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# **SWOT Analysis regarding Factor 1:** TECHNOLOGY, INNOVATION AND RESEARCH CAPABILITIES

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- \* *R: Document, report (excluding the periodic and final reports)*
- DEM: Demonstrator, pilot, prototype, plan designs*
- DEC: Websites, patents filing, press & media actions, videos, etc.*
- DATA: Data sets, microdata, etc*
- DMP: Data management plan*
- ETHICS: Deliverables related to ethics issues.*
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- OTHER: Software, technical diagram, algorithms, models, etc.*

# Table of contents

- 1 Context ..... 4**
- 2 STRENGTHS ..... 5**
  - 2.1 Diverse and Advanced Technological Infrastructure ..... 5
  - 2.2 Robust European Telecommunications Equipment Suppliers ..... 5
  - 2.3 Semiconductor Manufacturing Capabilities ..... 5
  - 2.4 European Aerospace Sector as a Transversal Innovation Engine ..... 6
- 3 WEAKNESSES ..... 7**
  - 3.1 Slow Adoption and Deployment of Advanced Technologies ..... 7
  - 3.2 Lack of Trust in AI Systems and Data Security ..... 7
  - 3.3 Limited Capabilities in Open-Source Technologies ..... 7
  - 3.4 Brain Drain and Loss of Technology Leaders to External Markets ..... 8
  - 3.5 Insufficient and Fragmented R&D Investment ..... 8
- 4 OPPORTUNITIES ..... 9**
  - 4.1 Promoting Open Hardware Initiatives for European Semiconductor Sovereignty ..... 9
  - 4.2 Developing a Federated Technology Ecosystem for Dispersed Resources ..... 9
  - 4.3 Reorienting Research Investment and the Structure of Horizon Europe ..... 9
  - 4.4 Clarifying Net Neutrality Rules for Innovative Use Cases Such as 5G Network Slicing ..... 10
  - 4.5 Coordinating Technical Standards at EU Level for Network APIs, Edge Computing and IoT ..... 10
  - 4.6 Exploring Niche Markets: Aerospace and Telecommunications ..... 10
- 5 THREATS ..... 11**
  - 5.1 Demographic Decline and Loss of Competitiveness ..... 11
  - 5.2 Brain Drain and Company Relocation ..... 11
  - 5.3 Global Competition and Strategic Dependencies ..... 11
  - 5.4 Dependence on Non-European Technologies if European Alternatives Are Not Sustained ..... 11
  - 5.5 Aggressive Strategies of International Competitors ..... 12
- 6 Synthesis ..... 13**

# 1 Context

**Factor 1** constitutes the core technological pillar for consolidating the cognitive computing continuum in Europe. It encompasses the technological capabilities, innovation capacity, and research competencies that enable the EU to develop a sovereign, resilient, and globally competitive digital infrastructure.

Europe's position in this domain is characterized by a paradoxical yet potentially complementary landscape. On the one hand, the EU has solid strengths in advanced infrastructures, specialised telecommunications equipment suppliers, semiconductor manufacturing capabilities, and a strategically relevant aerospace sector. These elements form the foundation for a differentiated technological architecture centred on digital sovereignty and interoperability across heterogeneous and distributed systems.

However, these strengths coexist with structural weaknesses that limit their full exploitation. Slow adoption of advanced technologies in the European market, lack of trust in AI systems and data security, limitations in open-source technology capabilities, the loss of technology leaders to external markets, and insufficient R&D investment create a situation in which technical potential does not automatically translate into industrial leadership or market competitiveness.

At the same time, emerging opportunities such as initiatives on semiconductor sovereignty, the development of federated technology ecosystems, the reorientation of research investment, and regulatory adaptation for advanced connectivity (e.g. 5G), provide concrete pathways to transform existing assets into sustainable competitive advantages. In parallel, external threats such as demographic decline, brain drain, dependence on non-European actors, and aggressive strategies of global competitors, require urgent and coordinated action to prevent the progressive erosion of Europe's technological capacity.

## 2 STRENGTHS

### 2.1 Diverse and Advanced Technological Infrastructure

Europe has built over decades a sophisticated and widely distributed computing infrastructure, comprising edge nodes, specialised data centres, and high-capacity interconnection networks. This diversity is the outcome of sustained public and private investment, rather than an accidental accumulation, and increasingly reflects a strategic orientation towards distributed and federated architectures suited to the computing continuum.

