OPEN CALL #1

TECHNICAL GUIDELINES CL1 INFORMATION

Revision: V1

COVER PAGE

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1 CLUSTER 1: BUSINESS INTEGRATION IN MINING

1.1 CLUSTER OVERVIEW

Cluster Title	Cluster 1: Business Integration in Mining
Domain	Mining, mineral extraction, autonomous systems
Location(s)	Sweden
Objective	Optimize mining operations through real-time monitoring, predictive analytics, and autonomous systems integration using edge-to-cloud computing

1.1.1 Generic description and focus

Cluster 1 focuses on digital transformation and business integration within the mining industry. It aims to create a secure, scalable, and interoperable computing continuum that connects IoT, edge, and cloud systems across mining operations. The cluster targets advanced digital services that improve safety, efficiency, and sustainability in harsh underground environments, where data access and interoperability have traditionally been limited. Its activities concentrate on integrating industrial IoT systems, predictive analytics, and intelligent orchestration platforms for real-time operational insight and decision support.

1.1.2 Main objectives and challenges

The cluster's overarching goal is to demonstrate how COP-PILOT technologies—particularly edge-to-cloud orchestration, secure data federation, and AI-driven automation—can enable next-generation digital mines. Key challenges addressed include:

- Achieving reliable, low-latency data exchange in constrained and security-sensitive mining networks;
- Enabling interoperability between multiple technology suppliers and heterogeneous sensor systems;
- Scaling and automating data processing across distributed infrastructures; and
- Overcoming operational barriers to deploying smart IoT solutions in mission-critical industrial environments.

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1.1.3 Cluster position and expected market impact

Cluster 1 positions the mining sector at the forefront of Europe's industrial digitalization efforts. By applying COP-PILOT's open, modular, and standards-based architecture, the cluster promotes vendor-neutral integration, cost efficiency, and safer operations. Its expected impact includes accelerating the uptake of edge-enabled IoT solutions in heavy industry, reducing downtime and energy consumption, and fostering a European ecosystem of interoperable digital-mine technologies that can be transferred to other process-intensive domains.

1.1.4 Pilot use cases

The cluster validates its objectives through four interconnected use cases:

- **IoT Mining Seismics** – multi-technology, multi-vendor seismic monitoring to enhance rock-mass understanding and safety.
- **Logistics of IoT** – underground asset-tracking and digitalized ground-support monitoring using smart rock-bolt networks.
- **Condition Monitoring and Predictive Maintenance** – real-time conveyor-belt diagnostics and analytics to prevent downtime.
- **IoT-Edge-Cloud Continuum for Digital Mines** – integration of the above systems into a unified testbed demonstrating secure, self-adaptive edge-to-cloud orchestration for digital mining.

Together, these pilots showcase how COP-PILOT enables intelligent, resilient, and interoperable industrial ecosystems for Europe's mining and heavy-industry sectors. Figure 1 illustrates how the four use cases with the involved organizations sit in the IoT-edge-cloud computing continuum, The figure also shows where the key technologies investigated in the cluster are being used, i.e., Arrowhead framework and ColonyOS.

