Next-Generation Internet of Things and Edge Computing

Event Report from the Fireside Chat of 9 March 2021

European Commission, CNECT-E4

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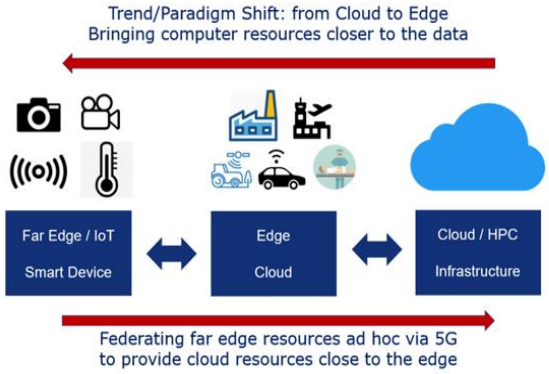

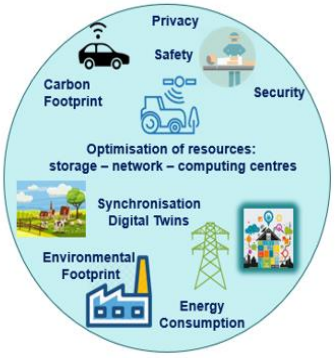

The Fireside Chat workshop mobilised and connected invited key stakeholders and experts to advance the design of a **strategic European vision for Next-Generation IoT and Edge Computing with a market window of 5+ years**. Edge computing is the logical evolution of the dominant cloud-computing model, avoiding the transfer of mission-critical data to the cloud, supporting resilience, real-time operations, security, privacy and protection while at the same time reducing energy consumption and carbon footprint. In Edge Computing, the processing moves from a centralised point, closer to (or even onto) the IoT device itself, the 'edge' or periphery of a network. Today's public cloud infrastructure market is controlled by three global companies headquartered in the United States, accounting for 80% of global revenues. Within the next 5 years, , a paradigm shift is predicted such that75**% or more of the data processing and analytics will run at the edge of the network where it is most efficient to create the "Internet of Intelligent Things.** This gives European industry a unique opportunity to capture this market by developing the technologies and common intelligent digital infrastructures, interoperability standards and regulations, to enable industrial digitalisation at scale. Digital technologies are part of the "New Economy and Society" and are essential to future industrial progress. Europe must fully grasp the potential of the next "Digital Decade", and **B2B platforms for industrial and business IoT and edge computing will be at the heart of digitisation across industrial sectors like automotive, manufacturing, energy, agri-food, healthcare, building and logistics**.

> Next-Generation IoT and Edge Computing unlock the potential for intelligent autonomous applications becoming a key factor in the coming years for creating the Internet of Intelligent Things.

> The opportunity for Europe is at the intersection of the Cloud IT world and the operational world, because we are stronger in the operational world.

The initiative on Next-Generation IoT and Edge Computing supports implementing **the European Strategy** for **data across the IoT-edge-cloud continuum**. It provides a **medium-term 5-years+ future-looking perspective complementing Europe's initiatives on common data spaces and federated cloud infrastructures**. Whereas these infrastructures are supported through the deployment-oriented Digital Europe Programme, the initiative on the Next Generation IoT and Edge Computing will be supported by a research and innovation theme on Cloud-to-Edge-to-IoT under the first Work Programme of Horizon Europe.

The Edge and Edge-Cloud federation is game changing and in real-time applications non-functional and functional requirements have to be addressed together. The winner will be the one who understands fully the sectoral requirements.

IoT and Edge Computing Platforms and Orchestration Mechanisms are needed to provide an integrated environment for the next-generation intelligent decentralised IoT systems, which embed IoT in distributed computing systems operating in a continuum from Cloud-to-Edge-to-IoT. These Next-Generation IoT and Edge Computing platforms will lead to new marketplaces and business models relying on orchestration[1] systems (or meta-operating systems), distributed intelligence, storage, cognitive cloud technologies, and resources heterogeneity.

A European Strategy to Seize the Opportunity

The EC is adopting a balanced approach with top-down actions stimulating alliances at a corporate level underpinned by bottom-up targeted R&I to build a solid foundation for an IoT and Edge Computing ecosystem.

