

The European vision and research directions in the Cloud-edge-IoT domain for 2025-2027

An executive summary of the Concertation meeting in Brussels on 11 May 2023

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European vision in Cloud-Edge-IoT 25-27: Executive Summary

The convergence of Cloud Computing and the Internet of Things (IoT) has been a key megatrend of the last years and, while still ongoing, it is now expanding into a much larger and more strategic vision for ICT infrastructure, services, and applications covering not only Cloud, Edge, and IoT computing but also other critical areas such as 5G/6G telecommunication, High-Performance Computing (HPC), and Quantum Computing. Such a vision has been named Computing Continuum, and Europe can and must continue to play a leading role in it.

The first day of the Concertation and Consultation meeting on the computing continuum event focused on the thriving European research community working around the computing continuum, spanning more than 40 projects and the two programmes Horizon 2020 and Horizon Europe; the second day moved forward from the current landscape, to tackle the next three years of Horizon Europe (2025-2027) and beyond. The comprehensive consultation meeting blended research agendas from relevant initiatives (SW Forum, HiPEAC, NESSI, AIOTI, European Alliance for Industrial Data, Edge and Cloud, INSIDE, FIWARE Foundation) with more than 30 Expressions of Interest from industrial players of all sizes, academic researchers, EC-funded projects and ad-hoc author groups, advocating and outlining the importance of continued support for several novel research and innovation directions to further the vision and progress of the Computing Continuum.

Above and beyond the specific research topics and their grouping into four larger domains, both the Expressions of Interest (EoIs) and the Strategic Research and Innovation Agendas (SRIAs), as well as the subsequent discussion, framed the challenges and opportunities of the Computing Continuum within a much larger socio-economic and geopolitical context.

The first aspect of relevance within this broader picture is value-based openness for technology and infrastructure: while Europe welcomes contributions and economic activity from anywhere in the world and encourages open collaboration, it also takes the necessary normative and consensual measures to ensure a level playing field for all operators and protect European values. This was touched upon in various parts of the event, such as the frequent mentions of Open Source and Open Hardware with their global nature, the presence of targeted calls inviting international cooperation on the cognitive Computing Continuum, or the pervasive focus on trustworthiness in Artificial Intelligence.

A second socio-economically relevant thread running through the consultation presentations and debate revolved around resilience and digital autonomy: Open Source and Open Hardware, initiatives like the European Data Spaces or the RISC-V family of processors, are not just to maximise the impact of globally well-intentioned contributors but also to remove the risk of any single (national or private) actor taking the results away from the community or jeopardising them through excessive and arbitrary control. From a more technical perspective, the Computing Continuum vision and infrastructure result in a hyper-distributed system of systems that is resilient towards both disasters (natural or human-made) and malicious actors. Multiple research topics, such as cybersecurity, dynamic orchestration,



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cognitive systems management, and industrial metaverse, hold great promise to benefit Europe's resilience, strengthen its strategic economic sectors and supply chains, and reduce critical dependencies from non-European providers (some of which have been clearly identified in multiple SRIAs and Eols).

Lastly, and perhaps most importantly and certainly on a much larger scale, the challenges and opportunities associated with the twin green and digital transition. Beyond the many use cases of environmental relevance that were considered in the presentations, energy sourcing and efficient usage are among the main parameters driving orchestration in the Computing Continuum, and the proposed AI techniques are often more resource- and energy-aware than in a traditional Big Data and Cloud Computing setting.

A thematic analysis of the submitted Expressions of Interest resulted in their classification into four macro-topics structuring the research agenda around the Computing Continuum:

- **The European Union (EU) Computing Continuum Infrastructure** needs to undergo a transformation, particularly in regard to European Cloud-Edge Servers. This transformation seeks digital autonomy through strategic interventions, including adopting the open-source Instruction Set Architecture (ISA) RISC-V to strengthen EU sovereignty in the Computing Continuum. Further developments should also consider energy-aware computing and resource sharing via federated computing.
- **The Cognitive Cloud-Edge Continuum** addresses challenges from emerging trends like Virtual Worlds. To create an Industrial Metaverse, digital and physical elements need to intertwine, orchestrated by an intelligent cloud to edge to the IoT continuum. This brings research challenges such as end-to-end AI integration, dynamic data orchestration, new runtime management, self-adapting clouds, decentralised optimisation, and convergence with 5G/6G technologies.
- **The Next Generation MetaOS for IoT-Edge** discusses the complexity of merging the physical and virtual worlds. With the proliferation of IoT objects, challenges include data inflation, heterogeneous data types, and task concurrency. The focus is on the transition to spatial-aware computing, extended reality (XR), and the vision of an Industrial Metaverse. It emphasises distributed intelligence and collaborative industrial systems at the IoT-Edge Continuum.
- Lastly, **cybersecurity, privacy, interoperability, open source, and software engineering** issues are addressed. This involves secure SecDevOps for complex systems, AI application throughout the Software Development Life Cycle (SDLC) and Service Operation Life Cycle (SOLC), data confidentiality in the cloud-edge continuum, and new software engineering mechanisms for (hybrid) quantum software, highlighting the importance of open hardware and software.





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