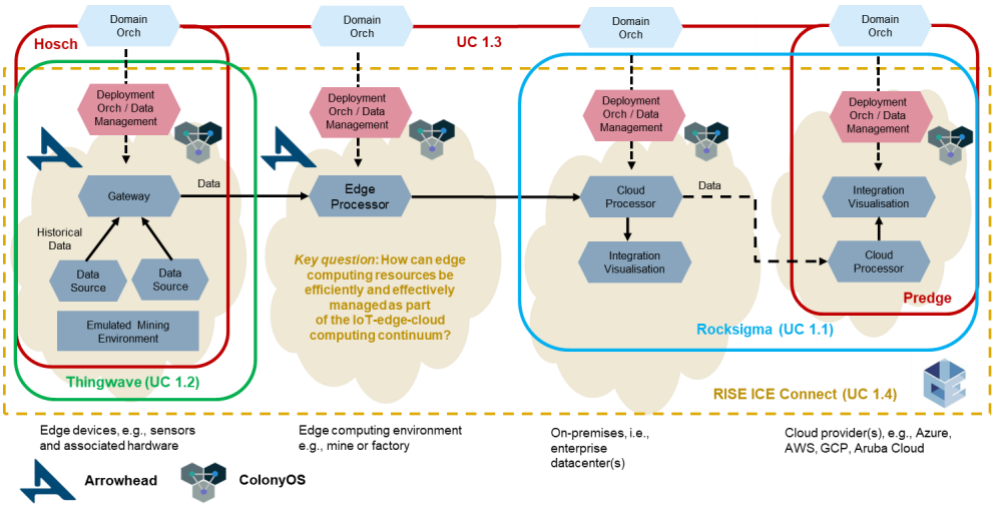

Figure 1- Cluster 1 Use Cases breakdown.

1.2 AVAILABLE INFRASTRUCTURE & TECHNICAL CAPABILITIES

1.2.1 Architecture overview

Cluster 1 implements an IoT–Edge–Cloud continuum dedicated to mining operations, integrating distributed sensing, processing, and orchestration infrastructures. The architecture connects underground IoT sensor networks (geophones, smart rock bolts, conveyor-belt sensors) with edge nodes located in mine or laboratory environments, and cloud data centers for large-scale analytics and orchestration.

The infrastructures in the cluster are owned and operated by mining companies that are not in the project. Hence, to enable experiments and demonstrations of the technologies, solutions and business opportunities developed in the cluster, use case 1.4 provides a testbed that conceptually resembles a typical IoT-edge-cloud computing continuum environment operated and used by a mining company. The ambition is that the testbed will include the following key architectural components:

- **IoT sensing and edge domain** – heterogeneous sensor arrays for seismic, structural, and logistics monitoring (RockSigma, ThingWave, Hosch). Data acquisition and preprocessing occur near the sensors to minimize latency.
- **Edge computing layer** – local compute nodes deployed in mining testbeds and at RISE ICE Data Center (Luleå) for near-real-time processing, running ColonyOS for distributed workload and deployment orchestration and Arrowhead for secure service discovery and local interoperability.
- **Cloud domain** – high-performance cloud resources for large-scale data analysis, machine-learning training, also running ColonyOS for distributed workload and deployment orchestration.
- **Orchestration management** – the COP-PILOT Domain Orchestrator (DO) integrated with ColonyOS based on GitOps principles for secure intent-based orchestration in closed infrastructures that cannot be directly controlled by external parties.

For each of the use cases, we list below the current infrastructure components and their availability to be utilized by applicants.

Table 1: Infrastructure components provided by the Cluster 1 testbed, i.e., the IoT-Edge-Cloud Continuum for Digital Mines integrating of the systems and technologies into a unified testbed

Infrastructure type	Description
Physical compute infrastructure	The RISE ICE Datacenter in Luleå provides scalable compute resources for experimentation and emulation of digital mining environments. It hosts dedicated edge and cloud nodes that can be allocated dynamically for data processing, analytics, and orchestration testing.
Virtual compute infrastructure	ColonyOS and Kubernetes clusters enable the provisioning of virtualized compute environments for distributed workloads. This includes automated scaling, meta-orchestration, and resource scheduling across edge and cloud domains.

Physical network infrastructure	High-bandwidth networking in the ICE Datacenter. The network supports secure data transport, low latency, and industrial-grade reliability for testbed operations.
Virtual network infrastructure	Kubernetes namespaces and VPNs for multi-tenant use of the testbed and demonstrations in context of multi-tenant environments.
Physical IoT infrastructure (or data sources)	Targeted integration of industrial-grade sensors and monitoring systems from RockSigma (seismic arrays), ThingWave (smart rock bolts), and Hosch (belt sensors). These physical IoT devices collect real-world data from mining environments for edge and cloud analytics.
Virtual IoT infrastructure (or data sources)	Simulated IoT data streams, emulating large-scale sensor deployments for experimentation. Supports integration testing, orchestration validation, and performance benchmarking.
Infrastructure Availability for COP-PILOT and Open Calls	All core components (ICE Datacenter, ColonyOS orchestration layer, Arrowhead framework, and IoT data sources) are available for third-party experimentation and Open Call projects. The infrastructure supports multi-tenant operation.