Initiatives such as Gaia X play a central role in this context. Gaia X is designed as a federated framework to guarantee digital sovereignty through interoperability among heterogeneous edge, cloud, and IoT service providers, allowing data and services to be shared under clear European rules. Complementary projects such as Structura X (which aims to create a federated cloud infrastructure aligned with Gaia X standards), SIMPL (facilitating interoperability and secure data access), and more recent initiatives such as Sovereign X and INFRA X, consolidate an architecture capable of supporting complex computing continuum applications across sectors and borders.

In addition, the Important Project of Common European Interest on Next-Generation Cloud Infrastructure and Services (IPCEI CIS) marks a significant step in Europe's commitment to developing competitive alternatives to hyperscaler platforms dominated by non-European actors. The planned IPCEIs on Artificial Intelligence and Cloud Infrastructures further reinforce a coherent trajectory of capability-building across critical layers of the computing continuum.

### 2.2 Robust European Telecommunications Equipment Suppliers

Europe hosts globally leading telecommunications equipment suppliers, notably Ericsson and Nokia, whose market presence and technological credibility constitute a strategic asset for the deployment of 5G, 6G and edge computing infrastructures. These companies are not merely hardware providers; they are active developers of frontier technologies in areas such as radio access networks, edge processing, network virtualisation, and distributed orchestration.

Their leadership is particularly relevant in a context of rising geopolitical tensions, where the availability of trusted suppliers becomes a key factor of national and European security. The presence of robust European vendors reduces dependency on non-European actors for critical network infrastructure and enables Member States and operators to base long-term cooperation on shared values, regulatory alignment and predictable governance. This underpins both strategic autonomy and the credibility of Europe as a secure technology provider.

### 2.3 Semiconductor Manufacturing Capabilities

Europe is home to ASML (Netherlands), the global leader in advanced lithography machines for semiconductor manufacturing. This position in the global value chain provides the EU with a unique technological and geopolitical asset: control over key production equipment that is indispensable for high-end chip fabrication.

This advantage is being reinforced by the European Chips Act, an ambitious initiative to strengthen Europe's competitiveness, resilience and sovereignty in semiconductor technologies and applications. At the same time, the growing adoption of open instruction set

architectures such as RISC V opens the possibility for European actors to develop their own chip designs without relying exclusively on proprietary architectures controlled by external players.

Semiconductors form the material substrate of the computing continuum. Without sufficient control and capacity in this layer, higher layers of infrastructure, software and applications remain exposed to supply disruptions and strategic dependencies. The combination of European strengths in manufacturing equipment, policy instruments like the Chips Act, and open architectures such as RISC V creates a credible basis for a more autonomous and resilient semiconductor ecosystem.

## 2.4 European Aerospace Sector as a Transversal Innovation Engine

The European aerospace sector with major actors such as Airbus, Thales and Leonardo, goes well beyond being a specialised niche market. It functions as a powerful driver of technological innovation, with effects that propagate transversally across the digital economy. Modern aerospace operations rely on sophisticated real-time data management, predictive analytics, distributed edge-cloud processing and large-scale IoT integration. Use cases such as predictive maintenance, route optimisation, satellite constellation management, and remote sensing data processing impose demanding requirements that push forward advances in cloud, edge and IoT technologies.

In this sense, the aerospace sector serves as a “living laboratory” where new computing continuum technologies can be developed, tested and validated under stringent reliability and security conditions before being generalised to other sectors. Aerospace actors are not only consumers of digital technologies, but also co innovators contributing to the definition of performance, safety and interoperability standards. With the rapid development of space-based connectivity and low-Earth orbit constellations, the sector also offers a strategic opportunity to extend European digital sovereignty into space and to counterbalance the concentration of orbital infrastructures in the hands of a few global players.

## 3 WEAKNESSES

### 3.1 Slow Adoption and Deployment of Advanced Technologies

Despite possessing advanced technological capabilities and infrastructures, Europe faces a persistent gap between technical potential and actual deployment in the market. The uptake of cloud computing, edge solutions, IoT and advanced data analytics remains slower than required for global competitiveness, particularly among SMEs, traditional industrial sectors and regions with lower levels of digital maturity.

