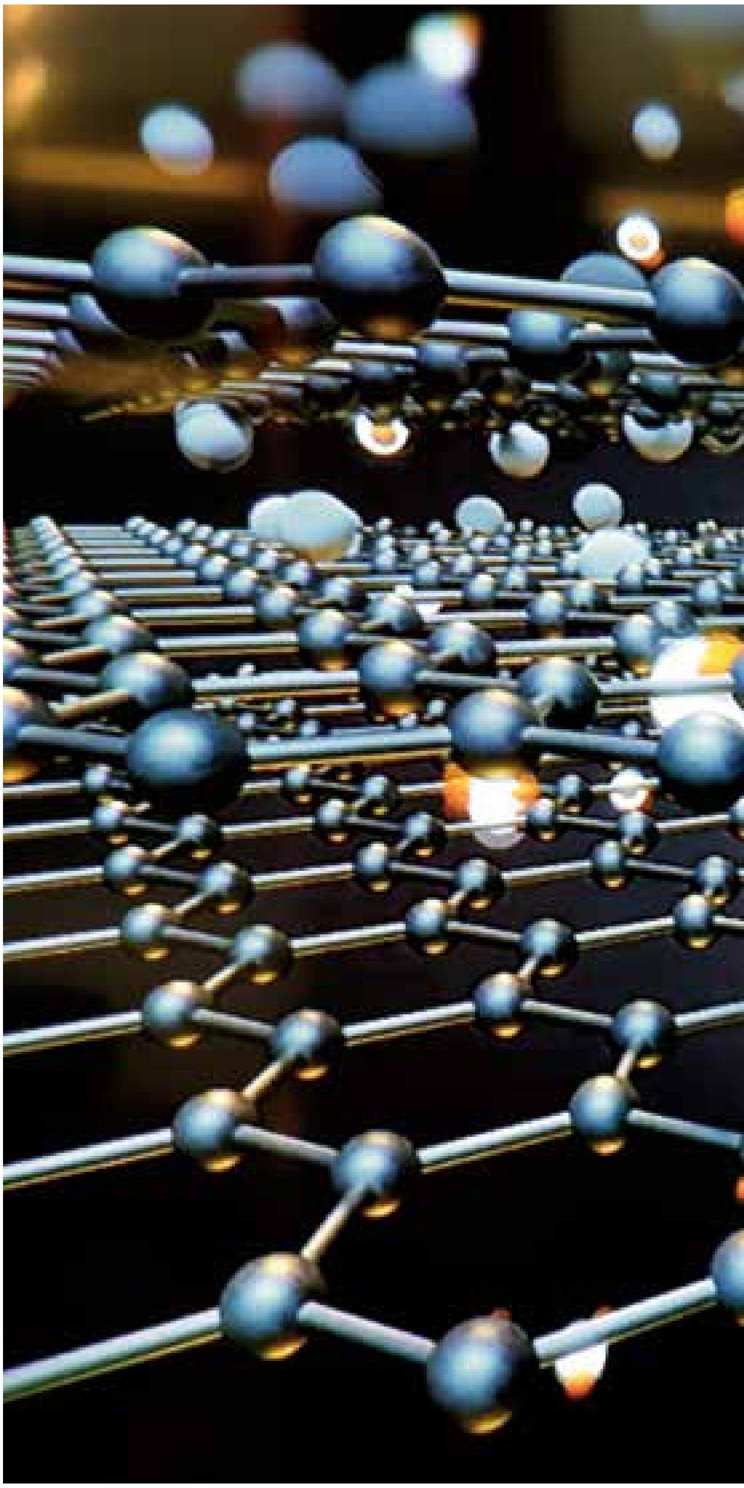
In addition to these European projects, there are ongoing projects funded by the Spanish government, as well as direct collaboration projects between Intel and nanoGUNE on spintronic device technology. The aim of this collaborative work with a leading electronics manufacturer is the integration and performance testing of new materials and metamaterials in real spintronic storage and processing devices (MESO technology) to assist in the selection of the most promising candidates for industrial-scale integration testing.