Within this paradigm shift towards Next-Generation IoT and Edge Computing and value creation at the edge, **Europe should capture the opportunity to benefit from its expertise in industrial real-time and safety-critical systems, embedded processing, industrial IoT combined with edge computing, industrial AI, intelligent connectivity and gain leadership in the New Digital Economy**. Robust European level intervention and coordination is needed to encourage industry, organisations, and research to come and act together to create the critical mass to address pressing challenges in Next-Generation IoT and Edge Computing and to provide open multi-vendor platforms enabling the advancement of IoT and edge computing technologies, applications and services, which operate in a dynamic continuum from Cloud-to-Edge-to-IoT. This requires new research and innovative developments that will allow Europe to compete successfully in the New Digital Economy landscape while maintaining its technological sovereignty for critical applications.

Already several key initiatives, e.g., Cloud Alliance, GAIA-X, are concentrated on the cloud and edge. The EC wants to complement these by strategically supporting activities in the next five

[1] Various services will rely on local traditional Operating Systems, but there is a need to orchestrate these services to build added-value and create applications from those distributed services. The real challenge is the orchestration.

years on Next-Generation IoT and Edge Computing, which seed investment and encourage European collaboration. With a budget of nearly **€150M, the aim is to support larger strategic projects bringing together key players in a way that reinforces and complements national and EU strategies**. The first call is planned on "Meta-Operating Systems for the Edge" to provide orchestration, AI at the edge and containerisation support for IoT and edge computing ecosystems. It aims to stimulating platforms and marketplaces driven by EU actors. In 2022 a call will be made on "New Paradigms for Distributed Computing and Swarm Intelligence", targeting the programming of groups/swarms of embedded devices in a computing continuum. This will be complemented by a call on cognitive cloud frameworks embedding cloud-to-edge-to-IoT in a compute continuum. Finally, in 2023 a horizontal call is envisaged to support "Open Sectoral Platforms and Ecosystems". The EC aims to bring together a critical mass to create the building blocks for European solutions.

Workshop Messages

Perspectives were discussed from the automotive, home automation, aerospace, agriculture, construction machinery and industrial automation industries, as well as from current partnerships, platform communities, and R&I set-ups. In the workshop, **there was general agreement, even between competitors, on the need for trusted IoT and Edge Computing Platforms and Orchestration Mechanisms to support this digitisation**. The balanced initiative was warmly welcomed by the industry as it is very much needed complementing and bridging between the Joint Undertakings on Key Digital Technologies and Smart Networks and Services; the partnership on AI, data and robotics (all under Horizon Europe); and the more adoption-oriented initiatives on sectoral data spaces and Cloud/Edge federations (under the Digital Europe Programme).

> The balanced approach was welcomed as it will bring actors together with a sense of urgency to play a significant role in supporting Europe's strategic autonomy and leading role in the Data Economy beyond 2025.

Industrial Focus on Integration Platforms

Automotive Sector

> In the automotive and mobility sector, Europe should lead in development of solutions but these needs to address the much larger worldwide markets.

There are strong Tier 1s within Europe in the automotive sector, but there is a revolution going on with extensive electronics integration in the last ten years. Electronics' role is expected to grow massively driven by surface mobility, safety (connectivity and autonomy), performance improvements in Advanced Driver Assist Systems, and electrification with battery and hydrogen fuel cell options. This radical change is strongly accelerating with a shift in vehicle models, more significant variants and shorter innovation cycles. **Software will play an increasingly important role in future vehicle generations. New trends such as electro-mobility, automated driving, and modern mobility services would not be possible without them.** This will

also require more frequent updates and upgrades in the future. Challenges arise with more functions and services implemented in software and the increasing complexity of electronic component interoperability, including managing agile and vulnerable supply chains in terms of logistics and production processes.

Integration Platforms - **Integration platforms are strongly needed to reduce development time and increase product quality**. However, there is some caution for developing meta-orchestrating systems even if they could provide an integration framework that provides better traceability, safety, and cybersecurity. Such systems will need to take into account the non-functional properties, such as time to execute a task, the response time (latency), the energy needs and carbon footprint (in term of memory, processing power), cost, etc. For example, in the automotive industry, mixed criticality is important: the goal is to consolidate critical and non-critical services on the same "module", but with a guarantee of service for the critical parts while providing a good segregation between services. The meta-orchestrator should ensure that all these requirements are met. Likewise, there is some caution for the development of swarm distributed intelligence. Currently, sensors need to act with valid secure, centralised intelligence, however, future V2X and V2I systems will need to act with distributed intelligence, but the industry is not yet at the point of having thousands and ten thousand sensors working in a coordinated way independently of each other. Security aspects will need special care, including the introduction in the system of false data by "rogue" cars or sensors.