The underlying causes are multifaceted. From an economic perspective, many companies face uncertainty regarding the return on investment of digital transformation, are concerned about the total cost of ownership of cloud solutions, or have had negative experiences with cost escalation. Culturally, a comparatively higher aversion to risk leads many European firms to wait for technologies to mature before adopting them. Furthermore, there is often limited access to dedicated financing for digitalisation, while public and private investment still prioritises traditional sectors over next generation digital capabilities. The scarcity of visible “early adopters” and large-scale success stories further weakens the incentives for rapid diffusion.

### 3.2 Lack of Trust in AI Systems and Data Security

Although Europe benefits from robust data protection frameworks (such as the GDPR) and a strong base of secure data centre infrastructures, this does not automatically translate into operational trust in AI systems and advanced data-driven decision-making. There is pervasive uncertainty about how AI models are trained, how reliable their outputs are, and how responsibility is assigned when automated decisions produce harmful or biased outcomes. These concerns are particularly acute in high impact domains such as health, finance, public administration and critical infrastructures.

In parallel, many organisations face issues related to data quality: data sources are often fragmented, incomplete or historically biased, which undermines the performance and fairness of AI systems. There is also a skills gap: while Europe has strong academic capabilities in AI research, many organisations lack multidisciplinary teams able to design, validate and maintain AI systems in production. The combination of technical opacity, quality concerns and limited in-house expertise fuels scepticism and slows down adoption, even when the regulatory framework is in principle favourable to trustworthy AI.

### 3.3 Limited Capabilities in Open-Source Technologies

Open-source software underpins a substantial share of today’s digital infrastructure, from operating systems and container orchestration to data platforms and AI frameworks. Yet Europe suffers from a shortage of teams with advanced capabilities to develop, maintain and evolve critical open-source components. This is a global challenge, but it tends to affect Europe more strongly given its fragmentation and the limited size of some national ecosystems.

The consequences are tangible. Key open-source projects on which European public administrations and companies depend may be maintained by small, overstretched teams with limited resources. Delays in security patches, lack of long-term maintenance and insufficient governance structures can directly affect the resilience of critical infrastructures. Moreover, the relative scarcity of large-scale European contributions to key open-source projects reduces

Europe's influence over technical roadmaps and standards. This creates a vicious circle in which weak participation in open-source communities leads to weaker capabilities and greater dependence on external actors.

### 3.4 Brain Drain and Loss of Technology Leaders to External Markets

A significant number of Europe's most promising technology companies and entrepreneurs relocate part or all of their activities to other regions, especially the United States, or are acquired by non-European actors. This "brain drain" and externalisation of high-growth companies is a symptom of deeper structural issues in Europe's innovation and scaling environment.

Financing conditions are a central factor: venture capital markets in Europe are comparatively more conservative, with smaller ticket sizes and lower tolerance for high-risk, high-reward projects than in other major innovation hubs. Regulatory and market fragmentation also complicate scaling across borders, whereas competitors operate in larger, more homogeneous internal markets. The result is that European-origin companies often need to move abroad to access growth capital and global networks, leading to a loss of talent, intellectual property and strategic control over key technologies that were initially developed in Europe.

### 3.5 Insufficient and Fragmented R&D Investment

Investment in ICT research and development in Europe remains below the level required to sustain leadership in rapidly evolving technological domains. Public programmes such as Horizon Europe mobilise substantial resources, but funding is often dispersed across numerous calls and relatively small projects, with complex administrative requirements that can discourage participation by SMEs and emerging actors.

Furthermore, the translation of research results into industrial innovation is still uneven. High quality research produced by European universities and research centres does not always find clear pathways to the market, due to gaps in technology transfer mechanisms, access to risk capital and the lack of long-term, mission oriented programmes. Fragmentation across Member States, with overlapping national initiatives that are not always aligned, can dilute impact and reduce Europe's ability to compete at scale with more centralised innovation systems.

## 4 OPPORTUNITIES

### 4.1 Promoting Open Hardware Initiatives for European Semiconductor Sovereignty

The recent global chip shortages have underscored the vulnerability of relying on external semiconductor supply chains for critical sectors such as automotive, telecommunications, health and defence. At the same time, the emergence of open instruction set architectures such as RISC V has broadened access to chip design capabilities and reduced barriers to entry for new players.

