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D5.3 - Use cases deployment and implementation (1)

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Description	*Will document the pilots and integrated third parties, addressing the proposed use cases and scenarios.*		

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Executive Summary

This document provides key aspects and accomplishments of the use cases deployment within Work Package 5 (WP5) of the aerOS project. This deliverable is the first version of two documents, that marks the completion of the initial phase in a two-part series dedicated to deploying and implementing specific use cases within the aerOS framework. This document presents the activities carried out and the results obtained at M18 related to aerOS deployment and implementation in pilots, providing as well an insight into the technical integration and the results obtained in the open call to validate aerOS architecture in one of aerOS use cases.

Use cases deployment offers insights into the planned activities and the agreed 3-stage validation process. This document not only outlines the strategic vision but also reports on the entirety of setup, procurement, development, and implementation activities executed by the pilots until the specified milestone at M18. It delves into the intricacies of each stage, providing a comprehensive narrative of the pilots´ journey.

The first Open Call provides an insight into the actions funded and the main goals that are envisioned to extend and validate aerOS functionalities in the use cases. Through a detailed examination of statistical results post-application, this document becomes a dynamic reflection of the impact and potential trajectory of the funded endeavours.

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List of acronyms

Acronym	Explanation
AI	Artificial Intelligence
AGV	Autonomous Ground Vehicle
AMR	Autonomous Mobile Robot
API	Application Programming Interface
CD	Continuous Development
CH	Chapter
CI	Continuous Integration
CMM	Coordinate-measuring machine
DPP	Digital Product Passport
DT	Digital Twin
ECU	Electronic Control Unit
EU	European Union
ELM	Evocortex Localization Module
ERP	Enterprise Resource Planning
ESR	Evaluation Summary Report
GHZ	Gigahertz
GNSS	Global Navigation Satellite System
GPU	Graphics Processing Unit
HLO	High Level Orchestrator
HW	Hardware
IoT	Internet of Things
IE	Infrastructure Element
IP	Internet Protocol
IPC	Industrial Personal Computer
IT	Information Technology
KPI	Key Performance Indicator
K8S	Kubernetes
LAN	Local Area Network
LLO	Low Level Orchestrator
ML	Machine Learning
MVP	Minimum Viable Product
MQTT	Message Queuing Telemetry Transport
OPC	Open Platform Communications

OT	Operational Technology
RAM	Random Access Memory
RIB	Realtime Information Backbone
ROS	Robot Operating System
RTO	Research and Technology Organisations
TH	Trial Handbook
SIM	Subscriber Identity Module
SME	Small and Medium-sized Enterprises
SSF	Swiss Smart Factory
PCB	Printed Circuit Board
PC	Personal Computer
PCC	Project Coordination Committee
PLC	Programmable-Logic Controller
PLM	Product Lifecycle Management
PoC	Proof of Concept
VM	Virtual Machine
VPN	Virtual Private Network
WIFI	Wireless Fidelity
WIP	Work In Process

1. About this document

This document represents a comprehensive approach to the aerOS project´s use cases deployment through strategic planning and preliminary implementation activities. The Use Cases Deployment document provides a detailed overview of planned activities and a structured 3-stage validation process, offering insights into the practical applications of aerOS within selected scenarios. This document is pivotal for stakeholders as it not only outlines the strategic vision but also chronicles the setup, procurement, development, and implementation activities carried out by pilots until a specified milestone at M18. On the other hand, the First Open Call document serves as a window into funded actions and overarching goals aimed at extending and validating aerOS functionalities within specific use cases. Beyond financial details, it delves into statistical results, providing a data-driven perspective on the outcomes of the Open Call process.

This document is the first version of two deliverables and it contributes to a holistic understanding of the project's pilots progress, offering stakeholders a roadmap for informed decision-making, highlighting successful initiatives, and providing valuable insights for refining and advancing the aerOS platform. Their uses extend to project management, stakeholder communication, and as references for future iterations within the project.

1.1. Deliverable context

Item	Description
Objectives	**O1 (Design, implementation and validation of aerOS for optimal orchestration)**. Operationalizing the design and validation aspects of aerOS, ensuring optimal orchestration in real-world scenarios. This deployment phase transforms the theoretical framework of aerOS into practical applications **O2 (Intelligent realisation of smart network functions for aerOS).** The deployment outcomes contribute valuable insights, validating the aerOS network capabilities. **O3 (Definition and implementation of decentralised security, privacy and trust)**. The practical application of aerOS in use cases significantly advances the objectives set forth for security, privacy, and trust within the aerOS project. **O5 (Specification and implementation of a Data Autonomy strategy for the IoT edge-cloud continuum).** Through practical implementation, aerOS becomes a robust supporter of the diverse needs of data producers and consumers. **O6 (Definition, deployment, and evaluation of real-life use cases)**. The deployment ensures the utilization of real-world data, considering factors such as interoperability, volume, variety, and rate, to validate the platform's performance and business impact.
Work plan	D5.3 Receives inputs from: **WP2** (reference architecture for the IoT edge-cloud continuum): architectural guidelines, design principles, and key considerations specified by WP2 to ensure that the deployed use cases align seamlessly with the established architectural framework.

	WP3 (secure, scalable and decentralised compute infrastructure): guide and provide the aerOS components for their implementation in the use cases. **WP4** (delivering applications intelligence at the edge): guide the implementation of intelligent components within aerOS, ensuring that the platform effectively supports applications with enhanced intelligence capabilities. D5.3 Influences: **WP2** (reference architecture for the IoT edge-cloud continuum): Through practical deployment, the use cases offer valuable feedback to WP2 regarding the applicability and effectiveness of the reference architecture in real-world scenarios. Insights from the deployment process inform potential refinements or enhancements to the reference architecture, ensuring that it aligns optimally with the intricacies and requirements observed during implementation. **WP3** (secure, scalable and decentralised compute infrastructure): The deployment process provides direct feedback to WP3 on the efficacy and performance of aerOS components. **WP4** (delivering applications intelligence at the edge): By implementing intelligent components in real-world scenarios, the use cases generate feedback that influences the evolution of applications intelligence.
Milestones	The deliverable contributes directly to the realisation of MS4 (Use cases deployed: Initial deployment of the five use cases). It also provides indirect contribution to achieving MS5 (Final architecture defined: Final architecture with feedback from use cases produced) and MS6 (Software structure finished: Components of aerOS system ready, apart from final improvements and integration-related activities).
Deliverables	This deliverable is the first part of a two-version deliverable. The first version is in M18 and the second in M33. It receives inputs from D2.1 (State-of-the-Art and market analysis report), D2.2 (Use cases manual, requirements, legal and regulatory analysis (1)), D2.6 (aerOS architecture definition (1)), D3.1 (Initial distributed compute infrastructure specification and implementation), D4.1 (Software for delivering intelligence at the edge preliminary release) and D5.1 (Integration, evaluation plan and KPIs definition (1)). It is expected to provide feedback to D2.7 (aerOS architecture definition (2)), D3.3 (Final distributed compute infrastructure specification and implementation), D4.3 (Software for delivering intelligence at the edge final release), D5.2 (Integration, evaluation plan and KPIs definition (2)), D5.5 (Technical evaluation, validation and assessment report (1)) an D5.6 (Technical evaluation, validation and assessment report (2)).

1.2. Outcomes of the deliverable

This document has enabled aerOS project to define a harmonised approach that will align the pilot infrastructures, scenarios and business processes with the development and subsequent releases of the CEI continuum enablers. This is implemented at two levels, on one hand addressing the planning of the pilots and the planning of the basic and advanced aerOS services. On the other hand, the set-up of the pilot facilities so that they are ready to operate the aeOS components. The document provides an updated status review on the set-up and implementation phases towards the evaluation and assessment of the aerOS MVP.

1.3. Lessons learnt

The adoption of continuum technologies will not simply imply the upgrade on the infrastructures of the IoT-edge-cloud hardware devices but the adoption of specific services will be required and the effort on the applications supporting the demonstration of the business processes should not be neglected and be properly planned. The first phases of the piloting activities (set-up and implementation) demonstrate that the brownfield scenarios can be upgraded to accommodate the aerOS reference architecture and metaOS services. It yet remains to fully assess to the required extent the fulfilment of the pilot KPIs set as part of D5.2.

1.4. Version-specific notes

This document presents the achievements of the initial phases of the piloting activities of the aerOS MetaOS. A subsequent document will provide additional details on performance of the aerOS services gradually integrated as part of the piloting activities.

2. Use cases deployment

In order to assess the versatility, flexibility and adequacy of the aerOS MetaOS framework it is necessary that the services provided by the framework are evaluated under different operational conditions and diverse business scenarios exemplified by the diverse verticals that comprise the aerOS piloting activities.

The following sections of the document provide an up to date presentation and a detailed explanation of each of the five following pilots. Section 2.2 will introduce Pilot 1 Data-Driven cognitive production lines. Section 2.3 will address the developments of the Pilot 2 Containerised Edge Computing near Renewable Energy Sources. Next, Section 2.4 will report on the progress of Pilot 3 High Performance Computing Platform for Connected and Cooperative Mobile Machinery to improve CO_2 footprint. Section 2.5 will share the most recent insights on Pilot 4 Smart edge services for the Port Continuum, while Section 2.6 will present Pilot 5 - Energy Efficient, Health Safe & Sustainable Smart Buildings

Every Use Case strategically occurs on a different field, adding a holistic representation of relevant schemes. i.e. Industry 4.0, Utilities, Smart Agriculture, Port Transportation and Logistics, and Smart Buildings. As real-world scenarios, ensure a TRL5 by the end of the project, through the validation of each component by at least one of the five pilots. These five use cases follow a strict structural and chronological process of acquisition, configuration, development, integration and validation, and while in some cases the terminology may differ, its fundamental meaning is clear.

A total of 27 partners with different roles, belong to the consortium formed by a balanced mix of public-private entities, more than capable of successfully complete the predefined goals.

This document, delivered by M18, means the initialization of the five use cases which requires them to be fully defined, as well as an ongoing MVP.

The selected pilots ensure that the basic aerOS MetaOS services can be tested and validated to full extent at least in one of the current piloting scenarions. Moreover, provided that each pilot has defined a number of business processes under various use cases, it is also possible to accommodate a number of advanced services from aerOS in different use cases across the family of pilots adopting aerOS metaOS enablers.

WP3, through D3.2 has already identified the components of the aerOS MetaOS that could facilitate the necessary computing continuity demanded by the aerOS pilots. This document reflects on the ongoing efforts to gradually support such reference deployment across the various domains that the MetaOS will support (edge-cloud).

2.1. Overall validation plan

The development and deployment of a new system require meticulous planning and rigorous validation. In aerOS project, a three-stage validation plan has been agreed in order to ensure the robustness, reliability, and performance optimization of its Minimum Viable Product (MVP). This section will delve into the intricacies of each stage, highlighting the significance of the Proof of Concept (PoC), MVP & aerOS system releases validation, and the scaling and optimization phase.

Stage 1: Proof of Concept (PoC) – M1 to M12

The first stage of aerOS's validation plan is the Proof of Concept (PoC), emphasizing the validation of individual components. Each component undergoes a step-by-step validation process. This approach ensures that the basic services and components of aerOS's architecture are robust and error-free.

During the PoC stage, pilots are conducted to validate the functionality and reliability of each component independently. This step-by-step validation mitigates the risk of potential issues that may arise when components are integrated into the larger system. By validating the foundational elements of aerOS architecture in isolation, the development team can identify and address any shortcomings, ensuring a solid foundation for the subsequent stages.

Stage 2: MVP & aerOS System Releases Validation – M12 to M24

The second stage involves the validation of different aerOS releases, including the MVP. Once individual components are confirmed to be reliable through the PoC stage, the focus shifts to the integration and validation of the complete MVP. This comprehensive validation ensures that the combined functionalities of aerOS operate seamlessly and meet the intended user experience.

Throughout the MVP validation process, aerOS's development team assesses the system's stability, security, and overall performance. By validating multiple releases, aerOS ensures that iterative improvements are thoroughly tested before being deployed. This stage also serves as a crucial feedback loop, allowing developers to incorporate user insights and address any unforeseen challenges.

Stage 3: aerOS Scaling and Optimization – M24 to M36

The final stage of aerOS's validation plan is dedicated to scaling and optimization. As new developments are introduced, the system undergoes rigorous validation with the goal of optimizing performance. This stage is essential for ensuring that aerOS can scale seamlessly to meet growing user demands while maintaining peak efficiency.

Validation during the scaling and optimization phase involves stress testing the system under various conditions to identify potential bottlenecks or performance issues. Continuous monitoring and analysis allow the development team to make data-driven decisions, fine-tune algorithms, and implement optimizations that enhance aerOS's overall performance.

2.1.1. Pilot activity categorization

Pilot phases encompass an activity progression and categorization through Setup & Procurement Activities, Development Activities, Integration Activities, and Validation Activities. Each category plays a crucial role in shaping the project's success, from acquiring the necessary resources to the on-the-field validation of key functionalities.

Setup and procurement Activities:

- **Equipment Acquisition:** This involves identifying, selecting, and acquiring the necessary hardware and equipment for the aerOS project. This could include servers, sensors, communication devices, and any other hardware required for the successful execution of the project.
- **Purchasing:** Involves the procurement of software licenses, third-party tools, and any other resources needed for the project. This may also include negotiating with vendors and ensuring that all necessary legal and financial processes are followed.
- **Scenario Setup:** This encompasses the physical setup of the entire testing scenario. It involves bringing materials to the designated locations, preparing the physical environment for the project, and configuring communication devices.

- **Location Preparation:** Involves preparing the testing locations, including any necessary infrastructure modifications, safety measures, and environmental considerations.

Development Activities:

- **Software Development:** This includes the creation of software components essential for the aerOS project. It may involve coding, testing, and debugging software that enables the functionalities required for the trial.
- **Component Development:** In addition to software, this category encompasses the development of other components, such as firmware or hardware modifications, necessary to achieve the goals of the scenario.
- **Version Control:** Managing versions of the developed software and components, ensuring that changes are tracked, documented, and can be rolled back if necessary.
- **Quality Assurance:** Testing and ensuring the reliability, functionality, and security of the developed software and components.

Integration Activities:

- **Module Integration:** Bringing together different modules of aerOS and ensuring they work seamlessly as a unified system within the trial scenario.
- **Technology Integration:** Integrating various technologies within the aerOS framework to create a cohesive and functional system.
- **Deployment Tasks:** Planning and executing the deployment of integrated modules and technologies in the trial scenario to achieve the desired technical results.
- **Testing for Integration:** Rigorous testing to confirm that all integrated components and modules work together as intended and can handle real-world scenarios.

Validation Activities:

- **On-the-Field Actions:** Involves the actual implementation of the aerOS system in real-world conditions. For example, users remotely managing CMMs, tractors moving across a crop field, and processing signals from sensors.
- **KPI Testing and Evaluation:** Testing and evaluating Key Performance Indicators (KPIs) to measure the effectiveness, efficiency, and reliability of the aerOS system.
- **Iterative Refinement:** Based on the results of the validation activities, refining and improving the aerOS system through iterations to address any identified issues or enhance performance.

By following these comprehensive activities, the aerOS project can systematically progress from setup and procurement to development, integration, and ultimately validation, ensuring a thorough and successful trial.

The objective of the following Section is to report on the progress of the various phases and to ensure compliance with the basic expected services of aerOS metaOS framework and those that particularly add value to each pilot. As a consequence, the aerOS core functionalities are evaluated and validated in at least one of the 5 available pilots.

The first pilot (Innovalia, MADE, POLIMI, SIPPBB and Siemens) has a strong sustainability approach by measuring and optimising the CO2 footprint of the production systems. This will be validated in 3 different scenarios, all aiming to proof the SOTA cognitive abilities.

For the second Pilot (CloudFerro, ELECT) we transition to the energy vertical, not particularly but with special emphasis on trust and security that will be intensively tested in 2 scenarios. This will be applied in Poland.

In the third Pilot (Jonh Deere, TTC), the objective is to assess metaOS capabilities to support the operation of a collaborative swarm of vehicles to proof safety, security and data autonomy.

The fourth pilot (EGCTL, PRO, CUT) takes place in the largest port of Cyprus, where optimisation of container handling to reduce human error will be used to assess the cognitive aerOS capabilities.

The last pilot will use the offices of COSMOTE, in Athens, to demonstrate a more energy efficient, sustainable and health-safe of Smart buildings, intensifying the assessment of aerOS metaOS features with respect to cybersecurity and data privacy.

The use case deployment ensures that aerOS metaOS services will be exposed to a diverse set of conditions providing the necessary evidences in terms of the resilience and flexibility/autonomy to self* operate the continuum to the service of the pilot business processes.

2.2. Data-Driven Cognitive Production Lines

In the heart of an innovative manufacturing plant, the Pilot 1 of the aerOS project was set to redefine the landscape of production, placing a spotlight on lot size 1 manufacturing. The collaboration of five key partners MADE, NASERTIC, SIEMENS, INNOVALIA, and SIPBB wove together a narrative that showcased their unique contributions within this cutting-edge initiative.

SIPBB, the environmental optimization expert specializing in modular production lines for drones, brings a sustainable edge to the narrative. Their Scenario 1 involvement aims at minimizing the environmental footprint of the entire production process, incorporating energy-efficient practices.

INNOVALIA, the quality control provider, defines the Scenario 2, ensuring that each product emerging from the lot size 1 production line meet the highest standards. Their cutting-edge inspection technologies, meticulously examined every dimensional detail, guaranteeing the flawless quality of each custom-manufactured item.

The hum of machinery and the orchestrated movement of Automated Guided Vehicles (AGVs) embraces the future of production. **SIEMENS**, a stalwart in lot size 1 manufacturing, is at the forefront. Their AGVs seamlessly navigates the factory floor, transporting raw materials to individual workstations tailored to specific products. This marked Scenario 3, where SIEMENS will utilize flexible and adaptive AGVs system to customize and produce unique items efficiently.

MADE, a specialist in AGV fleet management with a keen focus on machine learning provides optimized AGV routes, predicting production demands, and ensuring that each AGV moves with precision.

Meanwhile, the cloud-based expertise of **NASERTIC** provides the digital backbone for this intricate dance of machinery. Their contribution links all elements seamlessly, creating a dynamic and responsive manufacturing ecosystem. The cloud solution will provide real-time data analytics, enabling quick decision-making and adaptive adjustments to the production process.