Strategic emphasis is needed on multi-vendor integration platforms.

Connectivity - Connectivity was highlighted as a core element of an integration platform, and this is expected to grow as large amounts of data transfer will be needed. The Automotive Edge Computing Consortium (AECC) already works with leaders across industries to drive the evolution of edge network architectures and computing infrastructures to support high volume data services in a smarter, more efficient connected-vehicle future. **As vehicles become more connected and (partly) autonomous, the data collected and transferred will rise rapidly, leading to the need for distributed computing.** This requires management across multi-actors and on a global scale with the filtering of cloud data. Processing of data needs to be performed as close to the source as possible, meaning the far edge of the cloud network edge itself. Standards are required for real-time, secure and safety-critical communication as part of the system design.

Intelligent cellular and wireless connectivity are essential to provide real-time, low latency in mobile communication services.

Need for Industry Focused Edge Platforms - There is an intersection between the real-time safety and cloud worlds, and it is important not to replicate what cloud providers do but provide solutions that are cloud provider agnostic. Building supporting platforms would have a substantial impact. **Platforms and collaborations within ecosystems are needed, for instance, platforms for connected, autonomous driving and fully electric vehicles.** As there are many automotive companies, competition neutral standards are required that give some competitive advantages. In the transition towards more software-driven components and systems, there is

We need open solutions that are cloud provider agnostic.

a strong need for a data strategy and for establishing trusted data exchange frameworks across OEMs, system integrators and component vendors for innovative data-driven services like predictive maintenance, tracing of failure detection across the complex value chain, or agile production and logistics planning.

Home Automation

In the fragmented Home Automation market, interoperability standards are essential at an international level, particularly with the US (on IP). As a result, many European companies are actively engaged in US-based alliances and associations. **Key needs are interoperability backed by simple security to meet user expectations.** Amazon, with its Alexa ecosystem, Apple with Homekit (and Siri) and Google are actively promoting their solutions for B2C, and they are pushing a certain level of interoperability between their respective ecosystems with initiatives such as CHIP (Connected Home over IP). The move to edge computing enables the efficient optimisation of resources across different vendors and may reduce the attack surface by keeping data local. It can also be a guarantee of the continuity of service if the service provider goes bankrupt or changes its business model from free to subscription. An open meta-operating system might be interesting if it introduces new functions and aggregation of resources, but shared governance is needed on integration rules, APIs, presentation of non-functional properties for selection of services to orchestrate, and security management across different vendors. Cybersecurity is critical to get value from services and data.

Key needs in home automation are interoperability backed by simple security to meet user expectations.

Communication Standards and Protocols – Standards and protocols for communication are also essential. **Resilient 5G networks are needed to offer real-time, low latency communications in mission-critical applications. They must be seamlessly integrated with computing and control at the system level**. There are, in particular, opportunities to create a stronghold for networking in real-time Ethernet standards such as the Time Sensitive Networking (TSN) Standard. Finally, Telecom edge cloud service offerings will bring cloud services closer to the customer, opening a new strand of revenues to Europe's Telecom services providers.

Resilient 5G connectivity will open up many new real-time control applications.

Manufacturing and Industrial Automation

Support from the EC for industry-focused edge platforms would be useful for industrial automation and to be successful time to market and speed is important in order to gain independence from hyper-scalers. It is neither appropriate nor wise to exclude them, but it is important to ensure that they will fulfil the user's requirements in term of privacy of data, IP protection, etc. Technical solutions (such as Homomorphic Encryption) may offer a solution to this if they can be made affordable in terms of computing requirements. This would allow users to run trusted applications on untrusted servers. All services should expose to the orchestrators their properties, including the ones required for CPS applications (latency, processing time,

guarantee of service), for green (energy requirement) or privacy (localization, use of private data, encryption, …) etc.. The user (or later the automated orchestrator) could select the service (and therefore the service provider) that will correspond to system requirements. Time to market and speed is essential to gain diversification and provide alternative competitive solutions to hyper-scalers.