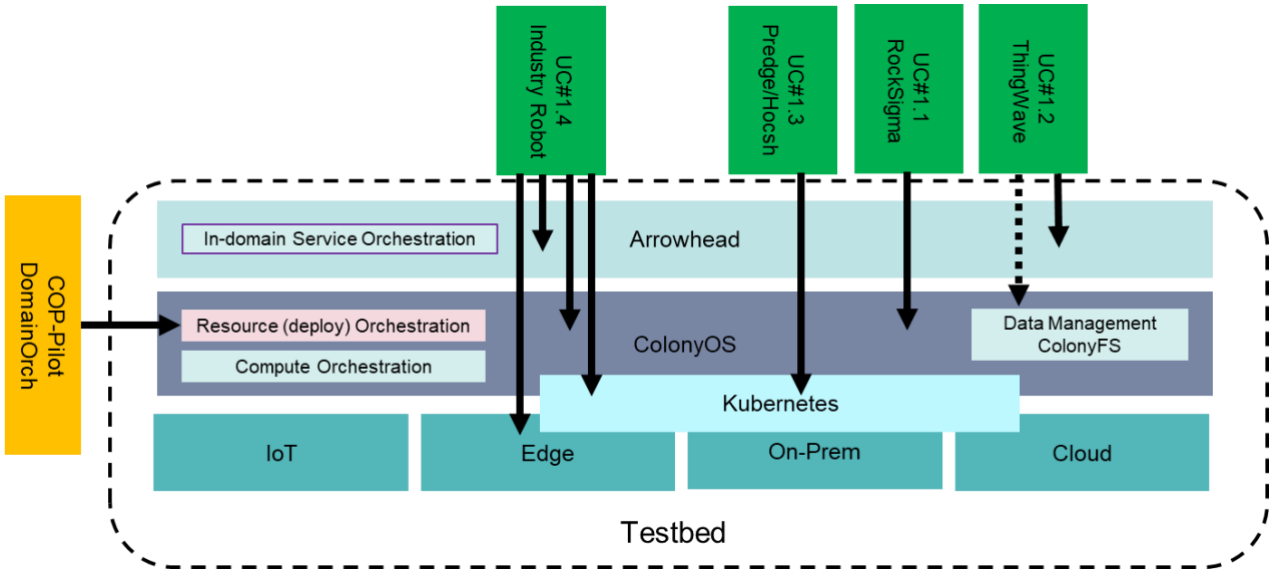

Figure 2: Cluster 1 – Overarching architecture.

1.3 OPEN CALL CHALLENGES & INNOVATION OPPORTUNITIES

1.3.1 Background

Due to the restricted communication possibilities in underground mines, e.g. no public telecommunication networks or fiber networks, software suppliers need to utilize the communication and computing infrastructure provided by the mining company. These systems vary in quality and

performance, depending on global location and the digital maturity of the mining site. As mining operations are very sensitive to any kind of operational disturbances, operational robustness and resilience are of utmost importance to the mining companies. This is reflected by very rigorous security constraints on the digital infrastructure, which sometimes prevent new technologies from being deployed and utilized.

1.3.2 Challenges

In cluster 1 of the COP-Pilot project we are working on novel system architectures and methods, that comply with the safety and security of the mining companies, and yet enable the possibility of more simple deployment, operation and management of solutions provided by our partners Rocksigma, Thingwave, Predge and Hosch.

Since data sovereignty, local survivability and latency are critical aspects, we expect that on-premises compute systems (edge computing) will be required to meet these requirements. An identified challenge is to find operators that are willing to integrate, operate and maintain the on-prem edge compute nodes scattered in mining sites across the globe. This includes integration with existing digital infrastructure in the mines and their security systems, maintaining the systems operational in potentially harsh environments, together with application providers ensure communication and system functionality to provide edge-to-cloud if applicable.

1.3.3 Opportunities

You will work with the highly motivated and competent team in COP-Pilot Cluster 1 and get the opportunity to tailor your solutions with the system architecture currently under development in the project. You will also get a unique possibility to learn about ColonyOS MetaOS and how this can be utilized to enable resource efficient, true edge-to-cloud solutions.

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