As the Pilot 1 unfolds within a manufacturing plant, the synergy of these partners under the aerOS umbrella becomes evident. The lot size 1 production line, driven by SIEMENS, guided by MADE's intelligent AGV fleet management, supported by NASERTIC's cloud solutions, verified by INNOVALIA's quality control, and environmentally optimized by SIPBB, showcases a new era in manufacturing innovation. The aerOS project, through this collaborative effort, not only optimizes production efficiency but also paves the way for a sustainable and intelligent future in manufacturing.

2.2.1. Technology & infrastructure

NASERTIC participates in this Pilot as an Infrastructure provider (Cloud domain). The infrastructure that NASERTIC will be providing to the project will consist in a cluster of servers that will be leveraged by the rest of scenarios of the pilot to delegate their tasks to. Basically, the infrastructure of NASERTIC will serve to test and validate aerOS' federation and orchestration functionalities across different domains. aerOS will count on the infrastructure of NASERTIC to intelligently distribute computation tasks and storage requirements.

2.2.1.1 - Demonstrator path

The cluster of servers that Nasertic will provide to aerOS will be made up of several virtual machines forming a Kubernetes cluster.

The provisioning of such infrastructure for the project will be carried out in several steps:

1. VM (Virtual Machines) dimensioning
2. Creation of VMs and deployment of the Kubernetes cluster
3. Granting access to the Kubernetes cluster
4. Continuous maintenance of the cluster

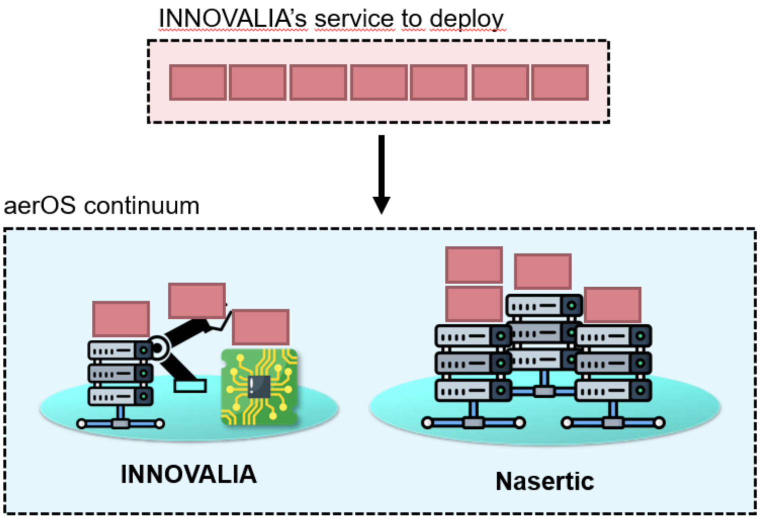

Figure 1. Example of smart service deployment across multiple domains leveraging NASERTIC infrastructure.

A detailed description of each of the necessary steps to carry out the deployment of the infrastructure follows:

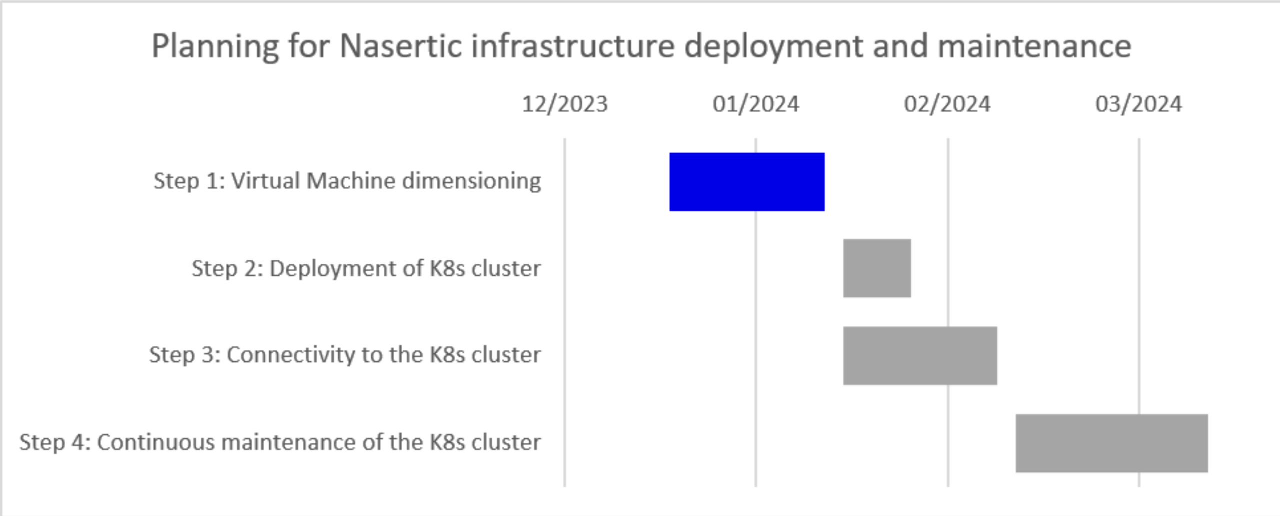

Figure 2 - Pilot 1 - Nasertic-Infrastructure provider planning

1- VM dimensioning

NASERTIC has a wide pool of servers which are used as a physical layer on top of which virtual machines are instantiated. NASERTIC is a public organization that operates for the Government of Navarre: a region of Spain. Thus, virtual machines hosted by NASERTIC are used by a wide range of stakeholders within Navarre, mainly public institutions (town halls, the parliament, the public administration of the province, public hospitals, public schools, universities…).

This is to say that the servers are a scarce resource: NASERTIC and the government intensively control how many VMs are currently instantiated and for what purpose. Any superfluous VM shall be deleted, as is it consuming precious resources that may be necessary for truly major tasks (e.g.: in the public hospitals, in the public administration…).

To prevent the creation of unnecessary virtual machines, NASERTIC works under a strict procedure which demands an extensive explanation about why are new VMs necessary, and how much RAM and storage is required for each of them. If any explanation falls short, the creation of the new VMs will be rejected.

Therefore, we must come with a compelling justification of the exact relation of resources required for the Federation & Orchestration testing within the Pilot 1.

In order to gather information about the required resources, the following strategy is proposed:

1. **Retrieving the resources required to execute the microservices of each use case.** We need to gather how much RAM and storage each service requires to run correctly. Also, we need to know whether the partners have any preferred OS to run their microservices on. Nasertic can provide virtual machines either with Rocky Linux or Windows Server 2019 installed.
2. **Setting the fraction of microservices that we want to host in Nasertic's premises**. The previous step provides Nasertic an accurate dimension of the total resources required to host the services of the use cases. However, the goal is not to host every service in Nasertic's infrastructure. As depicted in , we want the services to be split between several domains, being Nasertic's one of the domains; Nasertic should not monopolize the computations, aerOS should also leverage the computation power allocated in the premises of the use cases. As such, it is not required for Nasertic to dimension the virtual machines to entirely meet with the requirements provided in the previous task. In fact, we propose to meet up to a fraction of the resources. For example, if we consider that fraction to be 50% of allocation and all use cases require 512GB RAM and 20TB storage in total, then we would instantiate as many virtual machines as required to meet up with 256GB RAM and 10TB storage. In that way, Nasertic is not

capable of monopolizing the calculations within the continuum and other domains can be leveraged as well.

This whole resource obtention strategy, alongside the exact fraction of computation that needs to be hosted by Nasertic for sufficient pilot 1 validation needs to be agreed with the technical leaders (NCSRD).

To summarize the first step towards the provision of infrastructure:

- Reach the partners of the use cases in the Pilot 1 in regards to the expected resource consumption of their services.
- Agree with the technical coordinators whether this VM-dimensioning strategy is valid and, in such a case, determine an appropriate fraction of services hosting in Nasertic's infrastructure.

2- Creation of VMs and deployment of the Kubernetes cluster

The previous step should yield a clear justification of the exact resources that need to be allocated in Nasertic's infrastructure. Such justification will help the Distributed Systems department within Nasertic to properly calculate the appropriate number of VMs to instantiate and their specific resources.

Once the virtual machines are created, they need to be aggregated into a Kubernetes cluster. This will require several installations to make in each virtual machine:

- Installing a container runtime (e.g.: Docker) in all nodes.
- Installing Kubernetes components in all nodes.
- Creating a master node.
- Join the remaining machines to the cluster as worker nodes.
- Install a container networking module (e.g.: Calico).

3- Granting access to the Kubernetes cluster

Once the Kubernetes cluster is created, we need it to be accessible from the premises of the different scenarios. A networking solution will be designed and deployed to guarantee that the interested stakeholders (namely Pilot 1 partners) can properly access the cluster.

The networking solution to adopt must resemble as much as possible the connectivity implementations applied to other Kubernetes clusters that have already been deployed for aerOS during the development of the project. The rationale behind this is to assure that a homogeneous procedure exists to access all Kubernetes clusters across the project.

For instance, the partner CloudFerro hosts two Kubernetes clusters specifically created to test aerOS components, developed within WP3 and WP4. The clusters can be accessed via a Public Ingress IP – this allows for pod deployments within the cluster. However, to access all individual machines that make up the cluster (i.e.: all master and worker nodes) a VPN solution is adopted via Wireguard protocol. This connectivity schema will inspire the solution that Nasertic will adopt with its Kubernetes cluster once deployed.

4- Continuous maintenance of the cluster

In this step, a full-fledged K8s cluster will already be up and running. This cluster should be able to host the services that the Use Cases within Pilot 1 desire to deploy. From this point onward, Nasertic will be in charge of keeping the K8s cluster in good shape:

- Dealing with any technical issues that may arise.
- Solving any doubts that the partners may have.
- Implementing any readjustments to the cluster that may be required by the partners to guarantee that their services can be deployed, always looking towards aerOS and Pilot 1 testing and validation.

2.2.1.2 - Demonstrator related to infrastructure provider

The step 1 lasted until January 12th, 2024. This makes for about 3 weeks for the partners to gather the required resource information to correctly dimension the VMs.
Once NASERTIC received the information about the resources required per partner, it started deploying the K8s cluster, which will extend up to January/February, 2024. By that time, all the machines are ready to run and they should already be configured in a cluster.

Once the Kubernetes cluster was deployed, a connectivity solution will be implemented to grant access to the Pilot 1 partners. It is not required to start designing the connectivity schema right after the K8s cluster is deployed; such design task can start earlier. On February 2024, the infrastructure that NASERTIC committed to deliver within the project is already to be up. This task will keep going until the end of the validation tasks within the project. The figure below illustrates the preferred cloud domain infrastructure configuration:

	Partner	**Service**	**RAM requirement**	**Storage requirement**	**OS requirement for non-aerOS technology of the stakeholder**
Scenario 1	SIPBB	#1	8 GB	128 GB	Rocky Linux
Scenario 2	INNOVALIA	#1	8 GB	40 GB	Windows Server
Scenario 3	MADE & POLIMI	#1	8 GB	40 GB	Windows Server
		#2	8 GB	20 GB	Windows Server
	SIEMENS	#1	4 GB	8 GB	Rocky Linux
		#2	8 GB	20 GB	Rocky Linux

Figure 2. NASERTIC cloud domain aerOS infrastructure configuration.

2.2.2. Green manufacturing (zero net-energy) and CO2 footprint monitoring

Scenario 1 concerns the design of data models for green manufacturing (zero net-energy) and CO2 footprint monitoring related to the product life cycle. This will be done in connection with the implementation of Digital Product Passport (DPP), enabling a systemic shift towards circular economy, supporting de-manufacturing operations, optimisation of reverse logistics infrastructure and more sustainable product design. aerOS services will be used in Swiss Smart Factory’s test and demonstration platform to implement edge intelligence and analytics services to optimize impact and footprint of modular production lines for drones.

The Swiss Smart Factory is an extensive test and demonstration laboratory for Industry 4.0 on 1000m², which consists of a full production line for the manufacture of quadcopter and hexacopter drones in batch size 1. The production line demonstrates innovative manufacturing concepts and is built and operated in collaboration with more than 70 companies. It serves, among others, as an international test bench for data sharing in the POC-series with NTT and SIEMENS and in the EU-Project DIMOFAC.

The following equipment and machines will be used in the use-case: manual workstation Setago, smart conveyor, PCB THT-Assembly, Melkus C4060 AGV and quality check station. A standardized JSON configuration is generated and can be read and understood by all the machine of the Swiss Smart Factory "Lighthouse factory industry 4.0". The Picture below show the general process at the Swiss Smart Factory "Lighthouse factory industry 4.0".

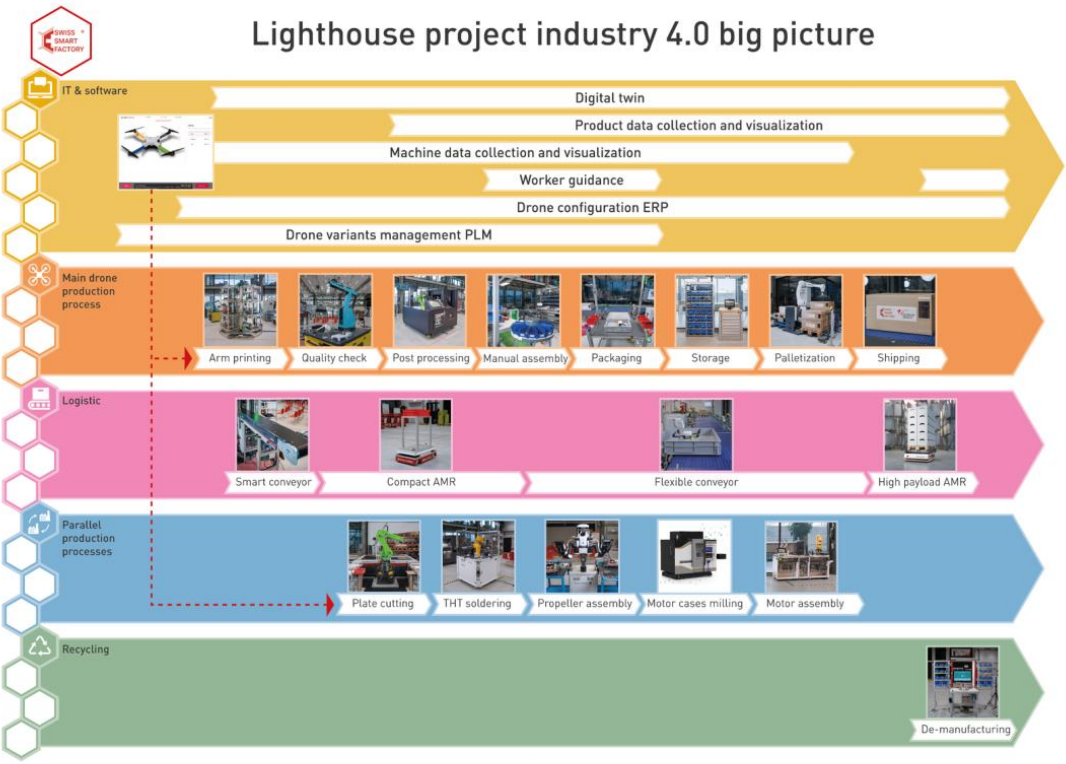

Figure 3. Big Picture of the Swiss Smart Factory "Lighthouse factory industry 4.0".

Until now, the data used to measure the product carbon footprint (PCF) of each drone produced in the Swiss Smart Factory was based on a national average calculation. This measurement does not always reflect the reality of on-site production and could be improved by analysing data generated and collected locally. Ultimately, the data collected should include all activities in the value chain, from production to logistics, and even include de-manufacturing activities for each product. At the same time, such data transparency would enable the implementation of a Digital Product Passport (DPP) and raise customer awareness of their specific PCF. Customers will be able to make more informed decisions when purchasing and configuring a customised drone. The next step will be to measure the carbon footprint of each drone component through sensor tracking and part marking. Next, the process of analysing the data in aerOS services will enable greener manufacturing, or a reduction in the carbon footprint, by optimising production and logistics processes. Finally, the knowledge generated by the project will be disseminated to the SSF network, which includes industrial companies and academic bodies.

2.2.2.1. Setup and procurement activities

The equipment and machines used in Scenario 1 are continuously developed with the help of the Swiss Smart Factory partners and used in the daily activities of the SSF, so no equipment has been acquired or purchased specifically for aerOS. The SSF is involved in other ongoing European projects, such as RE4DY and MODUL4R, where some configuration activities have already been carried out to accommodate other systems, providing a solid basis for the deployment of aerOS on SSF machines and demonstrating the modularity of the equipment. Thanks to SIPBB's involvement in the Dimofac project, the SSF's basis for deployment has been improved, taking into account the lessons learned from the project.

As the SSF is a living test and demonstration platform, its equipment and machines are constantly changing and being developed. The scenario environment therefore evolves rapidly and requires constant adaptation. Having identified the stations that will be used for the deployment of aerOS in scenario 1 (i.e. the manual workstation, the smart conveyor, the quality control, the AGV and the THT PCB assembly stations), some physical adjustments may be necessary to ensure that all the equipment is ready to host aerOS services.

Pilot1 – Scenario1- SetupActivity-1 (P1-S1-SA1).

The SSF has worked mainly on the deployment and implementation of the services enabling the monitoring of the machine and conveyor energy status. Below an screenshot of the JSON interface is depicted.