Data Sharing - **Support from the EC for Next-Generation IoT and Edge Computing would be useful for industrial automation only if backed by international standards for connectivity, communication and protocols and, in particular, for data access and exchange.** For instance, data access is still part of the bargaining process between suppliers and OEMs, and there are still pain points under discussion. A specific interest here is in sharing fault data between OEMs and suppliers in the context of collaborative quality management to reduce vehicle recalls. There are currently bottlenecks in gathering fault data that may take over six months to access from the aftermarket. Data is currently stored in different silos, and to shift from asset-driven quality management to data-driven quality management, there is a need to share data multilaterally between OEMs and suppliers. To encourage actors to engage with this and share data, a trusted platform and framework is being developed under the GAIA-X initiative for sharing relevant information to identify faults and reduce recalls. Cloud-to-edge computing is becoming pervasive in areas such as predictive and preventative maintenance.

> Future prosperity will continue to depend upon producing things, however, digital services will increasingly contribute to a percentage of this prosperity, firstly from smart products, and then from sharing data to creating new services – all requiring new thinking around value creation and business models.

European Leadership- Although Europe lacks hyper-scalers; there is strength in industrial embedded applications with a strong leading industrial capability in building things such as cars and aerospace with excellence in safety-critical and real-time systems. Many safety standards developed in Europe have propagated to the US and China. There is no point in trying to replicate what the US and China are doing. **Europe should leverage on its strengths in real-time safety-critical control and security in the car, aerospace, construction, energy, agri-food and industrial automation domains**. New European solutions should be built on top of existing widespread open solutions in order to gain fast and wide acceptance enabling companies to scale quickly.

Platforms and Partnership Perspectives

Trusted Environments - **A trusted environment is needed for the industry to create benefits in the data economy and encourage business to share data** so that they are not worried about theft of trade secrets, fears of customer poaching, etc. Data platforms could act as a gatekeeper at the edge, enabling data sharing but need to be open with open APIs to avoid vendor lock-in and create trust. The French-German initiative, GAIA-X, targets cloud and data sovereignty, data interoperability and portability and fits well with distributed

> For Europe to play a leading role in the future data economy, partnerships are needed between its digital and industrial actors within and across verticals to develop and deploy trusted, open multi-vendor platforms.

edge computing. The architecture provides terms and conditions for data sharing to promote trust. Within the architecture, data needs to be machine-readable, and "things" need to find each other via a federated catalogue. Cloud platform providers tend to use centralised business models to dominate the data value chain extending the applications to industrial and other edge data sources. The more data there is, the more network effects there are , and the more services provided by monetising the data value. To achieve Digital Sovereignty, it is essential to understand the whole data value chain, and Europe needs to support a transparent and trusted data governance framework.

Hyper-scaler Dominance Risk - The edge is seen as an extension of what many companies are aiming for processing their data, and hyper-scalers see the edge (mainly in the B2C approach, with smart orchestrators or aggregators of functionalities like Amazon's Alexa or Apple's Siri) as an opportunity to proliferate cloud business towards established industrial sectors. Europe must decide on which areas it wishes to extend the advancement of data collection, processing and analytics, and already initiatives such as GAIA-X are trying to address these opportunities. **The risk in transferring these functions to hyper-scalers is that the industrial stakeholders would need to share significant vertical knowledge from within their domains** such as manufacturing, etc., to optimise and make the systems work on the remote cloud platforms.

Real-Time Requirements - For Europe to keep its leadership in real-time requirements in industrial domains like manufacturing, energy, health, automotive or building automation, **a strategic approach is needed for a Next Generation IoT and Edge Computing programme starting with a real-time focus covering the complete continuum IoT-Edge-Cloud**. Mission and safety-critical real-time industrial applications and services require guaranteed latency, bandwidth, data integrity, security, resilience and controlled mesh networking. As proposed by GAIA-X, providing multi-stakeholder resilient and reliable infrastructure solutions that target reference implementations and use cases across industrial sectors to offer predictability and interoperability strengthen digital technologies development. **The EU needs to invest and facilitate investment in interoperable IoT and edge technologies, solutions and infrastructure so that Europe is prepared for 2025 when most data collection, processing and analytics will be performed at the edge.**

> Technology is a means, not an end: digital sovereignty is needed to avoid lock-in and lock-out effects, but we should not do it all ourselves – we must decide what we want to have control over.