Materials, Processes and Nanotechnology are key cross-cutting technologies identified in the PCTI Euskadi 2030 and, based on previous strategic decisions, the Basque Country is well positioned in the field of spintronics.

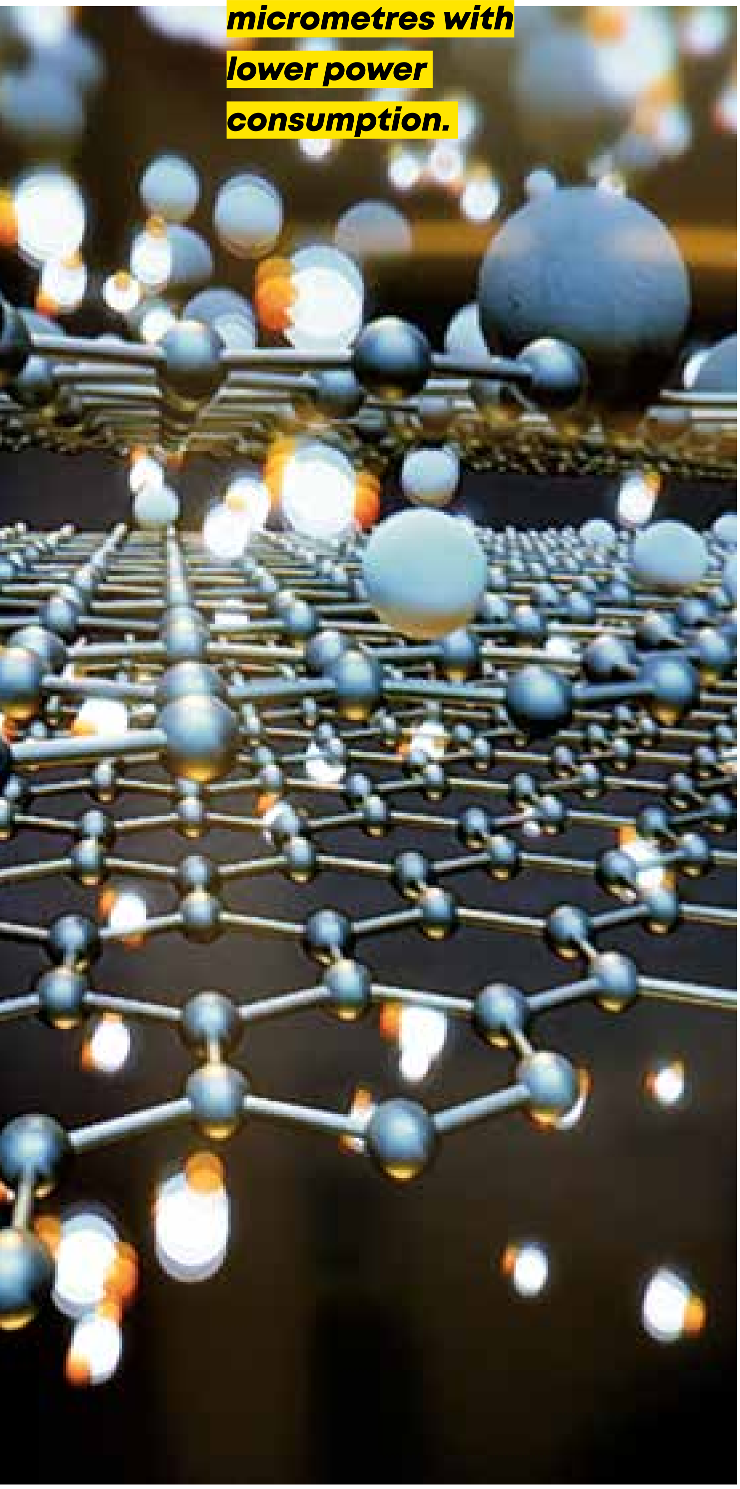
3.2.4 Technology Challenges / R&D Priorities

For spintronics to have a truly disruptive impact on digital technology, 3 key components are needed: **new materials**, **advanced device** designs and **novel materials and device fabrication methodologies**. New materials or metamaterials are needed to enable novel design operations as well as to massively improve the efficiency of existing device concepts. Academic studies have shown that novel devices that would constitute truly disruptive breakthroughs are possible and operational, but their properties are now clearly insufficient. For example, the resistance ratio in the 'On/Off' states of a spin transistor is very insufficient. Therefore, major efforts must be made in the field of new materials for spintronics.