CM_THTsoldering JSON layout


```
{
    "machine_status":{
        "machinename":"demonstrator name, data type string",
        "status":"1=idle, 2=running, 3=error 4=standby, data type int",
        "orderid":"actual order id, int",
        "timestamp":"timestamp as UNIX timestamp in milliseconds"
    },
    "environmental_data":{
        "temperature":"value in C, data type float, rounded to one decimal",
        "humidity":"value in %, data type float, rounded to one decimal",
        "vibration":"value in mm²/s v-RMS Magnitude, data type float, rounded to seven decimal",
        "atmospheric_pressure":"value in hPa, data type float, rounded to one decimal"
    },
    "energy_monitoring":{
        "power_current":"current watt consumption in W, data type int",
        "power_cumulated":"cumulated watt consumption in kW, data type float, rounded to three decimal",
        "co2_footprint_current":"footprint in kgCO2, data type float, rounded to three decimal",
        "co2_footprint_cumulated":"cumulated footprint in kgCO2, data type float, rounded to three decimal"
    },
    "robot_data":{
        "joint_1":"joint position, data type float",
        "joint_2":"joint position, data type float",
        "joint_3":"joint position, data type float",
        "joint_4":"joint position, data type float",
        "joint_5":"joint position, data type float",
        "joint_6":"joint position, data type float",
    }
}
```


CM_Smart_conveyor JSON layout


```
{
    "machine_status":{
        "machinename":"demonstrator name, data type string",
        "status":"1=idle, 2=running, 3=error 4=standby, data type int",
        "orderid":"actual order id, int",
        "timestamp":"timestamp as UNIX timestamp in milliseconds"
    },
    "environmental_data":{
        "temperature":"value in C, data type float, rounded to one decimal",
        "humidity":"value in %, data type float, rounded to one decimal",
        "vibration":"value in mm²/s RMS, data type float",
        "atmospheric_pressure":"value in hPa, data type int"
    },
    "energy_monitoring":{
        "power_current":"current watt consumption in W, data type int",
        "power_cumulated":"cumulated watt consumption in kW, data type float, rounded to three decimal",
        "co2_footprint_current":"footrint in kgCO2, data type float, rounded to three decimal",
        "co2_footprint_cumulated":"cumulated footprint in kgCO2, data type float, rounded to three decimal"
    },
    "conveyor_data":{
        "conveyor_velocity":"current velocity conveyor m/s, data type float,rounded to three decimal",
        "number_of_processed_parts":"number of check parts, data type int"
    }
}
```

CM_QualityCheck JSON layout


```
{
    "machine_status":{
        "machinename":"demonstrator name, data type string",
        "status":"1=idle, 2=running, 3=error 4=standby, data type int",
        "orderid":"actual order id, int",
        "timestamp":"timestamp as UNIX timestamp in milliseconds"
    },
    "environmental_data":{
        "temperature":"value in C, data type float, rounded to one decimal",
        "humidity":"value in %, data type float, rounded to one decimal",
        "vibration":"value in mm²/s RMS, data type float",
        "atmospheric_pressure":"value in hPa, data type int"
    },
    "energy_monitoring":{
        "power_current":"current watt consumption in W, data type int",
        "power_cumulated":"cumulated watt consumption in kW, data type float, rounded to three decimal",
        "co2_footprint_current":"footrint in kgCO2, data type float, rounded to three decimal",
        "co2_footprint_cumulated":"cumulated footprint in kgCO2, data type float, rounded to three decimal"
    }
}
```


Figure 4.Example of smart service deployment across multiple domains leveraging NASETIC infrastructure.

2.2.2.2. Development activities

Next, the IT architecture including the HTTP endpoint and OPC-UA servers has been defined and documented for each piece of equipment used in Scenario 1, so that an overview can be generated and the aerOS services can be deployed in the Swiss smart factory. A communication infrastructure and connection to API technology will be developed on each machine to collect environmental, energy and carbon emissions data in JSON format. Thanks to the connection between the SSF stations and a secure cloud, this data will be easily and directly accessible from anywhere using a traditional browser.

In addition, the software of the stations used in the aerOS project (currently ProAlpha ERP, SETAGO, Melkus AGV Navigation, Node-RED (auto-configured)), are being configured and/or programmed to push and pull data to and from the aerOS domain.

2.2.2.3. Integration activities

The deployment of aerOS services in the SSF may be the most difficult part of scenario 1. First, SIPBB will define where exactly these services will be deployed in the current architecture. Then it will test the data collection, make the necessary adjustments and create a dedicated dashboard to display the data in a user-friendly way, combining the values from all the different stations included in the scenario. This dashboard should help companies and their customers to better understand the carbon footprint of each product manufactured in the plant by displaying key information using graphs and tables. Data analysis should then be programmed to create reports showing areas for improvement and accurate production statistics.

2.2.2.4. Validation activities

Data collection is the most critical part of scenario 1, as it defines and influences all subsequent actions such as production optimisation, the dashboard and the implementation of the digital product passport. This stage therefore requires in-depth testing and validation steps to ensure that the data generated corresponds to the reality of production.

The results of the project will then be compared with the defined key performance indicators and conclusions will be drawn. The deployment of aerOS in the SSF should also contribute to other EU projects operating in the SSF, creating opportunities for testing, validation and improvement perspectives.

Finally, the evaluation will be carried out and the potential for actual deployment in Swiss industry could be discussed with visitors and SSF partners, reflecting industry's interest in this solution in their own production.

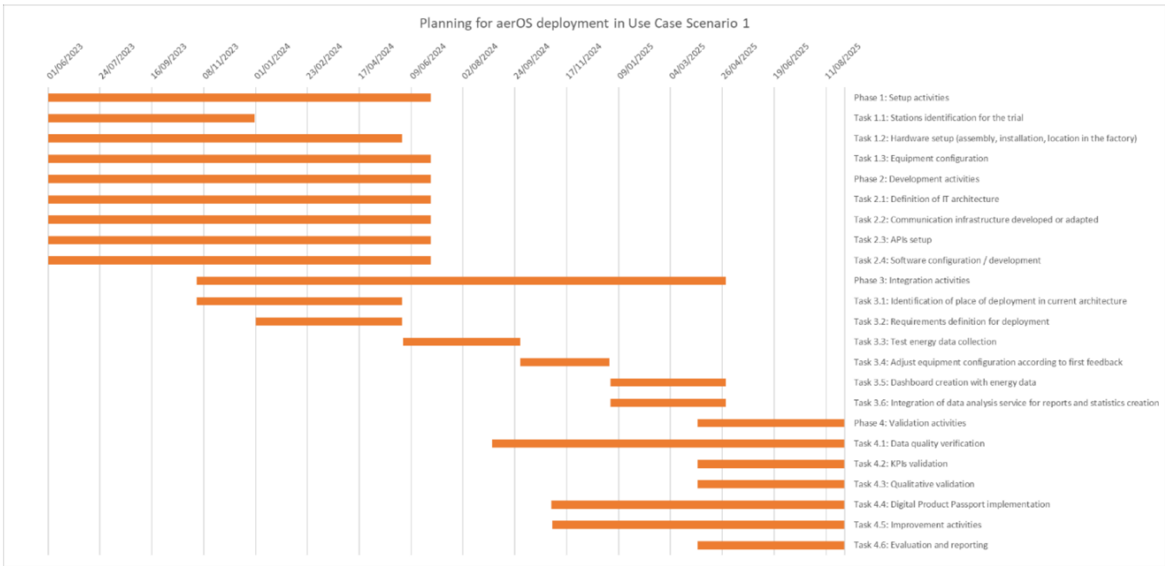

Figure 5.- Pilot 1 – Scenario 1 – Deployment planning

Table 1– Pilot 1 – Scenario 1 – Oveview of activities

	Start date	End date	Duration
Phase 1: Setup activities	01/06/2023	30/06/2024	395
Task 1.1: Stations identification for the trial	01/06/2023	31/12/2023	213
Task 1.2: Hardware setup (assembly, installation, location in the factory)	01/06/2023	31/05/2024	365
Task 1.3: Equipment configuration	01/06/2023	30/06/2024	395
Phase 2: Development activities	01/06/2023	30/06/2024	395
Task 2.1: Definition of IT architecture	01/06/2023	30/06/2024	395
Task 2.2: Communication infrastructure developed or adapted	01/06/2023	30/06/2024	395
Task 2.3: APIs setup	01/06/2023	30/06/2024	395
Task 2.4: Software configuration / development	01/06/2023	30/06/2024	395
Phase 3: Integration activities	01/11/2023	30/04/2025	546
Task 3.1: Identification of place of deployment in current architecture	01/11/2023	31/05/2024	212
Task 3.2: Requirements definition for deployment	01/01/2024	31/05/2024	151
Task 3.3: Test energy data collection	01/06/2024	30/09/2024	121
Task 3.4: Adjust equipment configuration according to first feedback	30/09/2024	31/12/2024	92
Task 3.5: Dashboard creation with energy data	01/01/2025	30/04/2025	119
Task 3.6: Integration of data analysis service for reports and statistics creation	01/01/2025	30/04/2025	119
Phase 4: Validation activities	01/04/2025	31/08/2025	152
Task 4.1: Data quality verification	01/09/2024	31/08/2025	364
Task 4.2: KPIs validation	01/04/2025	31/08/2025	152
Task 4.3: Qualitative validation	01/04/2025	31/08/2025	152
Task 4.4: Digital Product Passport implementation	01/11/2024	31/08/2025	303
Task 4.5: Improvement activities	02/11/2024	31/08/2025	302
Task 4.6: Evaluation and reporting	01/04/2025	31/08/2025	152

2.2.3. Automotive Smart Factory Zero Defect Manufacturing

The scenario 2 comprises the implementation of aerOS metaOS to support ZDM metrology services for dimensional measurement of components. The aim is to promote the manufacturing autonomy Level 4 and remote operation of CMMs. To achieve this, aerOS technological components will be deployed and validated in Innovalia Didactic Factory at AIC – Automotive Intelligence Center (Bilbao, Spain). Innovalia's facilities aim to develop the following competences and related technologies: Industrial IoT & CPPS, Metrology, Zero Defect manufacturing, Business Digitalization, Big Data & 3D Mobile Visualization, Cybersecurity and Digital Trust

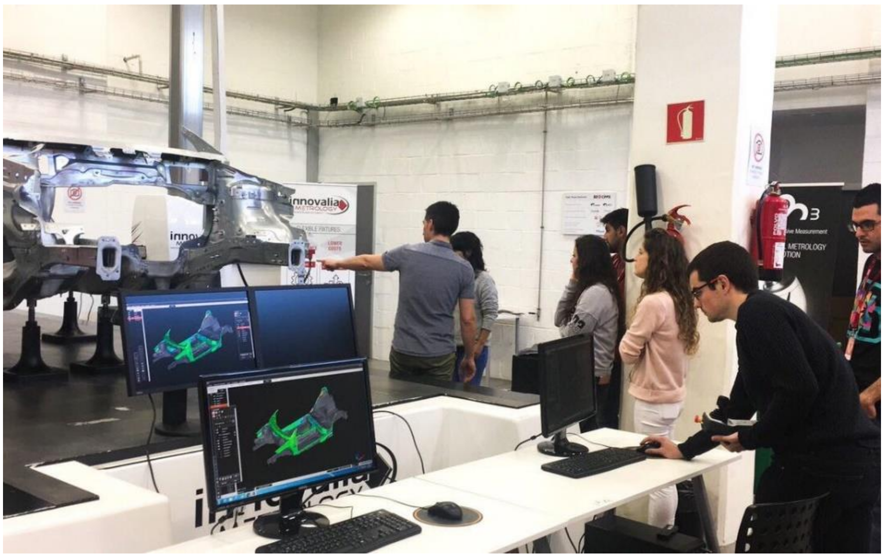

Figure 6. Dual CMM Instrumentation part of aerOS Trial.

Companies dedicated to the manufacture of parts and components for the automotive, aeronautical, energy, etc. sectors are receiving dimensional quality requirements and tolerances from large companies that cannot be achieved with traditional methods. Optical technology is currently being imposed for the realization of dimensional quality controls, since it allows the acquisition of a large amount of information in a much shorter time than probing technology. As a consequence, the number of pieces controlled is much higher. On the other hand, the amount of information that is handled is much greater, a point cloud of a car door can have 15 million points; therefore, the management and calculation algorithms have to be optimized to the maximum. Currently, the optical measurement system has its own information processing software parameterizable associated with it and depending on the operator, one result or another will be obtained, which the developers design as a "black box" making it difficult to verify how they process this information.

The specific objectives of the implementation of aerOS in ZDM (Zero Defect Manufacturing) use case are as follows:

1-Remote tactile operation (Metrology Project Engineering)

Currently, the operation of CMMs is mainly carried out on site. When it comes to the factory level, this implies that a metrologist expert must physically travel to the factory. As a consequence, there are operational inefficiencies and higher associated costs, as well as an increased risk to the operator working in hazardous areas. Aiming at the remote tactile, low latency operation, it would allow to face the aforementioned impact, requiring low latency communication protocols for reliable, fast and secure operation. aerOS MetaOS for metrology 4.0 continuum services via Metrology M3 platform virtualisation will allow a modular metrology service implementation driving towards autonomous operation of the process incorporating the possibility of asset monitoring and automation (Use case 2). The MetaOS will allow unlocalization of physical resources thanks to aerOS continuum between project engineering metrology (use case 1) and production metrology (use case 2).

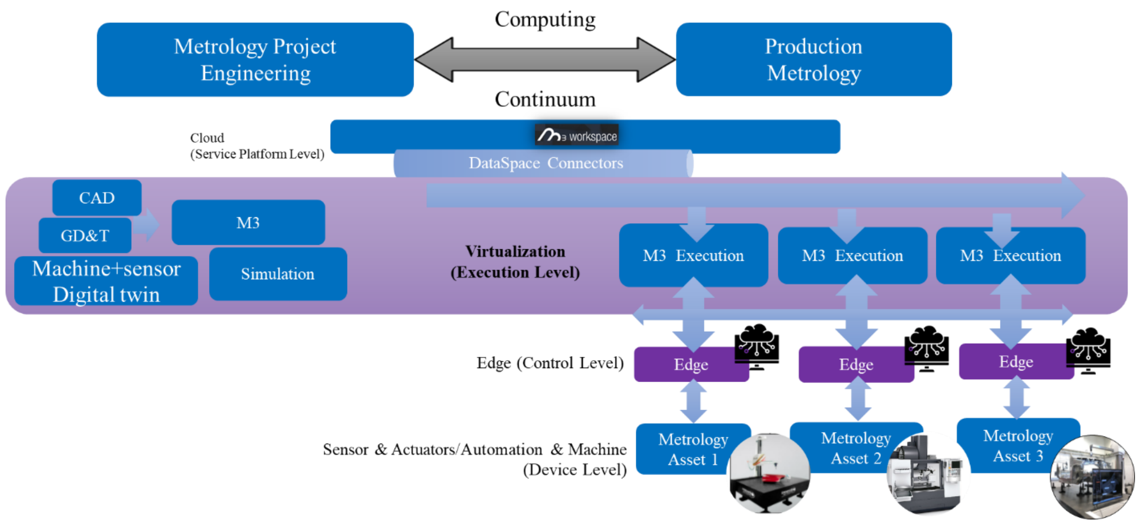

Figure 7. ZDM dimensional metrology continuum part of aerOS Trial.

2-Real-time monitoring and operation for machine error compensation, ensuring the accuracy of dimensional inspection:

The risk of false decision-making rises with higher measurement uncertainties. Since measuring is comparing, measurement is a physical process in which an iteration takes place between the object being measured and the instrument used for it. The result - the measurement - has to be collected and interpreted by the metrologist. Therefore, the ensemble will be subject to two types of influences: individual, inherent to the metrologist, and instrumental, arising from the method and the measuring device. Both will be the cause that exact knowledge of the magnitude is never possible, since the imperfection of the senses of the metrologist and the equipment used will always create an uncertainty in the value obtained and, consequently, a discrepancy between the exact value and the real, whose measure is the error interval. The uncertainty associated with the instrument can be controlled through calibration; however, this is not the case for the uncertainty due to the metrologist.

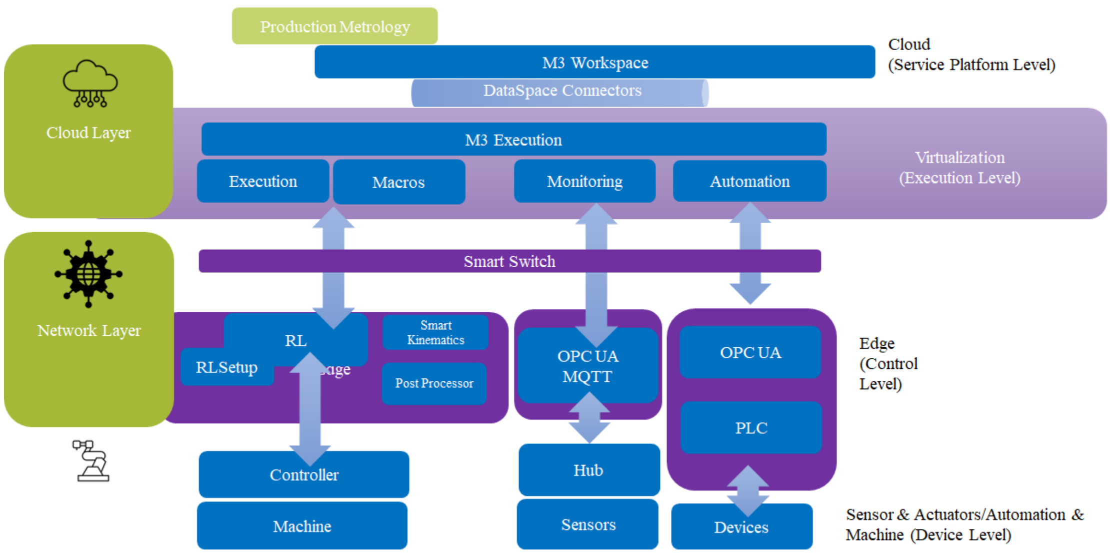

Figure 8. ZDM dimensional metrology service suite deployable in the aerOS continuum.

To this end, Innovalia is focusing specifically on setup activities towards the implementation of aerOS in their premises. Those activities are related with the placement of different IoT sensors in the CMM to promote real-time data acquisition and remote operation.