Data Sharing - To meet industry's digitisation challenges it is necessary to build a Next-Generation IoT and Edge Computing ecosystem based on corporate technologies, services and applications that are open to innovation and start-ups. **Large companies and SMEs are concerned about sharing data.** This is typically done in bilateral collaborations. The new digital economy paradigm requires multilateral partnerships based on clear business models to evolve new ecosystems and value networks involving stakeholders across the data value chain. Here help is needed in setting up these business models and in scaling up businesses. One of the challenges is to get large and small players to co-operate in a very segmented

> A challenge is to get big and small players to cooperate in a very segmented industrial infrastructure and field of players.

industrial infrastructure and field of players. This raises the question of how smaller players can contribute to development of IoT and edge computing platforms and how such platforms can be made easily accessible/useable for start-ups and scale-ups. Here, one must distinguish between different types of SMEs. There are start-ups/scale-ups that have a potentially huge contribution to make to European technological leadership in IoT and edge computing on the global stage. Other SMEs (for instance integrated in the automotive supply chain) will need to advance in technology adoption but will not necessarily develop their own technologies.

Success Factors - A top-down approach has to start with a dialogue with the leading industrial actors to address the level of interoperability and platform integration required to build on existing vertical ecosystems. Success depends on how efficiently EU actors can master competencies to create a complex software framework, leveraging on the next wave of edge/cloud technologies and services by exploiting the advances in AI and the microelectronics/semiconductor industry. **There is a need to act swiftly to ensure that a multi-vendor IoT and edge platform approach is adopted to avoid silos. Portability of data (and services) is key allowing both a true multi-vendor approach and avoidance of de facto lock-in.** Open source, with the source code publicly available for audit and inspection is one potential solution to promote rapid adoption. Internet companies are already teaming up with EU telecom providers extending their cloud ecosystem towards the edge, which could spill over into industrial sectors' domination, adversely affecting innovation in the edge-IoT/ far edge domain.

Future Research and Investment Priorities

Internet of Intelligent Things - IoT and IIoT are the driving forces behind Next-Generation IoT and Edge Computing, and there is a convergence of technologies in IoT, edge computing, AI, wireless and cellular 5G/6G, digital twins, etc., which is leading to new terms such as "artificial intelligence of things", "internet or intelligent things" and "swarm intelligence". **In particular, there is a need to address the collective intelligence in a system with no centralised control structure**. Bringing the data from the edge to the cloud providers is essential for digitising products and services, and Europe should drive the development of such integration bottom up. The EU needs to take urgent actions to facilitate and coordinate investment in interoperable edge solutions. There is a need to work together across IoT and NGI, Cloud, Smart Networks and Services, Key Digital Technologies, AI and Big Data Security, and Low Power Processing.

> Swarm Computing is a promising new concept for self-organising IoT systems with huge potential, which has to be developed further before it is ready for the market.

Web of ICT - **The integration of advanced digital technologies like IoT, AI, cloud, etc., will lead to radical changes in value creation for European industry, causing a paradigm shift from system-driven innovation towards a data and service-centric economy**. A "Web of ICT" exploiting cross-domain services utilising Apps built upon the continuum of computing is required. The evolution to "next web" will expose composable services getting their

> IoT is not the same as surfing the web and trusted IoT and Edge Computing Orchestration Platforms are important for the future to allow companies to share data under clear rules.

information from IoT devices and sensors, associated with contract-based programming approaches that will specify functional and non-functional requirements such as response time and latency, energy requirements, migration of the service to a local computing resource (IoT device), cost, etc. This will require the management of many networked objects and systems to create new applications and services.

Key elements needed by IoT and edge computing applications are platforms, ecosystems, acceptance/trust and interoperability.