To cope with the physical properties of existing materials and those to be developed in the future, new device concepts must be found to achieve an optimised use of the properties of these materials. One example is the spin-orbit interaction, which defines an alternative mechanism to STT, the SOT, as a current spin manipulation process and for which new device concepts have recently been proposed and explored. Finally, with new device concepts and especially with new materials, new fabrication challenges arise that will have to find robust technological solutions. The range of technological advances required is extremely wide, but given the very promising spintronic



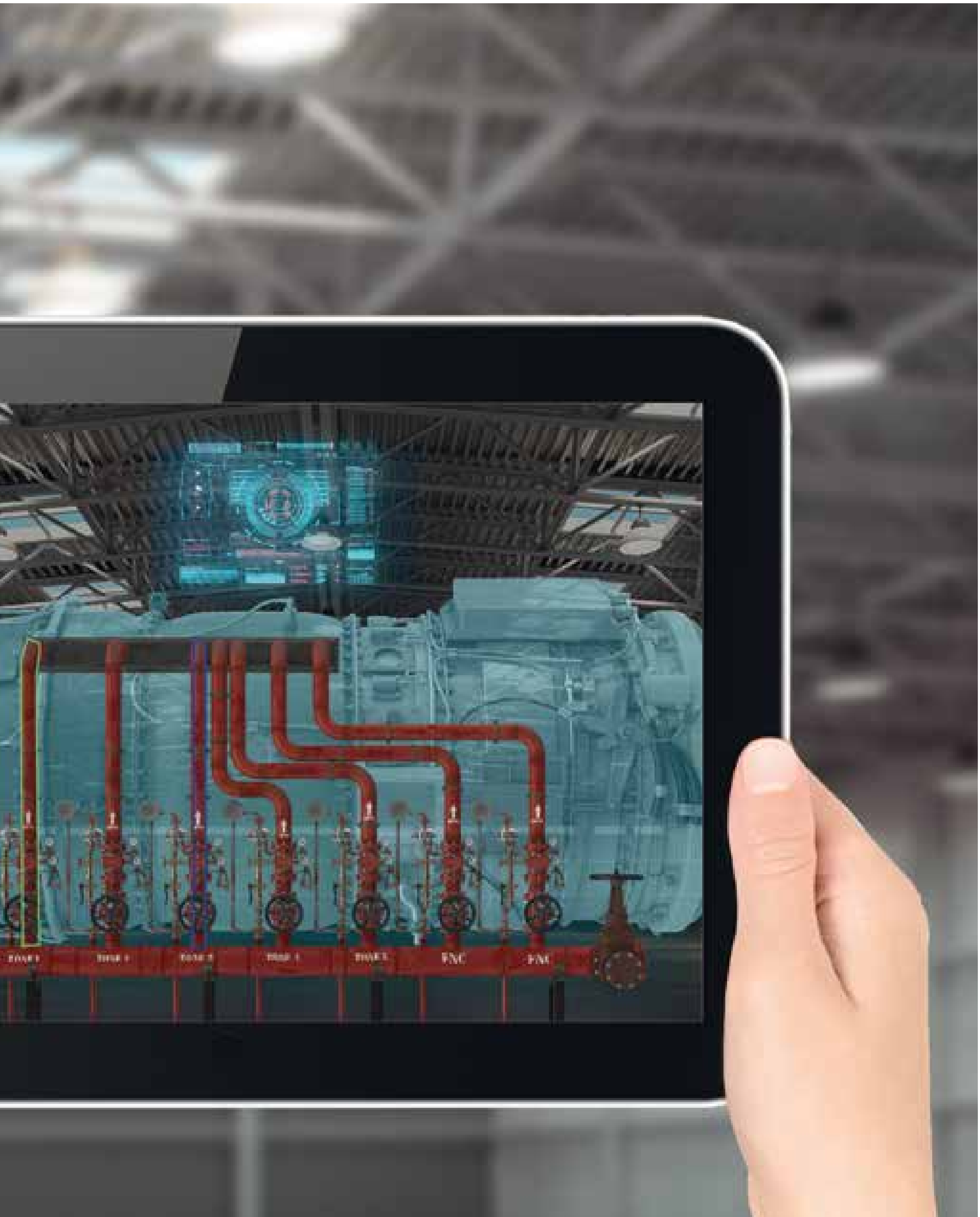
Graphene expands the field of spintronic communication between devices from nanometres to micrometres with lower power consumption.