2.2.3.1. Setup and procurement activities

The set-up activities have focused mainly in the preparation of the service suite to be operated over the aerOS continuum:

- **Spark Gage**. This is a bridge type measuring machine, available in different sizes to suit the customer's needs. The Spark model, as all Trimek machines, is built simple but robust, with the use of the most advanced manufacturing technologies. The machine is wholly built in black granite in its three axis, achieving a high dimensional stability and precise controlled movements. The measuring system of each axis is mounted on Robax (a thermally inert material) which together with the granite construction, makes the Spark Gage an accurate and fast machine even under temperature variations. The Spark is ideal for high accuracy measurements, scanning and digitising tasks. Therefore, the Spark finds its application typically in the machining, mould and stamping market. Max. Speed 3D: 500 mm/s. Max. Acceleration 3D: 1000 mm/s2. Air consumtion: 150 l/min. Air supply pressure: 6 bar. Electricity consumption: max 3000VA. Temperature Conditions: 20ºC ± 2K, 1,0K/h, 1,0K/m.
- **Vulkan**. Machine architecture based on horizontal arm with high stiffness structure. Main structure made of stabilized steel. Aluminium Y-axis unit with a pyramidal cross section arm. Linear shoes on all axes for high precision guidance. Rack and pinion drive on X-axis and ball spindle on Y- and Z-axes. Special mechanical system for arm bending control. Aluminium crosshead, supported by a guided counterweight joined through double steel cored strip. Measuring rulers and Renishaw linear optical heads on all machine axis. Continuous PHS1 head with extensions up to 750 mm.
- **CMM control.** Configured for direct CNC controlled CMMs. Number of CMM axes controlled: 4. Communications link with PC: Gigabit Ethernet. Direct Software integration EAGLE.driver. Emergency stop SS1 PL d, Kat. 3 . Motor types: DC-Brush.Touch-trigger probing function. Probepoint Plus up to 64kHz. Temperature sensor inputs (T-Bus™):16. Digital scale input RS422.
- **RL.** CMM middleware for metrology process work. Multiple equipment management (arm, gantry, portable, bridge, vulkan, manual). TCP communication.
- **Optiscan sensor.** Field of view width (max) 15-80 mm. Field of view depth (max) 20-44 mm. ISO probing size error 3-13 **µm.** ISO probing dispersion value. 4-16 **µm.** ISO probing dispersion error (plane) 6-20 **µm.** Point spacing (Lateral Resolution) 15-40 **µm.**

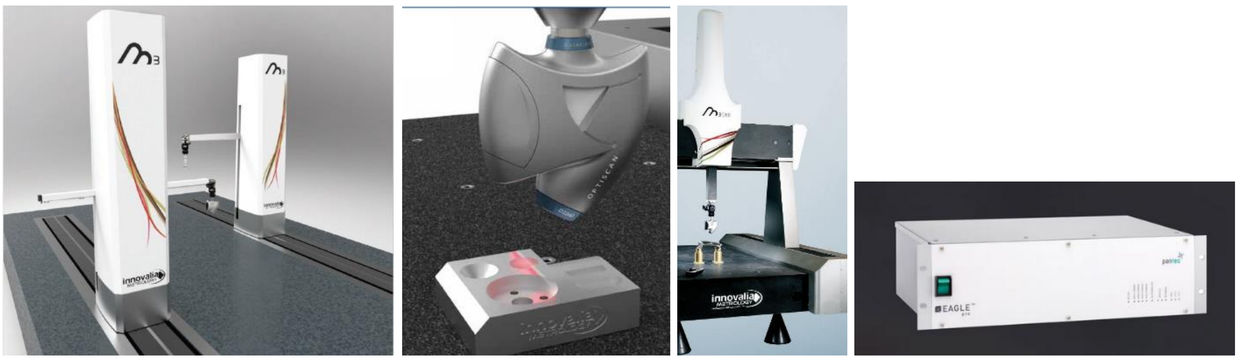

Figure 9. ZDM dimensional metrology service pilot assets for integration in the aerOS continuum.

- M3 Sfotware. Software to design the metrology process, configure metrology instrumentation and run metrology programmes.

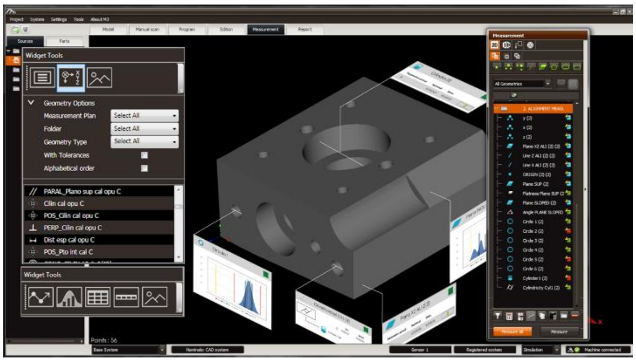

Figure 10. M3 metrology software platform for integration in the aerOS continuum.

2.2.3.2. Development activities

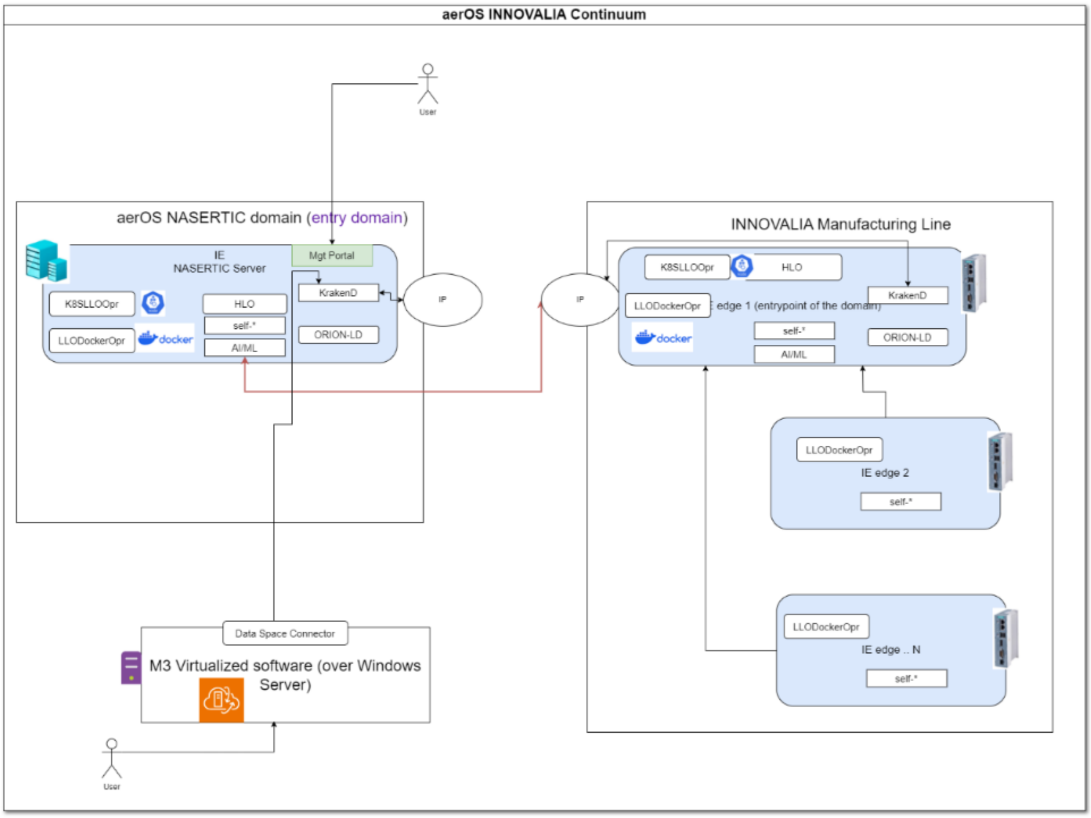

Figure 11. aerOS metaOS platform integrated in the metrology continuum.

- At the cloud continuum level, the development activities have focused mainly on the enablement of the main entry point (portal) to the metrology continuum and the development of an strategy for virtualisation of the M3 platform exposing the M3 execution engine in the cloud domain of the aerOS continuum.
- On the edge domain of the continuum the pilot has focused on the deployment of the basic services Low and High Level Orchestration services.

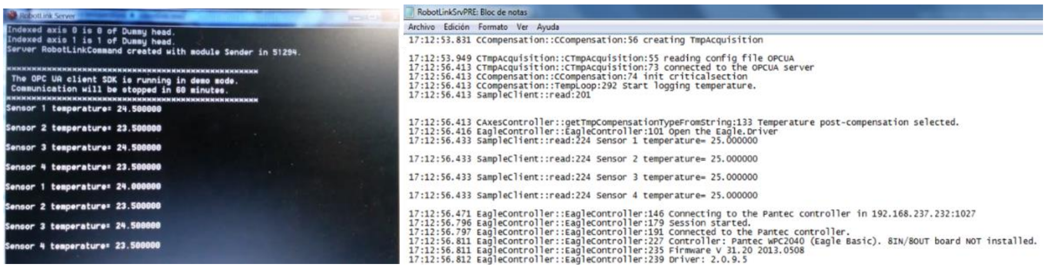

Figure 12. aerOS RL OPC-UA services

On the pilot side, the development of software based control services along with the RLSetup service for the dynamic execution of metrology services and Data Assembler for multi-platform data integration has been the focus of the development and deployment activities facilitating a modular metrology system approach as opposed to the traditional monolithic approach, which is not amenable to continuum operations and that cannot benefit from service orchestration.

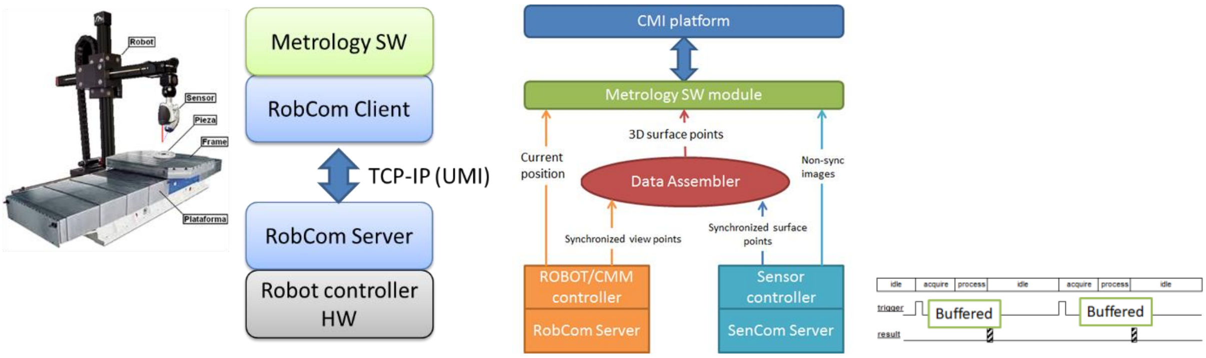

Figure 13. aerOS machine & sensor data synchronisation service

- At the IoT level the development of the IoT hub for the integrated collection and brokering of instrumentation information has also been the focus of the work to ensure that MQTT and OPC-UA protocols will align with the aerOS framework.

2.2.3.3. Integration activities

The deployment of aerOS metaOS services across the cloud-edge continuum is the critical element in the implementation of the pilot. The integration of the aerOS metaOS services will allow that simulation and engineering tasks of the metrology process can be decoupled from the actual execution of the programmes in the machine. The picture below depicts the first simulations of the production metrology envisoned by the aerOS metaOS and computing continuum for ZDM metrology task execution.

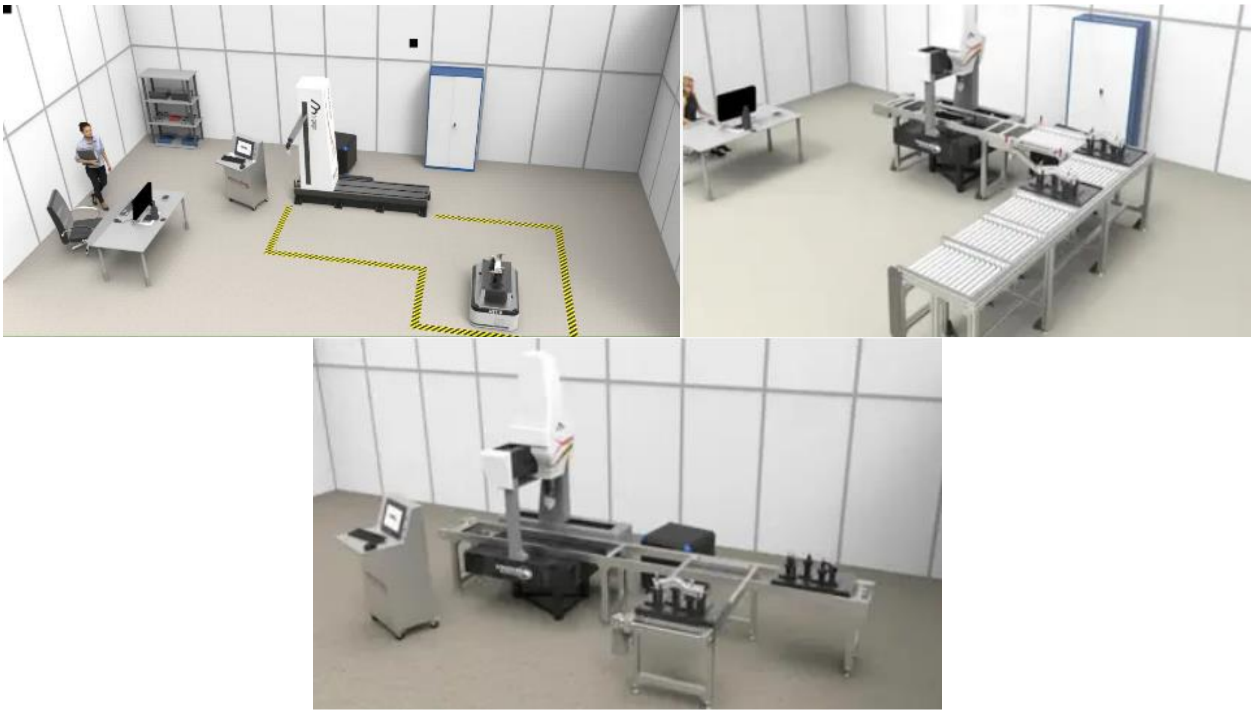

Figure 14. aerOS integrated scenarios to be supported in the continuum.

2.2.3.4. Validation activities

Remote configuration/set-up of the CMM instrumentation robotic and kinematic configuration (RLSet-up and RL) will be the most critical part of the scenario 1. This part connected with the automation and machine monitoring elements are the fundamental services from the pilot that need to be supported by the aerOS MetaOS. The operation and flexible set-up of these industrial services across the edge domain (IoT Hub, Automation OpenPLC and CMM control) will be extensively validated. The effective provisioning and release of the computing resources to effectively set up the machine configuration and automate the operation of the device for dimensional quality control will be the main element of validation. This should serve to assess the self-adaptation capabilities of the metaOS to serve the dynamic computing demands as the metrology production processes flow "on-demand".

The possibility to exchange and acquire CMM instrumentation data (IoT domain) from various sensors and share those across cloud-edge towards the M3 virtualisation system will be also be avaluated as part of the orchestration capabilities of the metaOS.

Final evaluation will also address security elements for automated sequencing of the operation, defining automation workflows across the automation equipment and the CMM device.

2.2.4. AGV swarm zero break-down logistics & zero ramp-up safe PLC reconfiguration for lot-size-1 production

The goal of this scenario is to establish a versatile production system distinguished by modularity, efficiency, and adaptability to dynamic manufacturing conditions. A key focus is placed on the development of a cyber-physical system that synergizes the capabilities of automated guided vehicles (AGVs) and robotic arms. This integration is facilitated through aerOS decentralized intelligence and communication technology, complemented by Siemens cloud systems services known as SIMATIC Industrial EDGE.

On the other hand, this scenario also aims to enhance the efficiency of a manufacturing process, specifically in the AGV optimization, in MADE case of a simulated company that performs assembly of valves. The use case involves a multi-phase system where orders for valves are generated, simulated, and stored in a database (Phase 1). Subsequently, automated guided vehicles (AGVs) are used to transport valve components and assembled valves between different zones, with smart warehouses and quality control systems integrated into the process (Phases 2-4). The AGVs are a critical component in this system, and their movements need to be optimized to improve overall efficiency.

In Phase 5, the AGV transports the assembled valve to a testing area, and the decision on whether to return the valve to the warehouse for sale or scrap is based on the test results. The challenge identified is that the AGV scheduling is not optimized, leading to potential inefficiencies and suboptimal use of resources. The proposal is to introduce artificial intelligence (AI) and machine learning (ML) to analyse historical data on orders, plant capacity, and testing capabilities. This AI/ML-based orchestrator aims to estimate the optimal number of valves to be taken before starting on an AGV trip, considering assembly and testing saturation. The goal is to improve AGV scheduling and maximize efficiency in the assembly and testing processes.

Additionally, the aerOS project explores a second scenario where outsourcing production is considered based on real-time tracking of AGV positions and order status. If the internal supply chains become saturated, the system can predict and implement a make-or-buy decision. The aerOS platform, with its AI/ML component, plays a central role in this decision-making process, simulating the paths of AGVs and optimizing logistics data to enable more informed decisions regarding in-house production or outsourcing.