This creates a window of opportunity for Europe to accelerate investment in open hardware initiatives, combining industrial policy (e.g. the European Chips Act), support for design capabilities, and collaboration with industry and research organisations. By doing so, the EU can reduce its structural dependency on external suppliers, strengthen its position in key segments of the value chain, and build a semiconductor ecosystem aligned with European values and security requirements. A robust and more autonomous semiconductor base is indispensable for underpinning the entire computing continuum, from constrained edge devices to high-performance computing.

### 4.2 Developing a Federated Technology Ecosystem for Dispersed Resources

The global cloud market is currently dominated by a small number of hyperscalers that centralise data and computing capacity. Europe has an opportunity to promote an alternative model based on federated infrastructures and services, in which multiple providers remain independent but interoperable through common standards, reference architectures and governance frameworks.

Projects such as Gaia X and IPCEI CIS embody this approach by enabling edge, cloud and IoT nodes to share services, improve resource utilisation and offer users greater choice while preserving data sovereignty. A federated ecosystem can: bring computation closer to where data is generated; enable smaller providers and industrial players to participate in common platforms; reinforce compliance with EU rules on data protection, cybersecurity and competition; and enhance Europe's capacity to shape global norms on trusted and interoperable digital infrastructures.

### 4.3 Reorienting Research Investment and the Structure of Horizon Europe

The current configuration of EU research and innovation programmes, while extensive, often results in fragmented efforts and limited capacity to address large-scale, systemic challenges such as the consolidation of the computing continuum. There is an opportunity to adjust the design and implementation of programmes like Horizon Europe to enable more ambitious, mission oriented initiatives.

A more strategic approach would involve concentrating resources on a smaller number of large, multi-country, multi-actor projects that explicitly target the development and deployment of end to end computing continuum solutions. Simplifying participation rules, especially for SMEs and emerging players, and providing longer-term, stable funding horizons would also

increase the likelihood that research outputs translate into industrial capabilities and competitive products and services.

#### 4.4 Clarifying Net Neutrality Rules for Innovative Use Cases Such as 5G Network Slicing

European net neutrality rules constitute an essential safeguard for an open and non-discriminatory internet. However, certain innovative technologies (particularly 5G network slicing and other forms of quality-differentiated services) require a regulatory framework that allows for technically justified differentiation while preventing anti-competitive practices and unfair discrimination.

Clarifying and updating guidance on how net neutrality applies to advanced connectivity use cases would enable operators and service providers to deploy network slicing and other innovative features in a legally certain environment. This would support new applications in areas such as connected and automated mobility, e health, industrial automation and public safety, while preserving the core principles of openness, fairness and user rights that underpin the European regulatory model.

#### 4.5 Coordinating Technical Standards at EU Level for Network APIs, Edge Computing and IoT

The fragmentation of technical standards and interfaces across national markets and vertical sectors remains a major barrier to the seamless deployment of computing continuum solutions in Europe. There is a clear opportunity to coordinate and align technical standards at EU level, particularly in areas such as network APIs, edge computing interfaces and IoT device interoperability.

By promoting common European reference frameworks and encouraging convergence around open, interoperable standards, the EU can reduce integration costs, accelerate deployment and make it easier for developers and service providers to scale solutions across borders and sectors. Coordinated standardisation efforts would also strengthen Europe's influence in international standard-setting bodies and help ensure that global norms reflect European requirements in terms of security, privacy, competition and sustainability.

#### 4.6 Exploring Niche Markets: Aerospace and Telecommunications

In several mature digital markets, non-European actors have already consolidated dominant positions that are difficult to contest. Nevertheless, Europe retains significant strengths in specific strategic niches, notably aerospace and telecommunications, where it still has strong industrial players, advanced capabilities and a solid regulatory framework.

Leveraging these niches as launchpads for computing continuum solutions can generate multiple benefits. In aerospace, extending the continuum to include satellites and space-based services can provide secure connectivity, Earth observation and navigation services that are tightly integrated with terrestrial infrastructures. In telecommunications, the deployment of advanced 5G and future 6G networks, combined with edge and cloud capabilities, can support highly demanding industrial and public-sector use cases. These niches can serve as anchor markets that accelerate learning curves and support the emergence of competitive European solutions.