properties of two-dimensional materials such as graphene and heterostructures based on the combination of graphene with other two-dimensional materials, the reliable production of electronic grade two-dimensional materials will be of great importance for spintronics technology.

04

DIGITAL SOLUTIONS



This section looks at quantum technologies and spintronics, two disruptive technologies that are still at an early stage of development but have the potential to bring about real technological revolutions.

Digital twin

A digital twin is a virtual model or representation of an object, process or physical system in real time, which is used to analyse and optimise its performance. A digital twin is composed of a) a layer of visual interaction with the reality it is intended to represent, b) a layer of connectivity to the recorded physical information and c) analysis, prediction and simulation modules that can help to understand or anticipate the behaviour of the real system. Digital twins have been developed to accurately reflect a physical element or system and have become an increasingly important tool in industry and are being used in different sectors such as manufacturing, energy, health and transport.

In the context of BRTA we can find Digital Twin activities oriented to:

- Digital modelling of factories, energy facilities, food production and healthcare systems to improve efficiency and quality of processes and products, as well as waste reduction.
- Robotics (manufacturing of parts and components).
- Biosciences: digital models from resonance imaging. Radiology to test the success or failure of modifications in a virtual environment. Omic sciences (proteomics, transcriptomics, metabolomics, etc.).

Robotics

Robotic solutions rely on and integrate many of the digital technologies of the different pillars. In particular, **sensorisation and embedded AI** contribute to cognitive functions, such as perception and decision making, which are the essential ingredients of autonomy in such solutions. In any case, these technologies must be **adapted and encapsulated** to take into account the particular **functional and operational requirements** of robotic applications, including the **high levels of reliability** demanded in these cases.

There are paradigms related to learning that can only be studied, understood and applied in robotics. **Learning by demonstration**, for example, is a valuable paradigm for robot training and programming, as it reduces the complexity of programming robots, reducing the programming knowledge required for their use, while leveraging the user's experience in solving specific tasks. This does not detract from other types of problems that may be more generalisable, such as autonomous navigation, manipulation and inspection. In general, robots learn from their particular experience, but in many cases the learning is

A digital twin is a virtual model or representation of an object, process or physical system in real time, which is used to analyse and optimise its performance.

transferable from one application context to others. Usually, however, the number of available cases is limited.

Therefore, highly efficient learning mechanisms that can learn quickly from very small data sets are required. It should also be noted that learning-based algorithms may have limitations in safety-critical applications, where certification is a necessary requirement for their deployment.

Finally, it should be noted that robots often act as data generators in those applications in which they are responsible for carrying out, for example, inspections. In these cases, their function is integrated with the technologies associated with the digital platform pillar.

CPS & IoT Networks

Cyber-Physical Systems (CPS), already introduced in Section 2.1.2, can be defined as automated systems that connect real-world operations with different computing and communication infrastructures. Typically, CPSs consist of microcontroller control units that manage sensors and actuators capable of interacting with the physical world, and which in turn are capable of processing the data obtained.

On the other hand, while traditional embedded systems are designed as stand-alone devices, CPSs operate in an interconnected way, i.e. CPSs require a communication interface to exchange data with other embedded systems or with the cloud. This data exchange or connectivity is the main characteristic of a CPS, and therefore a networked CPS is what gives rise to the Internet of Things (IoT) concept.

From the above, it can be concluded that CPS and IoT networks are mainly based on the technological pillar of connectivity for data extraction and on the digital platform pillar for data management and processing, although they also require strong support from the electronics and embedded hardware pillar, and from the cybersecurity pillar due to the sensitivity of the data they handle. At a third level, CPS and IoT networks also require support from the AI and data analytics and software engineering pillars.