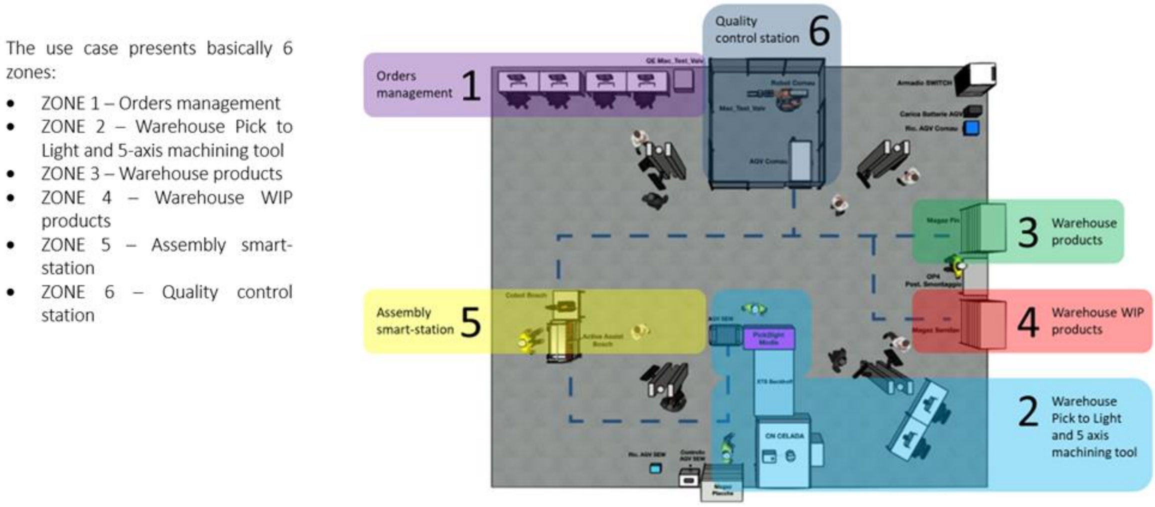

Figure 15. aerOS Pilot 1 – Scenario 3 – MADE´s Scenario zones

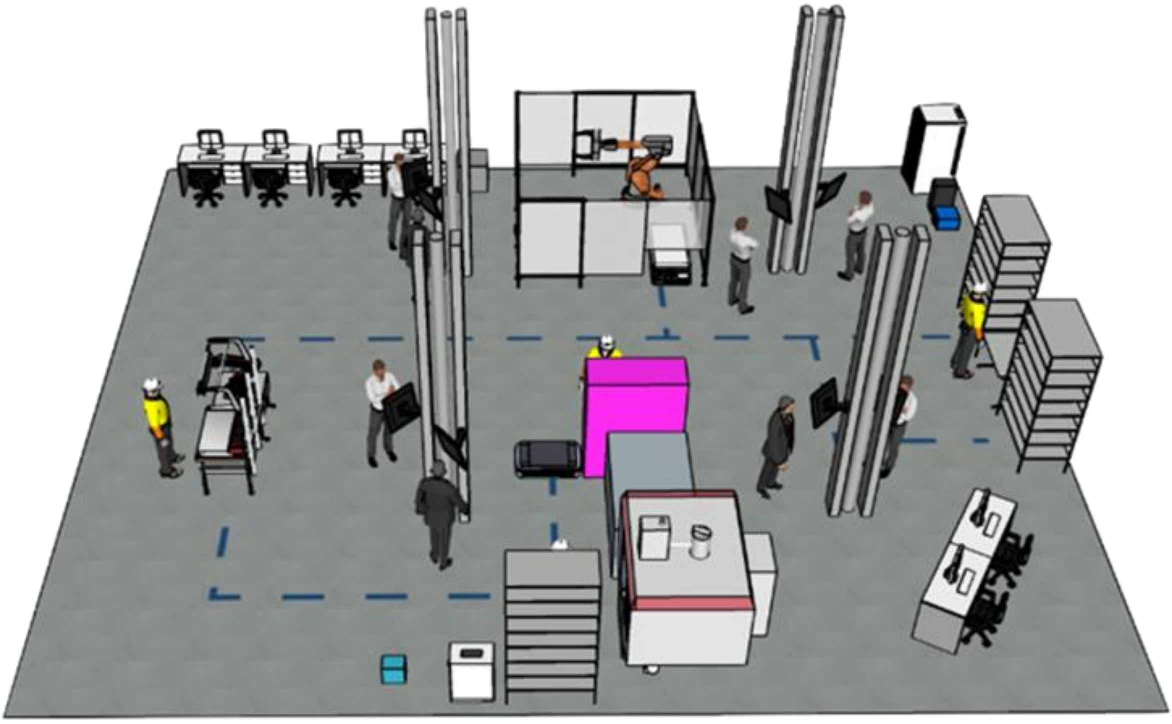

Figure 16. aerOS Pilot 1 – Scenario 3 – MADE´s working area

In this working period, MADE will focus on several key activities within the domains of procurement, integration, deployment, KPIs definition, and continuous analysis and evaluation of use cases. These activities are crucial for the successful implementation and optimization of the aerOS platform in the manufacturing environment. The following sections provide a brief overview of each major task.

This use case scenario delves into the exploration of flexible adaptation within a production line. This involves the modification of a particular process step to address a specific task, seamlessly facilitated through the utilization of a decentralized intelligent cloud system. This innovative approach permits a dynamic adjustment of the manufacturing process and ensures a smooth transition back to the previous production line configuration. Fundamentally, this scenario seeks to offer manufacturing solutions characterized by flexibility and modularity, departing from the limitations associated with contemporary static production systems. The effectiveness of this innovative system will be rigorously assessed for feasibility and robustness during a trial phase, poised to pave the way for the widespread adoption of this novel cyber-physical system and enhance the overall efficiency of the manufacturing process.

In the following lines, detailed activities to carry out the deployment of the scenario follows:

2.2.4.1. Setup and procurement Activities

The initial phase involves finalizing the definition of aerOS components and ensuring that comprehensive technical documentation is available for the identified use cases. This documentation will serve as a reference for the integration process, providing insights into the functionalities and requirements of each component.

The integration plan will be meticulously defined, and requirements will be validated based on the aerOS infrastructure. This step includes identifying the necessary equipment and minimum characteristics required for successful integration. Additionally, a thorough evaluation will be conducted to determine any adaptations or customizations needed for seamless integration with the specific use case.

About equipment MADE will exploit the NASERTIC infrastructure that will host the aerOS system and already existing one in MADE and POLIMI facilities. MADE will require two Virtual Machines that act as HLO (High Level Orchestrator) and LLO (Low Level Orchestrator) overall used for managing the whole system, monitoring the whole plant and coordinating the macro-actions and another one that operates close to the edge and uses aerOS AI/ML component to optimize AGV travels and if possible, avoid some of them assuring a better energy consumption of the system and improve availability of the assets.

Further in POLIMI facilities, will be installed the required aerOS components to manage AGV travels and production line. aerOS here will help to set up communication between the 2 areas and manage the requests coming from other Infrastructure elements.

The showcase setup at the Siemens TechHall provides different assets, which can be used to implement all required functionalities. It contains three small AGVs that are capable to drive autonomously and are able to lift e.g. palettes or boxes to drive those to different working areas. Additionally, there is one big AGV available, which is also equipped with a robot arm, do complete more advanced tasks. As working cells there are two mobile robot arm modules available, which can be lifted by the small AGVs and be placed in different working areas to perform tasks with their robot arm. All assets are connected to each other via Wi-Fi as well as to the internet and to a more powerful server placed in the TechHall.

The AGV environment can be divided into three different component setups:

- Small AGV setup (3x):
    - Siemens IPC: Industrial PC (OpenController2) based on an Intel Core i7 with four cores and 8 GB DDR3 RAM. One of those four cores is reserved for the Software based PLC. Furthermore, the Software PLC supports industrial grade protocols like ProfNet, Profibus, Modbus, and Ethernet/IP and IO interfaces. The IPC part is equipped with a Debian 11 based Siemens IndustrialOS with Real-Time capabilities. Additionally, the Linux and PLC can be connected via the so called Realtime Information Backbone (RIB) to the PLC side over shared memory or via OPC UA server (PLC) and client (Linux) connection. The global localization and navigation setup is based on the Siemens SIMOVE ANS+ software stack. All functionalities regarding movement, lifting and lightning can be controlled via ROS 2 packages. The whole setup is based on docker containers and docker compose for orchestration.
    - Nvidia IPC: Industrial PC with the focus on GPU and AI capabilities. Therefore, it is equipped with an ARM based CPU and additional Nvidia GPU and AI hardware setups. It runs an Ubuntu 20.04 Linux system. The actual setup only provides docker containers for controlling the Evocortex ELM camera via ROS 2.
    - Laser Scanner: Two SICK NanoScan3 modules are used for safety zone definitions and global localization capabilities.
    - Floor Camera: Additionally, an Evocortex Localization Module (ELM) is placed on the botton side of the AGV for precise global localization functionalities (<1cm).
    - Front & Back Camera: For extended safety mechanisms and vision capabilities there are two Intel Realsense cameras mounted (one looking at the front and one at the back).
    - Wi-Fi: Siemens Scalance W774 router for 2,4 & 5 GHz dual band Wi-Fi connectivity. It provides different industrial grade connection functionalities.
    - Wiferion: An induction-based platform for wireless charging capabilities.
    - Mecanum Wheels: For main movement and lifting purposes there are four Mecanum wheels used to be able to move freely in X, Y direction and to rotate around the yaw axis. Furthermore,

those wheels in combination with additional hardware are used to lift the AGV for carriage purposes.

- Robot Arm Module setup (2x):
    - Siemens ET200: PLC for the connection to the robot arm controller via Modbus and it provides an OPC UA server for IT based controls.
    - Universal Robots UR5e: A nine degree freely moving robot arm with cobot functionalities. Furthermore, it can be equipped with different grippers.
    - Wi-Fi: Siemens Scalance W774 router for 2,4 & 5 GHz dual band Wi-Fi connectivity. It provides different industrial grade connection functionalities.
    - Wiferion: An induction-based platform for wireless charging capabilities.
- Big AGV setup (1x):
    - Siemens IPC: Industrial PC (IPC427E) based on an Intel Xeon processor with 8 cores and 8 GB DDR 4 RAM. One of the 8 cores is reserved for the Software based PLC. It therefore provides the same capabilities as the OpenController2, but better performant. In the IPC there is a ROS 2 based setup running to provide autonomous navigation and robot arm control.
    - Siemens ET200 SP: A separated PLC to provide safety functionalities for fail safe robot arm and laser scanner control.
    - Laser Scanner: Two SICK NanoScan3 modules are used for safety zone definitions and global localization capabilities.
    - Wi-Fi: Siemens Scalance W774 router for 2,4 & 5 GHz dual band Wi-Fi connectivity. It provides different industrial grade connection functionalities.
    - Universal Robots UR5e: A nine degree freely moving robot arm with cobot functionalities. It is equipped with a Robotiq 2f-140 gripper.
    - Wiferion: An induction-based platform for wireless charging capabilities.
    - Mecanum Wheels: For main movement the AGV is based on the Evocortex EvoRobot platform, which provides four Mecanum wheels used to be able to move freely in X, Y direction and to rotate around the yaw axis.
- Server Rack (1x):
    - Siemens IPC: Industrial PC (IPC547G) based on an Intel Xeon 8th generation processor with 8 cores and 32 GB DDR 4 RAM. Additionally, it has an integrated iGPU. Running system is the Siemens IndustralOS based on Debian 11. At this stage the server is used as the fleet manager of the AGVs and to run tasks that need more processing power than the AGVs can provide.
    - Wi-Fi: Siemens Scalance W774 router for 2,4 & 5 GHz dual band Wi-Fi based connectivity. It provides different industrial grade connection functionalities. The router acts as an access point. All AGVs, robot arms and other assets are connected to it.

The AGV arena is currently under development to provide a factory like setup. There will be different areas for the AGVs. There is a separated parking lot for all three AGVs. Next to it there are three Wiferion charging stations placed for the EvoCarrier AGVs and the OCP AGV. As main working stations there will be differentkinds of areas. The first one is equipped with a robot arm cell, which is stationary fixed. Besides, there are two more areas that are meant to be flexible production cells. For example, the mobile robot arms can be placed in those areas to fulfil tasks. Additionally, there will be another coworking area for two AGVs combined with a conveyor belt and one of the mobile robot arm modules. Furthermore, there will be an additional Siemens internal fleet manager used to be able to orchestrate the whole AGV fleet via VDA5050 interface.

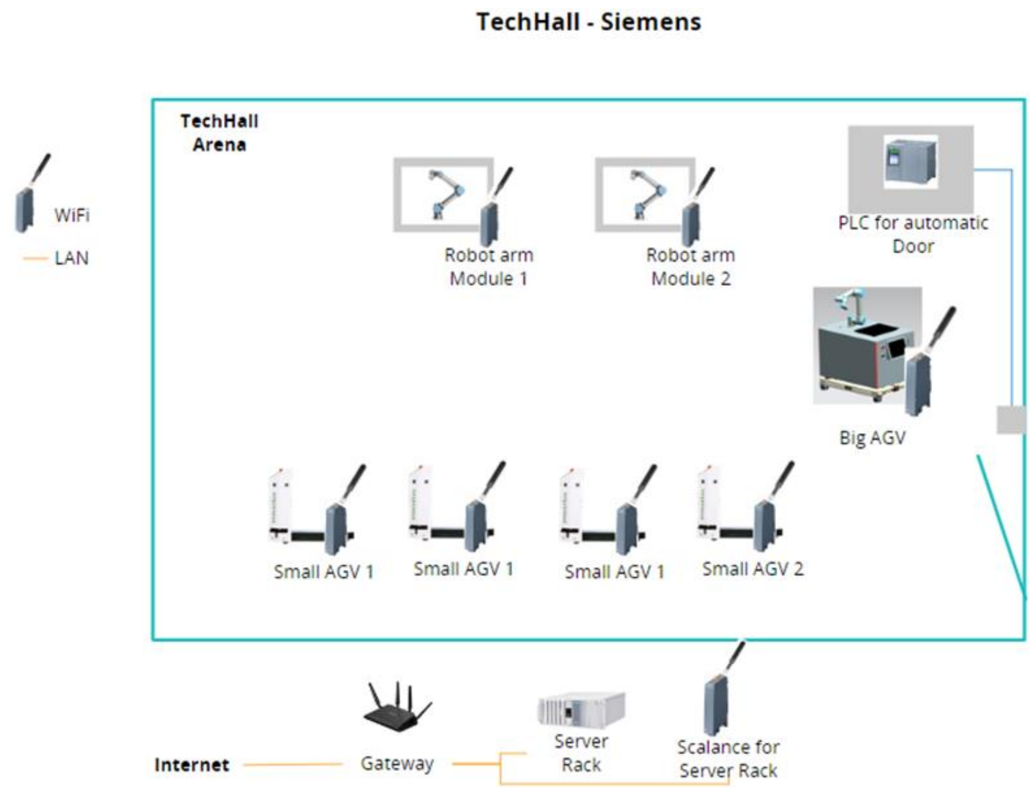

Figure 17. aerOS Scenario 3 – Siemens AGV´s arena

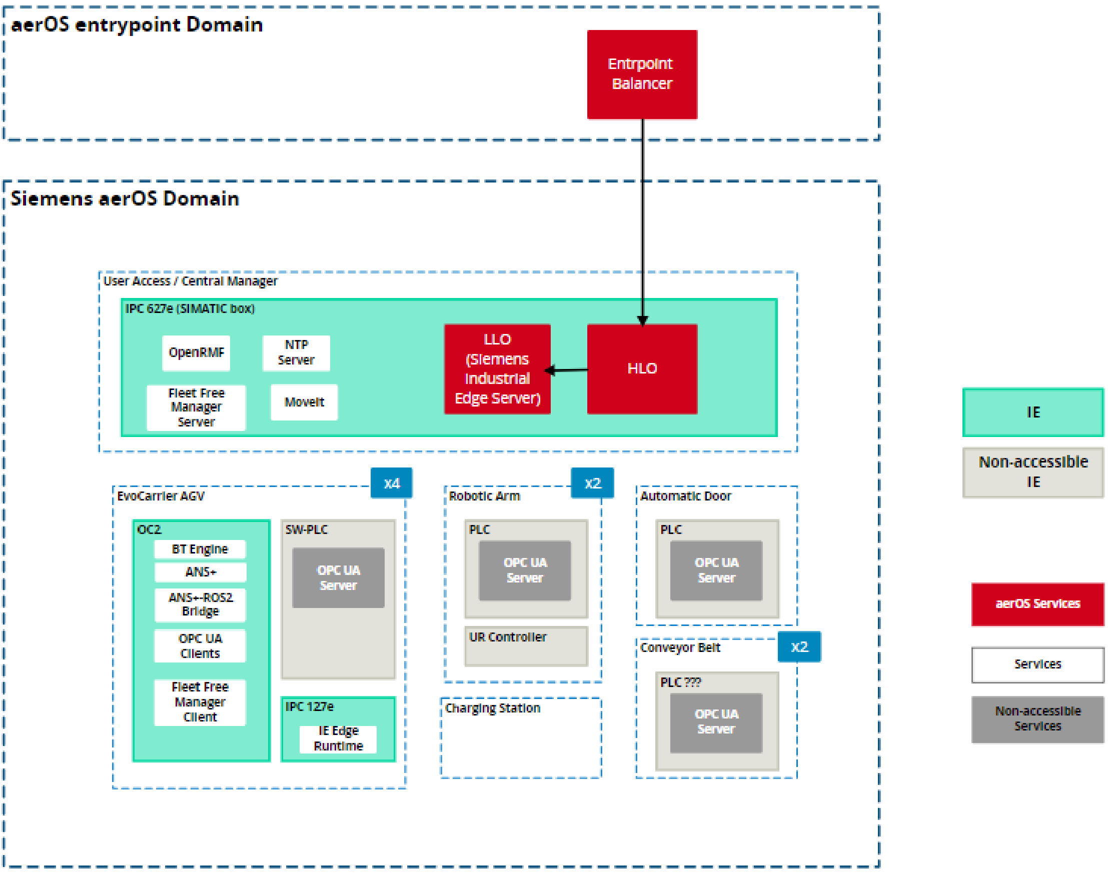

Figure 18. aerOS Pilot 1 – Scenario 3 – Setup of Siemens adaptation to aerOS

The management portal with the entrypoint balancer and some auxiliary service could be in an external server provided by Narsetic (aerOS Entrypoint Domain).

The HLO and the LLO will run in the SIEMENS domain, using as LLO the SIEMENS Industrial EDGE (IE in the schema), offering functionalities comparable to the widely recognized Kubernetes.

As can be seen in the architecture schema, there are PLC devices that can communicate with Siemens devices and services, as well as aerOS services over industrial protocols like OPC UA.