## 5 THREATS

### 5.1 Demographic Decline and Loss of Competitiveness

Europe is facing a structural demographic decline, characterised by ageing populations, low birth rates and, in some cases, net outward migration of younger cohorts. This trend directly affects the availability of skilled labour for technology-intensive sectors and constrains the capacity to renew and expand the digital workforce required by the computing continuum.

When contrasted with regions that enjoy more favourable demographic dynamics and larger young populations, Europe risks a relative reduction in its innovation and entrepreneurship base. This may limit the ability of European companies and research institutions to sustain the pace of technological change and compete effectively in global markets.

### 5.2 Brain Drain and Company Relocation

The ongoing loss of high-skilled professionals and high-potential companies to other regions exacerbates Europe's demographic challenges. When leading technology firms relocate or are acquired by non-European actors, not only are jobs and tax revenues affected, but entire innovation ecosystems are weakened, including supplier networks, research collaborations and startup communities.

Over time, this process can generate a self-reinforcing cycle in which the reduced presence of successful scale-ups and innovation leaders makes Europe less attractive for entrepreneurs, investors and talent, further accelerating the outflow of key actors. For the computing continuum, this implies that critical know how, intellectual property and strategic decision-making may progressively shift outside the EU.

### 5.3 Global Competition and Strategic Dependencies

The EU operates in a global environment where a limited number of non-European actors dominate key technological layers, including cloud infrastructures, operating systems, key software platforms and advanced semiconductor manufacturing. These dominant positions are supported by coordinated industrial policies, large internal markets and deep pools of capital.

Such concentration creates strategic dependencies for Europe. In times of geopolitical tension or trade disputes, access to essential technologies, components or services could be restricted or become subject to conditions that do not align with European interests or values. Even in normal conditions, the asymmetry of bargaining power between European users and dominant external providers can limit Europe's ability to shape technical and contractual terms, reinforcing lock-in and limiting room for manoeuvre.

### 5.4 Dependence on Non-European Technologies if European Alternatives Are Not Sustained

Europe has launched several initiatives aimed at strengthening technological sovereignty including the Chips Act, Gaia X, IPCEIs and various national programmes. However, there is a material risk that some of these initiatives may not reach sufficient scale, maturity or market adoption to constitute credible alternatives to non-European technologies.

If promising projects are not adequately funded, sustained over time and aligned across Member States, Europe may find itself in a situation where it has invested significant resources without achieving the intended autonomy, while external dependencies persist or deepen. This would weaken trust in public interventions, discourage private investment and reduce Europe's capacity to influence the evolution of key technologies in line with its strategic objectives.

## 5.5 Aggressive Strategies of International Competitors

Major international competitors, notably large US and Asian technology companies, deploy comprehensive strategies to expand their footprint in European markets and integrate European talent, data and infrastructures into their global ecosystems. These strategies combine acquisitions of European startups, large-scale infrastructure investments, intensive recruitment of local experts and strong engagement with public authorities and regulators.

While such investments can bring short-term benefits in terms of jobs and services, they can also contribute to the externalisation of strategic control, the erosion of local competitors and the concentration of data and intellectual property outside the EU. Over time, this may limit Europe's ability to autonomously define its technological trajectory, set its own standards and ensure that digital infrastructures and services evolve in line with European values and policy objectives.

## 6 Synthesis

**Factor 1** - Technology, Innovation and Research Capabilities, is characterised by a complex configuration in which solid structural strengths in infrastructure, semiconductor-related capabilities and strategic industrial sectors coexist with significant weaknesses in technology uptake, trust in emerging technologies, open-source participation, talent retention and the scale and coherence of R&D investment.

The EU has concrete opportunities to build technological sovereignty and competitiveness through open hardware and semiconductor initiatives, the development of federated infrastructures, the reorientation of research and innovation programmes, regulatory adaptation for advanced connectivity, the strategic use of strong niche sectors such as aerospace and telecommunications, and the coordination of technical standards at EU level. At the same time, threats related to demographic trends, brain drain, global competitive asymmetries, persistent dependencies and aggressive strategies of non-European actors underline the need for a sustained, coordinated and long-term response to ensure that Europe's technological potential is effectively translated into leadership across the computing continuum

**Factor 1** constitutes the core technological pillar for consolidating the cognitive computing continuum in Europe. It encompasses the technological capabilities, innovation capacity, and research competencies that enable the EU to develop a sovereign, resilient, and globally competitive digital infrastructure.