In terms of application fields, CPS together with IoT networks and Smart Factories are the basis of what is currently known as Industry 4.0 or the fourth industrial revolution. There are also other fields of application for CPS in addition to the purely industrial ones, such as medical applications, autonomous driving systems, or the control of power generation plants.

Monitoring, diagnosis and prediction

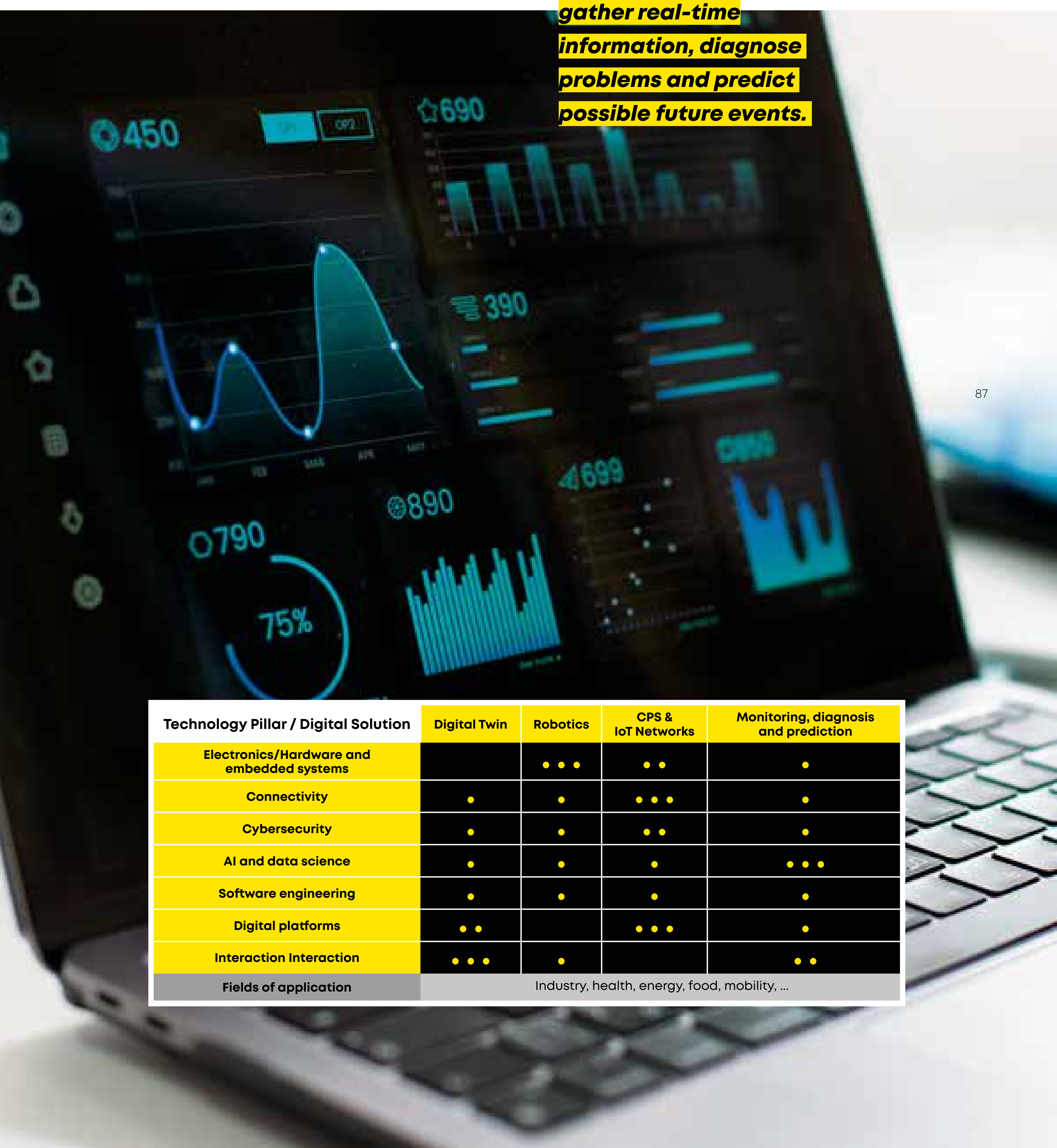
Digital solutions for monitoring, diagnosis and prediction leverage digital technology, such as data analytics and machine learning algorithms, to gather real-time information, diagnose problems and predict possible future events. Therefore, the Artificial Intelligence and Data Analytics pillar will be the cornerstone of this solution.