2.2.4.2. Development activities

There is certain software and component development necessary for the success of this scenario. Some aspects of this have already been outlined in Trial Handbook 2, Scenario 3, and are divided into four distinct topics. For the main four objects of the Scenario 3, the following developments need to be fulfilled or are already done:

- Flexible asset usage: As all AGVs and robot arm modules are equipped with either an IPC or a PLC. Therefore, all assets are controllable directly over MQTT, ROS 2 or OPC UA. Different functionalities like robot arm movement, moving from A to B or triggering can be flexibly done over those interfaces. Therefore, either the server or overlaying IT systems can be used as orchestrating instances.
- Risk reduction: As all AGVs are equipped with safety certified laser scanners including safety fields e.g. 50 cm around the platform, in principal they can work in areas where also human interactions are necessary. The robot arms are also designed to work as co-bots and therefore in a safe way. As the EvoCarrier AGVs provide lifting functionalities, they can be used to lift boxes and drive them to the production areas. Those capabilities combined in the Siemens TechHall allow the usage as a completely autonomous and flexible production show case.
- Siemens Industrial Edge: The Siemens ecosystem offers an IT cloud-edge solution through its edge computing platform "Industrial Edge." This ecosystem provides Siemens apps for seamless IT/OT integration, production analytics, and efficient maintenance. It also includes ready-to-use devices for edge computing, already incorporated by the AGVs and servers in this scenario. However, there is still a need for a solution/adapter to combine all the advantages of this ecosystem with the aerOS ecosystem. This requires additional software components that enable external control of the Industrial Edge platform. As all Siemens services will run inside this ecosystem, it is necessary to find a solution to manage services with external applications.
- Optimized network capabilities: Currently, the network setup inside the TechHall is not optimized The server device that act as an access point for all AGVs is still not ye purchased and will probably be acquired and installed in the first quarter of 2024. Then the combination of a performant access point, Wi-Fi/LAN infrastructure as well as high bandwith internet access to all assets will have to be tested.
- Optimized network capabilities: Currently, the whole Wi-Fi setup inside the TechHall is on client’s side (AGVs, robot arm modules) at a production ready. The server side (access point, internet access) is still under construction and will probably be ready in the first quarter of 2024. Then the combination of a performant access point, Wi-Fi/LAN infrastructure as well as high bandwith internet access to all assets will be guaranteed.

Further, the project will define the tools, platforms, and development frameworks to be used throughout the integration process. Simultaneously, hardware/software APIs will be identified to ensure effective communication and integration with the use case equipment.

Here ad-hoc synthetic data will be studied accurately to understand the limits of the production line and define the rules to consider it saturated. These data will be used to start training the AI/ML models that will be used to make prediction to drive actions on AGVs.

2.2.4.3. Integration activities

In this scenario, the utilization of AI modules plays a crucial role in determining the deployment of user services across various devices such as AGV, robotic arm modules, near-edge devices, or the cloud. Consequently, the integration of the High-Level Orchestrator (HLO), particularly the HLO allocator, takes precedence in this project. To facilitate this, several essential aerOS core modules are necessary for a proper assessment of service allocation.

Self-capabilities and embedded analytics are pivotal in collecting pertinent information for the HLO to make informed decisions. Monitoring CPU resources is essential for the HLO to analyse which devices possess sufficient resources for executing resource-intensive or complex operations, such as AI services. The data fabric is another integral component that works in conjunction with the HLO and self-capabilities modules. It gathers crucial data, primarily from OPC UA and DDS protocols, given our laboratory's reliance on Siemens PLCs and IPCs operating on these protocols. This involves retrieving information about devices registered within the Siemens-aerOS domain, among other details.

Integration activities are expected to commence post the initial Minimum Viable Product (MVP) release of aerOS. Until then, certain modules can be tested independently. Notably, the HLO allocator is already undergoing testing. An early version has been deployed on a near-edge device, functioning as the main server communicating with all AGVs. Initial tests involve the deployment of a service illuminating the lamp of an AGV. As there is currently no Low-Level Orchestrator (LLO) like Kubernetes deployed into our systems, the HLO directly connects to the AGVs via SSH, triggering a docker container to illuminate the lamp. A simple web application has been developed for visual demonstration.

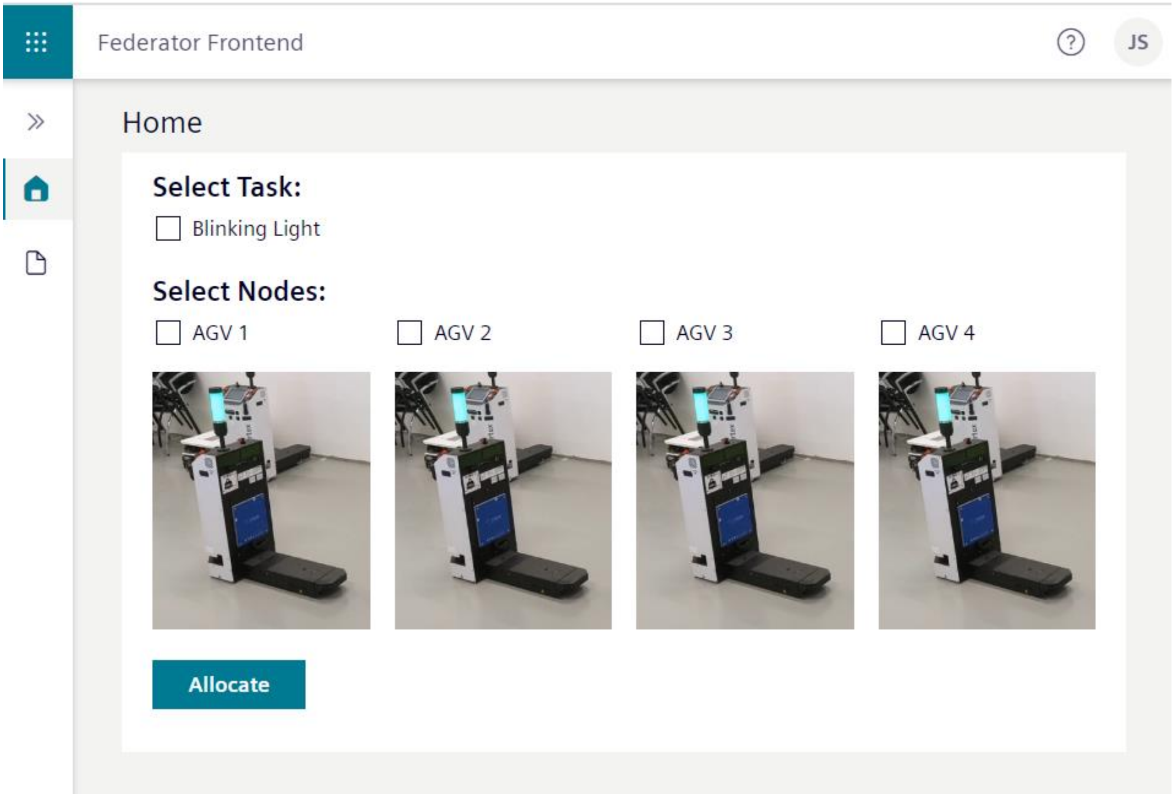

Figure 19. aerOS Pilot 1 – Scenario 3 – Task allocator

The scenario does not envision using Kubernetes as the primary LLO for managing device services. Instead, Siemens Industrial EDGE is planned to serve the same purpose. The custom LLO offers advantages such as a direct connection to the Siemens App Store, housing essential Siemens services in the cloud for deployment on any Siemens device. However, the process of connecting the HLO to custom LLOs still requires clarification.

Integration of the management portal is anticipated in the coming months to monitor Siemens domain registration and resource status. OpenVPN and KrankenD installations are also slated for the following year. Concerns arise regarding the connection of Siemens Network Infrastructure to external cloud management systems like CloudFerro or Nasertic. This remains a focal point for future consideration.

The deployment phase will commence with setting up the use case environment, building up the hardware/software planned solution, configuring communication systems with existing and new equipment, and obtaining synthetic datasets to be used to reinforce AI/ML module training process.

The aerOS modules will be integrated to communicate with existing systems in the use case and make informed decision to orchestrate from high level point of view the system, in particular the system should be able to cooperate with current orchestrator software and helping itself with data fabric module should use the data available to coordinate the the real behaviour of the AGVs.

A critical step involves configuring the data pre-processing component and training the AI/ML module with synthetic datasets. The system will be set up to exploit prediction data for piloting the AGV start time, optimizing the scheduling process.

2.2.4.4. Validation activities

KPIs Definition and Evaluation Framework Setup

The project will focus on defining key performance indicators (KPIs) and establishing an evaluation framework. Various validation strategies will be explored to ensure the effectiveness of the implemented use cases.

Testing and Validation

The use case will undergo rigorous testing, and the outcomes will be measured against the predefined KPIs. Validation reporting will include contributions outlining the results achieved, providing valuable insights into the performance of the aerOS platform in the manufacturing environment.

Continuous Use Cases Analysis, Evaluation, and Assessment

Business Evaluation and Stakeholder Satisfaction

Ongoing analysis will include a thorough business evaluation, considering stakeholders' and users' satisfaction. Ethical, societal, and environmental aspects will be considered, ensuring the alignment of the project with broader objectives.

Performance Analysis

Qualitative and quantitative analyses will be conducted to assess the performance gains achieved against use case-specific performance indicators. The assessment will extend to processing/response latency, storing costs, and privacy considerations.

The validation of SIEMENS’ system and aerOS components will unfold in SIEMENS laboratory setting. The High-Level Orchestrator (HLO), in collaboration with other aerOS components, will actively collect sufficient information to make informed decisions about which AGV or robot module to deploy for a specific task. This strategic decision-making process aims to optimize the time utilization of AGVs and further automate production, eliminating the need for user intervention in task assignment. The key performance indicators (KPIs) defined for this scenario include AGV availability and AGV utilization. The target for the first KPI is set at 10 minutes, while the goal for the second is 12 minutes. These metrics will guide our evaluation of the system's efficiency and effectiveness in streamlining operations and enhancing production automation.

2.2.5. Pilot 1 Timeplan

PILOT 1	jun.-23	jul.-23	ago.-23	sep.-23	oct.-23	nov.-23	dic.-23	ene.-24	feb.-24	mar.-24	abr.-24	may.-24	jun.-24	jul.-24	ago.-24	sep.-24	oct.-24	nov.-24	dic.-24	ene.-25	feb.-25	mar.-25	abr.-25	may.-25	jun.-25	jul.-25	ago.-25
	Year 1			Year 2												Year 3											
Name of the activity	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
Setup & Procurement Activities																											
A1. Pilot mapping with aerOS architecture																											
Flow Diagrams generation																											
Resources & infrastructure diagram generation																											
Mapping pilot resources with aerOS architecture																											
A2. Equipment Setup & procurement																											
A2.1 P1UC1																											
A2.1.1 Stations identification for the trial																											
A2.1.2 Hardware setup																											
A2.1.3 Equipment configuration																											
A2.2 P1UC2																											
A2.2.1 Installation of control camera in the CMM																											
A2.2.2 Installation of pressure sensor in the CMM																											
A2.3 P1UC3-1																											
A2.3.1 aerOS components defined and technical documentation for use case																											
A2.3.2 Integration plan definition and requirements validation																											
A2.3.3 Define equipment and minimum characteristics																											
A2.3.4 Evaluate required adaptation and customisation on the use case																											

A2.3.5 Define (i) tools, platforms and development framework(s)																											
A2.3.6 Set up use case environment and components installed/integrated																											
A2.3.7 Set up communication system with existing and new equipment																											
A2.3.8 Get/Use synthetic dataset to train AI/ML Models																											
A2.3.9 Set up system to exploit prediction data to piloting input of AGV start time																											
A2.4 P1UC3-2																											
A2.4.1 Procurement and setup of 4 AGVs																											
A2.4.2 Procurement and setup of 2 robot arm modules																											
A 2.4.3 Setup wireless charging modules for AGVs																											
A2.4.4 Setup server rack																											
A2.4.5 Setup techhall Network																											
A2.4.6 Procurement camera for robot arm																											
A2.4.7 Setup AI camera detection																											
A2.4.8 Procurement and setup gripper for robot arm																											
A2.4.9 Procurement and setup of automatic door																											
A2.5 P1UCIP																											
A2.5.1 VM dimensioning																											
A2.5.2 Deployment of K8s cluster																											
A2.5.3 Connectivity to the K8s cluster																											
Validation Activities																											

Figure 20. aerOS Pilot 1 – Overall High-level planning

Table 2– Pilot 1 - Overall view of Activities

ID	Topic	Activity	Who	Plan	Real	Status
A2.1.1	Stations identification for the trial	*Setup activity*	SIPBB	December 2023	December 2023	Done
A2.1.2	Hardware setup	*Setup activity*	SIPBB	May 2024	N/A	Ongoing
A2.1.3	Equipment configuration	*Setup activity*	SIPBB	June 2024	N/A	Ongoing
A2.2.1	Installation of control camera in the CMM	*Setup activity*	Innovalia	April 2024	N/A	Ongoing
A2.2.2	Installation of pressure sensor in the CMM	*Setup Activity*	Innovalia	April, 2024	N/A	Not started
A2.2.3	Dimensioning NASERTIC´s Infrastructure	*Setup Activity*	Innovalia	April, 2024	N/A	Ongoing
A2.4.1	Procurement and setup of 4 AGVs	*Setup Activity*	SIEMENS	April 2024	N/A	Ongoing
A2.4.2	Procurement and setup of 2 robot arm modules	*Setup Activity*	SIEMENS	August 2024	N/A	Not Started
A2.4.3	Setup wireless charging modules for AGVs	*Setup Activity*	SIEMENS	Mai 2024	N/A	Ongoing
A2.4.4	Setup server rack	*Setup Activity*	SIEMENS	February 2024	January 2024	Finished
A2.4.5	Setup TechHall Network	*Setup Activity*	SIEMENS	April 2024	N/A	Ongoing
A2.4.6	Procurement camera for robot arm	*Setup Activity*	SIEMENS	August 2024	N/A	Not Started
A2.4.7	Setup AI camera detection	*Setup Activity*	SIEMENS	December 2024	N/A	Not Started
A2.4.8	Procurement and setup gripper for robot arm	*Setup Activity*	SIEMENS	December 2024	N/A	Not started
A2.4.9	AGV Navigation and control over ROS2	*Development Activity*	SIEMENS	February 2024	N/A	Ongoing
A2.4.10	AGV Fleet Manager	*Development Activity*	SIEMENS	July 2024	N/A	Not started
A2.4.11	Device simplified programming over low code tools	*Development Activity*	SIEMENS	August 2024	N/A	Ongoing
A2.4.12	AGV Safety Assurance and collision avoidance with laser scanners	*Development Activity*	SIEMENS	February 2024	January 2024	Finished
A2.4.13	PLC to IPC interface (RIB or OPC UA)	*Development Activity*	SIEMENS	September 2024	N/A	Not started
A2.4.14	Siemens Industrial Edge configuration for AGV and robot arm	*Development Activity*	SIEMENS	February 2025	N/A	Not started
A2.4.15	Network optimization in Techhall	*Development Activity*	SIEMENS	December 2024	N/A	Not started
A2.4.16	Definition of IT architecture with aerOS	*Integration Activity*	SIEMENS	March 2024	N/A	Ongoing
A2.4.17	Integrate data fabric context broker	*Integration Activity*	SIEMENS	April 2024	N/A	Not started
A2.4.18	Integrate Self-capabilities nodes	*Integration Activity*	SIEMENS	September 2024	N/A	Not started
A2.4.19	Integrate HLO	*Integration Activity*	SIEMENS	July 2024	N/A	Not started
A2.4.20	Integrate LLO interface for Siemens Industrial Edge	*Integration Activity*	SIEMENS	February 2024	N/A	Not started
A2.4.21	Integrate Embedded Analytics Tool	*Integration Activity*	SIEMENS	Mai 2024	N/A	Not started
A2.4.22	KPI validation	*Validation Activity*	SIEMENS	March 2025	N/A	Not started
A2.4.23	Improvement activities	*Validation Activity*	SIEMENS	June 2025	N/A	Not started
A2.4.24	Evaluation and reporting	*Validation Activity*	SIEMENS	June 2025	N/A	Not started
A2.5.1	VM dimensioning	*Setup activity*	NASERTIC	Mid January, 2024		Ongoing
A2.5.2	Deployment of K8s cluster	*Integration activity*	NASERTIC	Ending January, 2024		Not started
A2.5.3	Connectivity to the K8s cluster	*Integration activity*	NASERTIC	Mid February, 2024		Not started
A5.4.1	Continuous maintenance of the K8s cluster	*Validation activity*	NASERTIC	As long as activity last		Not started

2.3. Containerised Edge Computing near Renewable Energy Sources (CF/ELECT)

The primary goal of Pilot2 is to prove applicability of aerOS for set up and management of cloud-edge architectures distributed between "big" central clouds and small edge nodes located directly at energy producing locations, gathering information and events from the deployed smart devices.

The edge nodes will have connectivity to the private cloud infrastructure of CF.

The current architecture of the containerized edge node consists of physical server racks, one control plane node, 17 compute nodes and 2 storage nodes.

The trials will be divided in three global stages, as described in the following lines:

- **Stage 1: Validation of 1 containerized edge node**

The first stage is the validation of 1 containerized edge node, as an individual component. Container with dedicated HW & SW undertakes a step-by-step validation process. Such an approach ensures that the basic component of Pilot2 Use Case is ready to proceed with Scenario 1 and 2.

- **Stage 2: Validation of 2 containerized edge nodes with aerOS System and aerOS Scenario 1 deployment**

The second stage involves the validation of aerOS's system. This validation ensures that the combined functionalities of aerOS operate containerized edge nodes and meet the potential user experience. This stage also serves as a crucial feedback loop, allowing aerOS developers to incorporate user insights and address any unforeseen challenges.

- **Stage 3: aerOS Scenario 2 deployment**

The third stage is the validation of aerOS capabilities to create secure ad-hoc resource federations composed from heterogeneous edge nodes and traditional "big" clouds. It means that the main challenges of this Scenario are in security and data and information management domains. It will be built on top of Scenario 1 and extend the federation beyond infrastructure owned by CF.

2.3.1. Green Edge Processing

In this scenario we deploy necessary components on private CF cloud located in a datacenter and two federated edge nodes (containers) located directly at renewable energy premises. The Green Edge Processing scenario will be evaluated in which the information on energy price forecast and green energy availability is used to orchestrate the edge nodes (containers) in the most economically efficient way. The energy price and availability schedule is being developed as the Future Energy Price K8s microservice that is to be integrated with aerOS HL Orchestrator. The platform architecture allows to deploy local MLOps pipeline with the energy price and availability microservice, where data inference runs in synchronization with aerOS IoT-Edge-Cloud continuum components. The MLOps inference server runtimes are deployed on Edge Computer(s) with neural network accelerators provided by Electrum for the Demonstrator.

The installation of Edge Computers provided by Electrum is available in two options: (1) DIN-rail, or (2) 19" 1U rackmount, with possibility to be installed either in electrical switch station or directly in HPC Container. The Edge Computer features max power at 60W and can be powered either by provided 12V charger or PoE. Edge Computer must be connected to local network through Eth port or optional WiFi module.