Orchestration - Orchestrators will select and compose services according to users' preferences and will orchestrate their execution in a coherent and "smart" way. There are many challenges for this orchestration layer. **All the pieces exist, but there is a need to glue these together, requiring a cross-disciplinary synergetic orchestration programme**. The orchestrator, or trustable distributed meta-level operating system, will also be in charge of managing the in-bound (security, verification of trust) and out-bound (privacy and confidentiality) of data, acting as the "Guardian Angel" of users' assets. The "programming" of this intelligent orchestrator can be done using natural interfaces, such as voice, drawings and schematics, or even by examples, thanks to innovations brought about by AI techniques. In this context, new IoT and edge computing open decentralised and distributed architectures are needed to provide cross-domain resource orchestration for the continuum-X integration (end-to-end capabilities). The new operating systems and orchestration mechanisms need to address the heterogeneity of devices and technologies while integrating lightweight virtualisation, virtual machines, micro-services, containers, and uni-kernels. This includes methods for updating and upgrading multiple IoT edge devices and providing parallel processing capabilities. Swarm intelligence capabilities require further development of physical and virtual IoT edge systems to integrate into IoT platforms (digital and virtual IoT twins in the computing continuum). Scalability, efficiency, dependability/trustworthiness, adaptability and transparency (processing capabilities, bandwidth, resources, management and orchestration) will be some of the challenges that need to be addressed. **Europe should quickly synergise its talents in a cross-domain programme and initiate the next wave of Internet of Intelligent Things edge and swarm computing following European ethics before non-European initiatives impose it.**

Concluding Remarks

A feature of the Fireside Chat meeting was the agreement from participants in the need for European level action to act quickly to stimulate the community to come together to avoid silos, exploit existing strengths, and seize the opportunity in the rapidly developing next generation IoT and edge computing ecosystem. **There is a need for a trusted collaborative group discussion on topics, particularly in the systems design domain, where there are strong competencies in sensors and systems to make reliable systems.** The importance of a top-down governance and orchestration approach complementing bottom-up research was emphasised. The EC is keen to seed investment within Horizon Europe and Digital Europe to encourage European collaboration on cloud-to-edge-to-IoT infrastructures and dataspaces to create critical mass via a range of research and deployment programmes that develop and roll out technologies as they come to

market. The participants indicated that support for research and development in the following topics would have strong potential in boosting the emergence of a European Next-Generation IoT and Edge Computing ecosystem:

- Future Platforms for the IoT exploiting Meta-Operating Systems and orchestrators
- Development of a Cognitive Edge-Cloud Frameworks and federation for the AI-Enabled Computing Continuum
- Environments and Tools for Decentralised Intelligence at the Edge of the IoT and swarm computing
- Open Sectoral Platforms and Ecosystems addressing vertical sectors

The Data Economy is seen as key for the future and capturing and creating value from data will lead to new business cases and wealth creation. The aim is to create a single European Data Market while maintaining data sovereignty as IoT data generation at the edge explodes.

Participants

Distinguished Speakers	Industry Guests	European Commission
Ovidiu Vermesan (SINTEF, AIOTI)	Daniela Haubner (TTTech)	Pearse O'Donohue (Future Networks, CNECT)
Hubert Tardieu (GAIA-X)	Andreas Eckel (TTTech)	Max Lemke (IoT , CNECT)
Marc Duranton (CEA)	Michaela Pany (TTTech)	Rolf Riemenschneider (IoT, CNECT)
Svenja Falk (Accenture)	Francesca Flamigni (TTTech)	Zoe de Linde (IoT, CNECT)
Jean-Michel Orsat (Somfy)	Daniel Kern (Bosch)	Joel Bacquet (IoT, CNECT)
Jean-Luc di Paola Galloni (Valeo, Artemis-IA)	Alina Mextorf (Fraunhofer)	Jan Komarek (IoT, CNECT)
Boris Otto (Fraunhofer, IDSA)	Franziska von Scherenberg (Fraunhofer)	Arian Zwegers (Microel. & Photonics, CNECT)
Tanya Suarez (Bluspecs, AIOTI)	Max de Spirt (Fraunhofer)	Maria Tsakali (Cloud & SW, CNECT)
Christer Boberg (Ericsson)	Haydn Thompson (THHINK, reporter)	Luis Carlos Busquets Pérez (Cloud&SW, CNECT)
Michael Jochem (Bosch)		
Stefan Poledna (TTTech)		Olivier Trouille (IoT Unit, DG CNECT)

This report of the Fireside Chat Meeting was compiled by Haydn Thompson (Thhink) under guidance of the European Commission, DG CONNECT, Unit E4 "Internet of Things".

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