Monitoring involves capturing sensor data and transmitting it via communication networks to analysis systems in a cyber-secure manner. Therefore, pillars such as Electronics and Embedded Systems, Connectivity and Cybersecurity are of great relevance.

In addition, digital monitoring involves the continuous tracking of specific parameters or variables to collect real-time data, allowing the performance of equipment, systems or processes to be remotely monitored and controlled. While digital diagnostics involves the analysis of collected data to identify problems or anomalies. Machine learning algorithms and Artificial Intelligence are used to process large amounts of data, detect significant patterns or deviations, and make predictions of future events. These results interact with people or other systems so the Digital Platforms pillar and the Interaction Technologies pillar form two fundamental pillars, with increasing importance in the solution.

In the context of BRTA we can find monitoring, diagnosis and prediction activities in the fields of advanced manufacturing, sustainable mobility, energy transition and personalised health. Therefore, this wide variety of applications of monitoring, diagnostics and prediction allows it to be **present** in the full **range of activities that are carried out when creating a product or a service**.

Digital solutions for monitoring, diagnostics and forecasting leverage digital technology, such as data analytics and machine learning algorithms, to gather real-time information, diagnose problems and predict possible future events.



Technology Pillar / Digital Solution	Digital Twin	Robotics	CPS & IoT Networks	Monitoring, diagnosis and prediction
Electronics/Hardware and embedded systems		• • •	• •	•
Connectivity	•	•	• • •	•
Cybersecurity	•	•	• •	•
AI and data science	•	•	•	• • •
Software engineering	•	•	•	•
Digital platforms	• •		• • •	•
Interaction Interaction	• • •	•		• •
Fields of application	Industry, health, energy, food, mobility, ...			

05

BRTA CAPABILITIES


KU

Singular infrastructures

IKERLAN has the DIGILAB digital technologies laboratory, whose main function is to transfer technology to industry in the field of digitisation. It is a 2000 m2 space that integrates state-of-the-art infrastructure for research into different cutting-edge technologies such as collaborative robotics, cybersecurity, safety and reliability, 5G communications, Artificial Intelligence and quantum computing. DIGILAB is also the first industrial cybersecurity laboratory in Spain to be accredited by ENAC in accordance with the UNE17025 standard. It can carry out electronic product conformity assessment tests in accordance with the new IEC 62443 standard. IKERLAN also has an advanced AI laboratory equipped with several heterogeneous computing clusters (CPUs and GPUs) of very high performance that allow both the training and distributed inference of Artificial Intelligence models and the execution of conventional computing loads.

CEIT has a Clean Room consisting of several rooms where devices are manufactured using microtechnologies. These include a class 100 room dedicated mainly to the definition of geometries in photosensitive resins, two class 1000 rooms where deposition and thin film etching processes are carried out and a class 10000 room for post-processing and characterisation of

samples. To carry out these processes, CEIT has state-of-the-art equipment and infrastructure, including ultraviolet lithography techniques, thin film deposition from both physical and chemical (gas) phases, selective etching of materials using both wet and dry techniques, hot embossing of polymers (hot embossing), anodic bonding of silicon and glass wafers, bonding of polymeric materials by oxygen plasma, controlled atmosphere heat treatments, diffusion and oxidation processes of silicon wafers, morphological characterisation techniques by profilometry, micrometric precision substrate cutting and micro-welding station.