Managing the system shall be performed in energy, network, and self-conscious manner, measuring the reductions provided (benchmarking of parameters based on real-time own analytics in the IE) in the orchestration of tasks deployed in the edge instead than in the cloud.

CloudFerro participates in this Pilot as an Infrastructure provider. The infrastructure that CloudFerro provides to the project will be containerized edge nodes based on container filled in with physical server racks and one control plane node, 17 compute nodes, 2 storage nodes an. On the system level we are planning to make use of existing CF infrastructure in the private cloud based on OpenStack for compute and CEPH for storage. For edge nodes we will be using Kubernetes deployed on bare metal nodes. The containerized edge node will serve to test and validate aerOS' orchestration functionalities across different domains. The cluster of servers that CF will provide to aerOS will be made up of couple bare metal servers forming 2 Kubernetes clusters.

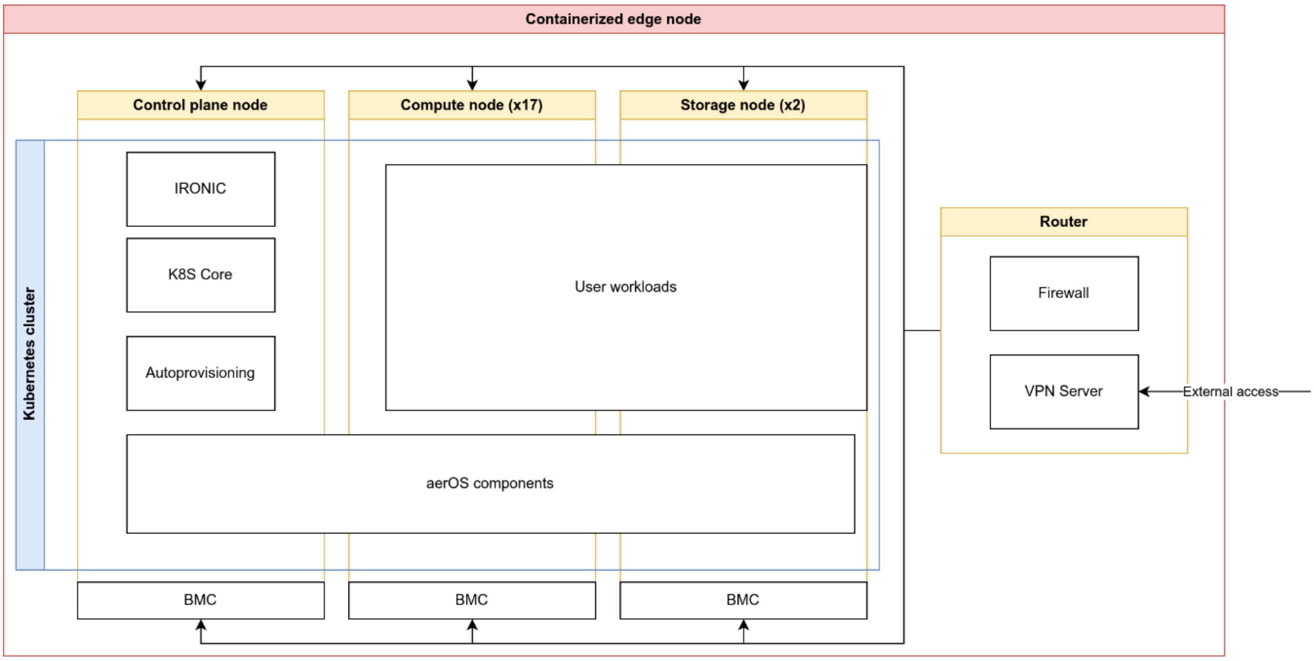

Figure 21. Pilot 2 – Scenario 1 - Diagram of containerized edge node showing how aerOS will be ran on bare metal cluster.

For both scenarios, most of the activities refer to setup, integration and validation, without a development per se, therefore the section is neglected for now. Even though for this stage progress has been made on installation and integration on the infrastructure, actual developments will be made on AI and Frugal AI during the next months.

2.3.1.1. Setup and procurement activities

Provided environment will consist of two containerized edge nodes, minimum each containing:

- Two server racks
- One router node with following specification: 2 processors 12 core 2.3 GHz, 128 GB RAM, 2 x SSD Boot Disk 1TB, ethernet port 4xSFP+ 25G, 4xSFP+ 10G, 2xUTP 1G, IPMI, redundant power supply]
- One control plane node with following specification: 2 processors 12 core 2.3 GHz, 256 GB RAM, 2 x SSD Boot Disk 1TB, ethernet port 2xSFP+ 25G, 2xUTP 1G, IPMI, redundant power supply
- 17 compute nodes with following specification: 2 processors 12 core 2.3 GHz, 192 GB RAM, 2 x SSD Boot Disk 120GB, ethernet port 2xSFP+ 10G, 2xUTP 1G, IPMI, redundant power supply
- 2 storage nodes with following specification: 2 processors 12 core 2.3 GHz, 192 GB RAM, 2 x SSD Boot Disk 120GB, ethernet port 4xSFP+ 25G, 2xUTP 1G, 22*0,96TB SSD, IPMI, redundant power supply

These nodes will be connected with switches to form several VLANs allowing access to their BMC and regular network interfaces.

2.3.1.2. Cluster preparation activities

As containerized edge nodes will be based on bare metal machines, they must be first provisioned and important software components must be installed to provide an appropriate environment for the aerOS.

The goal of these activities is to have a functioning Kubernetes cluster running on each containerized edge node.

Each edge node will have one router node that is preconfigured with firewall and VPN solution. This will let authorized users access all necessary devices inside the container. This node will be used exclusively for networking purposes and will not handle server provisioning or management.

The first step is to have each node working with appropriate Operating System and software. To automate deployment of bare metal servers Openstack Ironic is used. It leverages IPMI interfaces of the nodes and their ability to boot from network to clean them of existing configuration, install specified operating system image and perform necessary actions through cloud-init mechanism. Its actions can be controlled through a REST API which has been automated to provision all detected nodes by a custom *autoprovisioner* service created by CloudFerro during previous project related to bare metal deployment.

This approach allows us to deploy the second and following machines in the cluster. The first machine has to be deployed manually, as at the time of its deployment there is no host on the network to provide the necessary configuration. This must be done either by accessing the machine physically and inserting boot drive with OS installation files or by making use of virtual media mechanism. Supermicro servers used in edge nodes provide an option to mount a virtual CD-ROM drive of size up to 4.7 GB from a Windows Samba share. Such share can be created temporarily on central cloud by using appropriate docker image and exposing it on address accessible to the deployed server. After mounting the server can be booted up from the web interface and one can go through OS using a KVM interface.

When OS is installed on the first machine (from now called master) the next steps are to install and configure ssh server, IP tables masquerading rules for remote access to other nodes, kubelet and kubeadm.

When one node Kubernetes cluster is established on master CNI solution, ironic, dnsmasq and autoprovisioner can be deployed on it to start managing other bare metal nodes. Booting up all servers while these components are in place leads to all of them joining the Kubernetes cluster. When the cluster is ready, and all nodes have joined aerOS and auxiliary components can be deployed on it.

2.3.1.3. Integration activities

Cluster deployed according to instructions above will need to integrate with components provided by Electrum (ELECT). These components are two servers (one per edge node) external to the cluster with all software already installed and ready to be turned on and connected to the edge node's network. These servers will not be managed by ironic. They will be booted up on master node startup and shut down on master node shutdown. This will be handled by a job making appropriate calls to IPMI interface of those servers.

These servers will contain an aerOS installation and expose API for SCADA (*Supervisory Control and Data Acquisition)* and Future Energy Price microservice. Thanks to them aerOS deployment on the cluster will be able to schedule tasks in a more energy aware way.

2.3.1.4. Validation activities

To validate that this scenario is complete we will check if the following conditions are fulfilled:

- All nodes are up and running an appropriate OS
- All nodes have joined the Kubernetes cluster and are ready to run pods
- The cluster is accessible from the outside and resources can be created on it
- The aerOS components are running correctly on the cluster without crashing
- The deployed aerOS infrastructure allows running tasks
- Tasks can access CF EO-Data archives from central cloud
- Scheduled tasks are run in an energy aware way – periods in which Electrum APIs signal an upcoming generation of green power are preferred. The edge compute orchestration in aerOS can be configured to automatically distribute tasks on the nodes as per the lowest energy price and availability indication provided by the Electrum's micro k8's.

.

2.3.2. Secure Federation of edge/cloud

In this scenario the aerOS capability to create secure ad-hoc resource federations composed from heterogeneous edge nodes and traditional "big" clouds. It will build on top of Scenario 1 and extend the federation beyond infrastructure owned by CloudFerro. Simultaneously, it will on-board multiple, independent tenants and execute unmoderated (thus, not trusted) workload provided by these tenants. It means that the main challenges of this scenario are in security and data and information management domains. Secure federation scenario will leverage aerOS functionalities that will be developed within work packages 3 and 4 – WPs that tackle cybersecurity and data privacy. Additionally, integrating 3rd party-owned resources will verify aerOS' interoperability.

2.3.2.1. Activities related to preparation for running untrusted workloads

Kubernetes by default runs pods using runc runtime. Its advantages are that it is fast and lightweight. Although it is secure it is not the perfect solution for running untrusted workloads. For that reason, kata containers runtime will be used. To run pods, it uses lightweight virtual machines based on QEMU or other VM hypervisor. This approach provides better isolation and security. Cloud hypervisor will be used as hypervisor that kata will use to start VMs.

To use kata it will need to be installed on all nodes used to run workloads, containers will need to be configured to allow its usage and kata-clh will need to be specified as spec.runtimeClassName by aerOS when creating workload pods.

Using this approach will prevent untrusted workloads from interfering with the environment in an unwanted manner. It will also prevent one workload from accessing data used by another.

2.3.2.2. Inter-cloud integration activities

To allow establishing connection between aerOS on containerized edge node and external cloud some of the aerOS services will need to be exposed to the public. As router node is the only host in the containerized edge node with public IP port forwarding must be used to direct traffic to appropriate hosts inside the container.

To secure traffic between the clouds TLS will be used with termination on nginx-based ingress running on the cluster. If there is need to verify connecting hosts mTLS functionalities of nginx controller can be used for that purpose.

2.3.2.3. Validation activities

To validate that this scenario is complete we will check if the following conditions are fulfilled:

- Instance of aerOS running on containerized edge node is able to connect to instance of aerOS running on external cloud environment in a way that they run as different domains.
- HLO of each of the connected domains is able to transfer its tasks to the other domain and is able to receive tasks from HLO of that domain.
- Instance of aerOS running on containerized edge node is able to host Management Portal and accept Service Placement Requests from authenticated users.
- AerOS running on containerized edge node is able to run untrusted workloads in a secure and isolated way.

2.3.3 Pilot 2 Timeplan

The figures below illustrate the planning for the 2 scenarios of Pilot 2

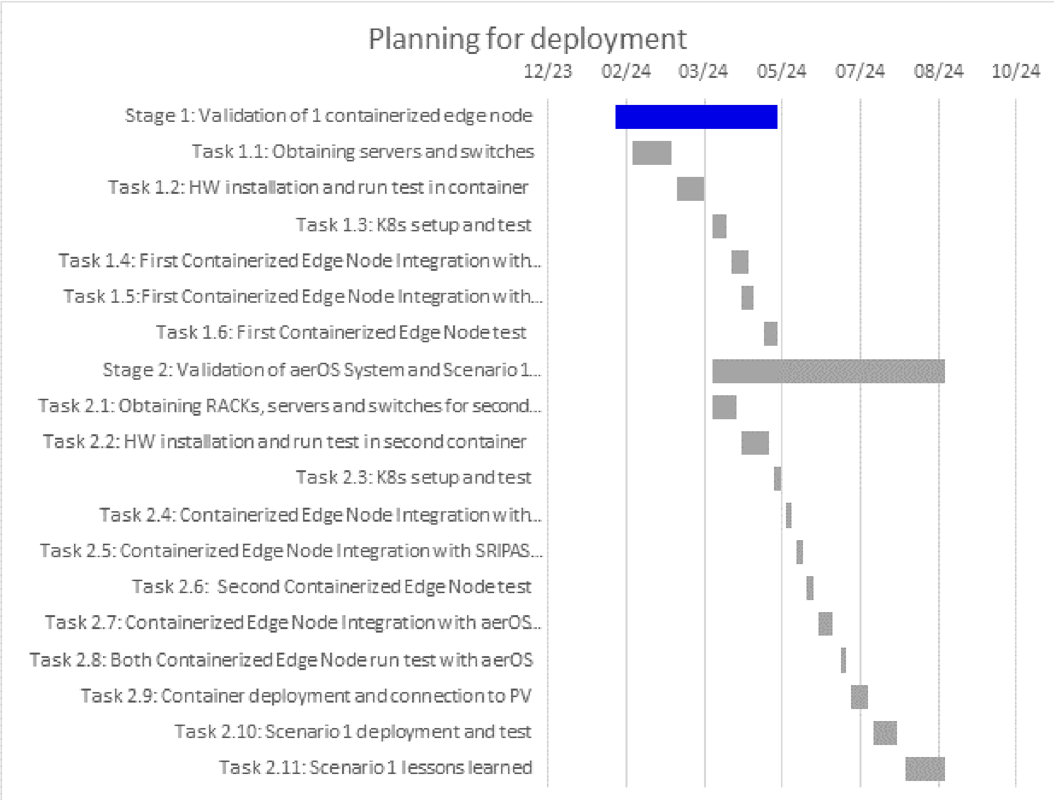

Figure 22. Pilot 2 – Scenario 1 – Planning for deployment

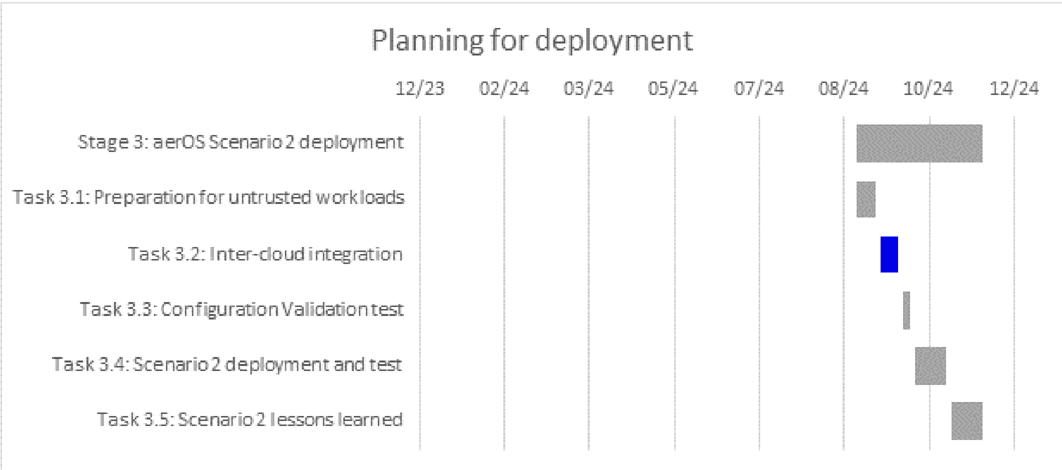

Figure 23. Pilot 2 – Scenario 2 – Planning for deployment

Table 3– Pilot 2 – Scenario 1 – Overview of activities

ID	Topic	Activity	Who	Plan	Real	Status
T1.1	Obtaining servers and switches	Set-up Activity	CF	Feb 2024	23.02.2024	Done
T1.2	HW installation and run test in container	*Development Activity*	*CF*	Mar 2024	N/A	Ongoing
T1.3	K8s setup and test	*Development Activity*	*CF*	Apr 2024	N/A	Not started
T1.4	First Containerized Edge Node Integration with Electrum components	*Integration Activity*	*ELECTRUM*	Apr 2024	N/A	Not started
T1.5	First Containerized Edge Node Integration with SRIPAS components	*Integration Activity*	*SRIPAS*	May 2024	N/A	Not started
T1.6	First Containerized Edge Node test	*Validation Activity*	*CF*	May 2024	N/A	Not started
T2.1	Obtaining RACKs, servers and switches for second container	Set-up Activity	*CF*	May 2024	N/A	Not started
T2.2	HW installation and run test in the LAB	*Development Activity*	*CF*	Apr 2024	N/A	Not started
T2.3	K8s setup and test	*Validation Activity*	*CF*	Apr 2024	N/A	Not started
T2.4	Containerized Edge Node Integration with Electrum components	*Development Activity*	*ELECTRUM*	Apr 2024	N/A	Not started
T2.5	Containerized Edge Node Integration with SRIPAS components	*Development Activity*	*SRIPAS*	Apr 2024	N/A	Not started
T2.6	Second Containerized Edge Node test	*Validation Activity*	*CF*	May 2024	N/A	Not started
T2.7	Lab Edge Node Integration with aerOS components	*Development Activity*	*CF, SRIPAS, ELECTRUM*	May 2024	N/A	Not started
T2.8	Both Containerized Edge Node run test with aerOS	*Validation Activity*	*CF, SRIPAS, ELECTRUM*	May 2024	N/A	Not started
T2.9	Container deployment	*Integration Activity*	*CF*	Jun 2024	N/A	Not started
T2.10	HW installation and run test in container	*Validation Activity*	*CF*	Jun 2024	N/A	Not started
T2.11	Container connection to PV	*Integration Activity*	*CF*	Jun 2024	N/A	Not started
T2.12	Scenario 1 deployment and test	*Validation Activity*	*CF, SRIPAS, ELECTRUM*	Jul 2024	N/A	Not started
T2.13	Scenario 1 lessons learned	*Validation Activity*	*CF, SRIPAS, ELECTRUM*	Jul 2024	N/A	Not started

Table 4 - *Pilot 2 – Scenario 2 – Overview of activities*

ID	Topic	Activity	Who	Plan	Real	Status
T3.1	Preparation for untrusted workloads	Set-up Activity	CF	Sep 2024	N/A	Not started
T3.2	Inter-cloud integration	*Integration Activity*	*CF, SRIPAS, ELECTRUM*	Sep 2024	N/A	Not started
T3.3	Configuration Validation test	*Validation Activity*	*CF*	Oct 2024	N/A	Not started
T3.4	Scenario 2 deployment and test	*Validation Activity*	*CF, SRIPAS, ELECTRUM*	Oct 2024	N/A	Not started
T3.5	Scenario 2 lessons learned	*Validation Activity*	*CF, SRIPAS, ELECTRUM*	Nov 2024	N/A	Not started

2.4. High Performance Computing Platform for Connected and Cooperative Mobile Machinery to improve CO_2 footprint (JD/TTC)

The High Performance Computing Platform for Connected and Cooperative Mobile Machinery (Pilot 3) is a ground-breaking solution designed to elevate agricultural technology by enhancing the efficiency and sustainability of heavy machinery. This state-of-the-art platform focuses on optimizing machine performance and minimizing the CO2 footprint through the deployment of a sophisticated edge solution that enables semi real-time data communication and automated data management. Utilizing the innovative aerOS edge-cloud continuum concept, the system drives further improvements, ensuring a more sustainable and productive approach to large-scale mobile machinery (e.g. agricultural) domain operations.