CIC nanoGUNE has a unique state-of-the-art infrastructure including ultra-sensitive laboratories and a clean room (class 100 - 10,000) of about 300 m2 for micro- and nanofabrication, equipped with two electron beam lithography systems. The building presents a unique environment, free of electromagnetic interference and with an ultra-low level of vibrations. In the CIC nanoGUNE laboratories we use ultra-precise techniques, such as ultra-low temperature tunneling microscopes and unique magnetometers, thin film or thin film growth facilities, as well as an electron microscopy laboratory including a Cs-corrected TEM and multiple FIB systems that can operate at cryogenic temperatures.

VICOMTECH has research infrastructures in different aspects related to digital technologies. For this purpose, it has different laboratories. The medical laboratory has equipment for capturing, processing, analysing and visualising biomedical aspects. The autonomous driving and intelligent transport laboratory has infrastructures for mass data capture and annotation. The industry division has infrastructures for digitalisation (industrial, linear, polarimetric, thermal cameras, etc.), communications integration (industrial protocols, TSN, 5G, etc.), data management and application of Artificial Intelligence technologies, including equipment for industrial robotics. The media laboratory has extended reality resources (volumetric capture systems, chroma), multi-device broadcasting and stacks for broadcast and 5G transmissions. Finally, VICOMTECH has an HPC for mass storage and high-performance computing that allows it to tackle Artificial Intelligence projects that include massive amounts of data and/or intensive training in terms of computational load.

IDEKO has a 2000m^2 space for the development of digital technologies and high-precision manufacturing solutions, the Digital Grinding Innovation Hub (DGIH), the new Basque Country node for research and development of innovative solutions in digitalisation applied to advanced manufacturing. There is also a prototype workshop with a space of more than 500m2 with robotised cells for research into the application of robotics in collaborative and intelligent manufacturing. Finally, IDEKO has a cloud platform for mass data storage and the computation of Artificial Intelligence algorithms applied to advanced manufacturing, such as predictive maintenance, process optimisation or predictive quality.

CIC energiGUNE has an innovative experimental materials acceleration platform that integrates high-performance modules for the synthesis of electroactive inorganic compounds for batteries, as well as their structural and electrochemical characterisation. This platform aims to become an autonomous laboratory, able to be constantly updated as needed, and has already successfully explored new families of electrode

materials in collaboration with several European industrial partners. The platform is currently under development and includes automated high-throughput synthesis modules, data analysis software capable of handling large amounts of data, as well as AI-assisted experimental planners.

CIC biomaGUNE has state-of-the-art research and development infrastructures focused on biomedical imaging and disruptive biotechnologies. We have several highly equipped laboratory facilities ranging from cyclotron for research and clinical application to advanced PET, CT, SPECT and MRI systems, including unique technologies in Spain for multinuclear imaging and advanced procedures such as accelerated MRI acquisition. Our capabilities in data science and high-performance computing allow us to handle and analyse large volumes of biomedical data, applying artificial intelligence to identify disease and treatment patterns. We are committed to innovation and constant collaboration with research institutions, companies and hospitals, always with the goal of advancing medicine and technology to improve health and quality of life globally.

CAPABILITIES OF BRTA ACTORS

DISTRIBUTED BY TECHNOLOGICAL CHALLENGES

	AZTERLAN	CEIT	GAIKER	IDEKO	IKERLAN	LORTEK
Challenge 1: Electronics and embedded systems		●	●	●	●	●
Challenge 2: AI and data science	●	●		●	●	●
Challenge 3: Connectivity		●		●	●	●
Challenge 4: Digital platforms	●	●	●	●	●	●
Challenge 5: Interaction technologies		●	●		●	
Challenge 6: Cybersecurity		●			●	
Challenge 7: Software engineering	●	●		●	●	●

	TECNALIA	TEKNIKER	VICOMTECH	CIC bioGUNE	CIC biomaGUNE	CIC energIGUNE	CIC nanoGUNE
	●	●	●				●
	●	●	●	●	●	●	●
	●	●	●				●
	●	●	●			●	
	●	●	●				
	●		●				
	●	●	●				

Alliance members

BRTA
BASQUE RESEARCH & TECHNOLOGY ALLIANCE

Kurutz Gain Industrialdea, 10
20850 Mendaro, Gipuzkoa
T.: +34 943 05 33 25
info@brta.eus

www.brta.eus