The platform's foundation lies in processing the data gathered from a wide range of sources, including energy consumption, CO2 emissions, and cloud-based operating instructions. This comprehensive system seamlessly integrates machine-to-machine (M2M) connectivity in large-scale agricultural production, ensuring reliable communication from any location. Data collection takes place through various components, with both on-board and off-board analysis for informed decision-making. AI-supported applications are utilized to synchronize and optimize the operation of mobile machinery, offering unparalleled productivity and environmental responsibility. With real-time embedded analytics, the platform achieves notable reductions in CO2 emissions, solidifying its role as a vital instrument for sustainable agriculture in the modern era. The main goals and system capabilities are summarized in the next figure.

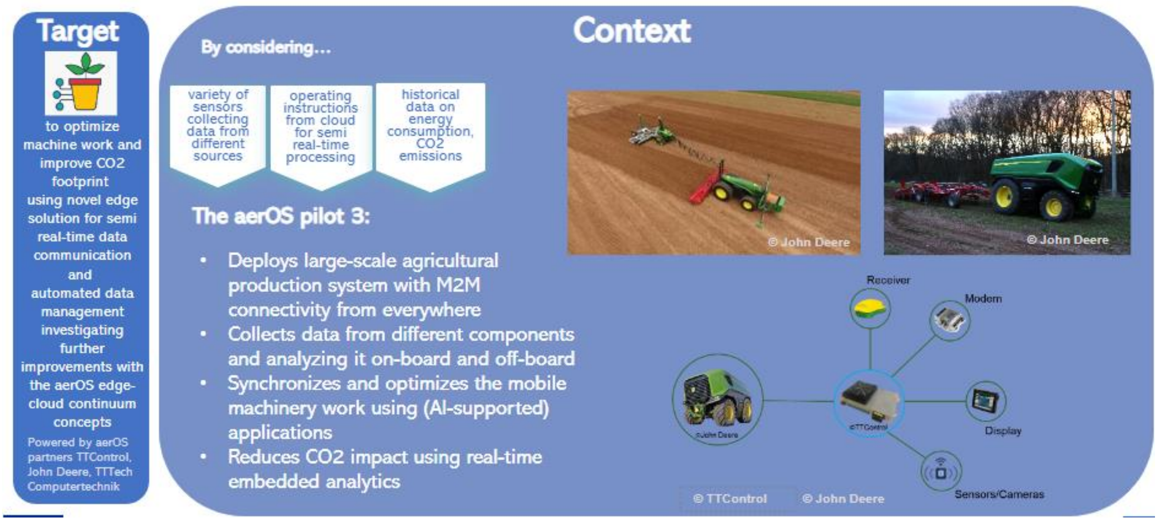

Figure 24. Pilot 3 – Main goals for High Performance Computing Platform for Connected and Cooperative Mobile Machinery

There are two global phases of integration activities in Pilot 3, called Alpha (due to M18) and Beta (due to M34). In the first phase we are working on the setup of a laboratory environment that includes partner and COTS components, described in Section 2 IT Infrastructures Profiling of TH Ch3. The main goal of this phase is to develop the middleware and preliminary software components required to setup the Pilot 3 system architecture and establish the connectivity between the components, as well as to ensure the availability and performance with temporary network infrastructure.

The successful completion of the Alpha phase will be measured using two KPIs:

- Performance with temporary network infrastructure
- Performance without using AI-supported application(s)

In the second phase of the project, we are going to extend this setup with the AI-supported applications, and measured CO2 indicators. For this reason, two other KPIs must be validated:

- Performance using AI-supported application(s)
- CO2 indicators

The vital part of the Beta phase will be also dedicated to the deployment and validation of the aerOS MVP technical components (Figure 25).

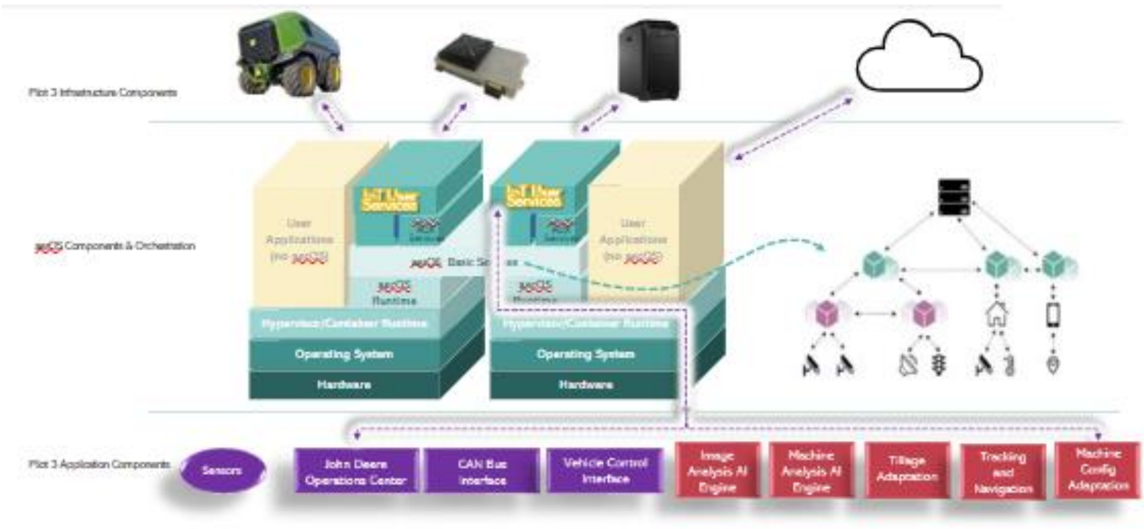

Figure 25. Pilot 3 – "High Performance Computing Platform for Connected and Cooperative Mobile Machinery" in aerOS architecture

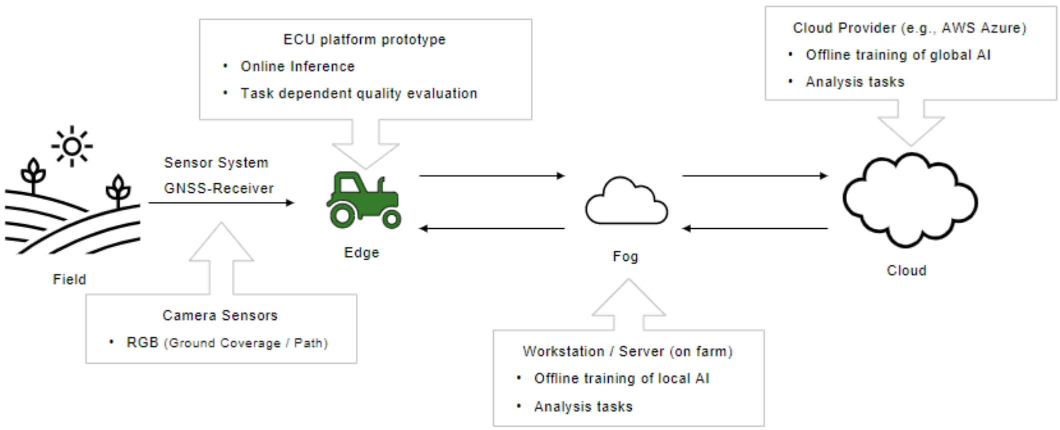

Figure 26. Pilot 3 – "General system architecture showing the main components and computation levels

This figure provides a visual representation of the High Performance Computing Platform for Connected and Cooperative Mobile Machinery, illustrating the interplay between edge, fog, and cloud elements in the system. The edge component encompasses the sensors and IoT devices that collect data from various sources, while the fog layer serves as an intermediary processing and communication stage, allowing for localized analysis and decision-making. The cloud element stores and manages a more comprehensive data repository for advanced analytics and global accessibility. The connections depicted between these elements highlight the seamless integration and data flow between edge, fog, and cloud layers. This interconnected architecture showcases the platform's ability to facilitate efficient data communication, real-time processing, and machine synchronization, ultimately resulting in a more sustainable and productive approach to agriculture

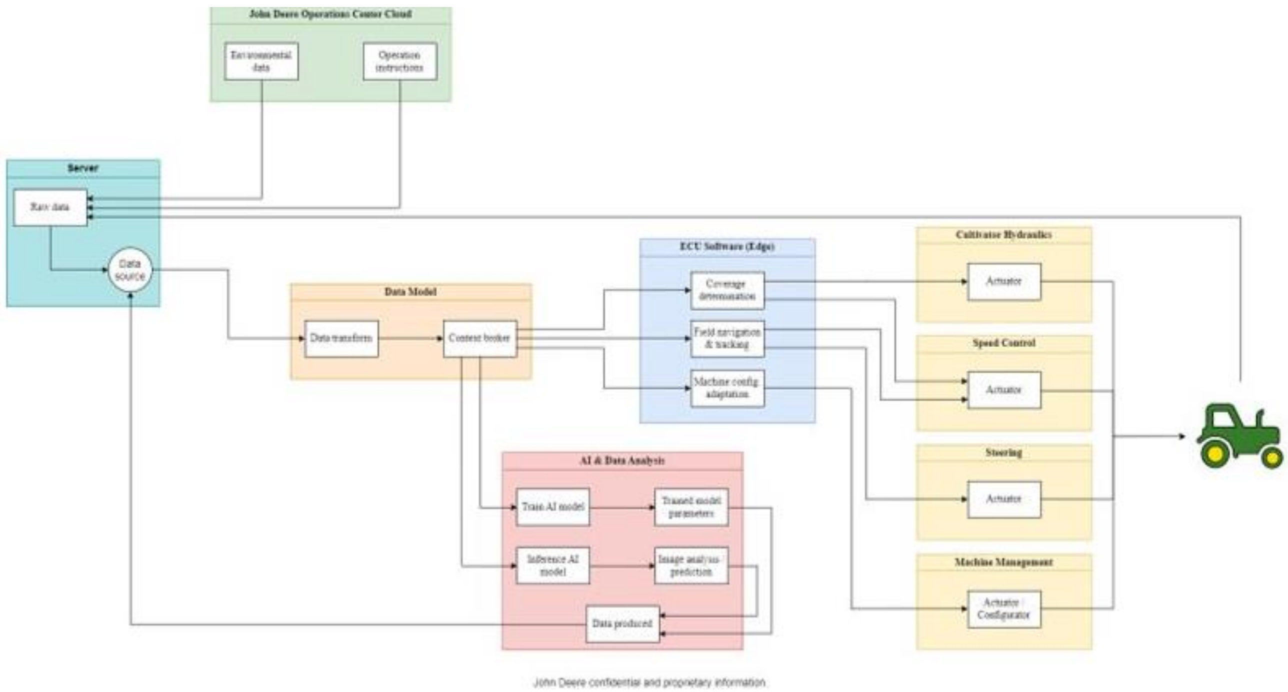

Figure 27. Pilot 3 – Data flow between key platform components

Figure 27 presents a flow diagram that highlights the data flow between key components of the High-Performance Computing Platform for Connected and Cooperative Mobile Machinery. The diagram begins with the server, which collects raw data from various sensors embedded within the machinery. The collected data then moves to the context broker, responsible for providing a structured data model and ensuring efficient data organization. Next, the AI and data analytics component processes and analyzes the structured data, employing advanced algorithms for AI inference, with the capability to provide further training of the employed AI model. The insights generated by this analysis are consequently passed on to the context broker and then used to optimize the operation of the machinery. The electronic control unit (ECU) software on-edge plays a pivotal role in translating the AI-generated instructions into precise control signals, adjusting various parameters of the prototype tractor to enhance its performance and energy efficiency. Through this flow diagram, the figure effectively illustrates the seamless interplay of data acquisition, processing, AI implementation, and real-time adaptation to optimize agricultural machinery performance and promote sustainable farming practices.

There are two scenarios in Pilot 3 (Figure 28). This figure outlines two distinct use case scenarios demonstrating the practical applications and effectiveness of the High-Performance Computing Platform for Connected and Cooperative Mobile Machinery in contemporary agricultural settings.

Scenario 1 visualizes cooperative large-scale production, emphasizing the significance of synchronized fieldwork performed by a platoon of electric vehicles. The platform's advanced algorithms and AI-assisted optimization enable the efficient coordination of multiple vehicles, enhancing productivity while minimizing the environmental impact of agricultural operations.

Scenario 2 showcases the potential for achieving CO2-neutral intelligent operations by addressing two primary objectives: reducing latency through real-time data processing and minimizing energy consumption by employing electric vehicles. The platform's robust edge solutions and real-time analytics provide instant feedback, ensuring precise machine adjustments, while the adoption of electric vehicles contributes to reduced carbon emissions, promoting sustainable agriculture.

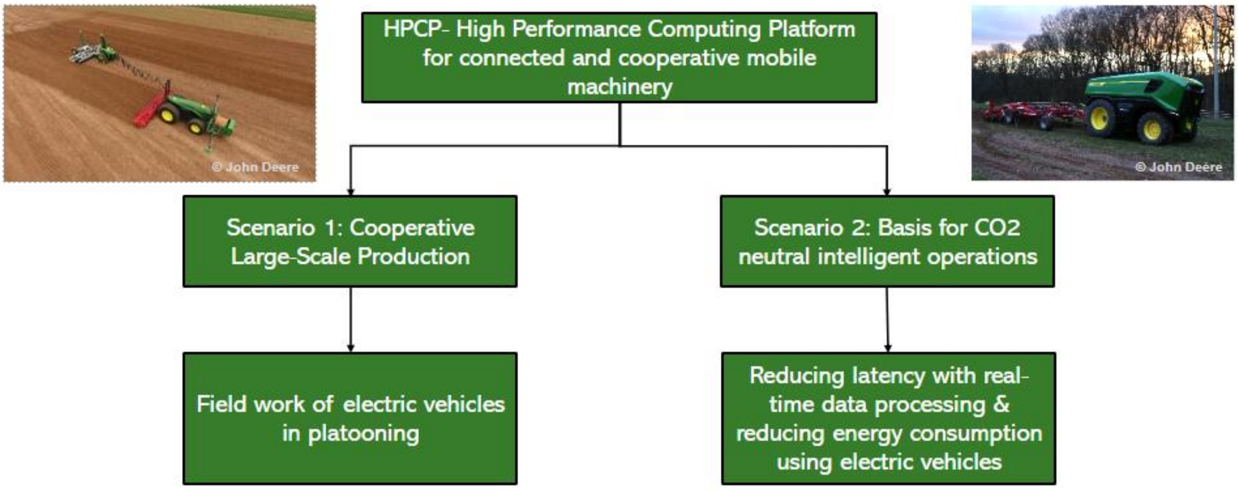

Figure 28. Structure of Pilot 3: Cooperative and CO2-Neutral Scenarios for Enhanced Agricultural Performance

The figure offers a concise overview of how the High Performance Computing Platform transforms agricultural practices by optimizing machinery performance, fostering cooperation across large-scale production systems, and prioritizing environmental responsibility. Further elaboration on these scenarios can be found in the following text, detailing the platform's comprehensive benefits and capabilities.

2.4.1. Cooperative large-scale producing

The primary goal of this pilot project is to assess the current fieldwork operations to identify areas for improvement. By leveraging the advanced Electronic Control Unit (ECU) from TTControl, John Deere aims to enhance its fieldwork processes. The computing capability of the ECU serves as a catalyst for optimizing performance and efficiency within agriculture and construction tasks, enabling significant advancements in these areas.

Essential tasks in agriculture and construction often necessitate the collection and analysis of data from various components. The integration of a High-Performance ECU facilitates both on-board and off-board data processing, significantly impacting the overall analysis of fieldwork (Figure 29 and Figure 30).

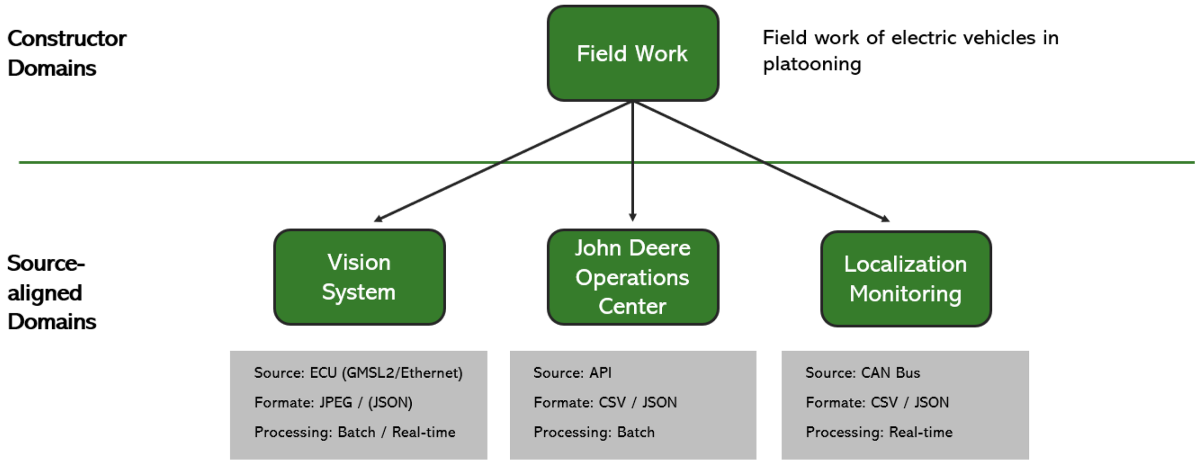

Figure 29. Data Sources Employed in Scenario 1 (Cooperative large-scale production) to Optimize Field Work

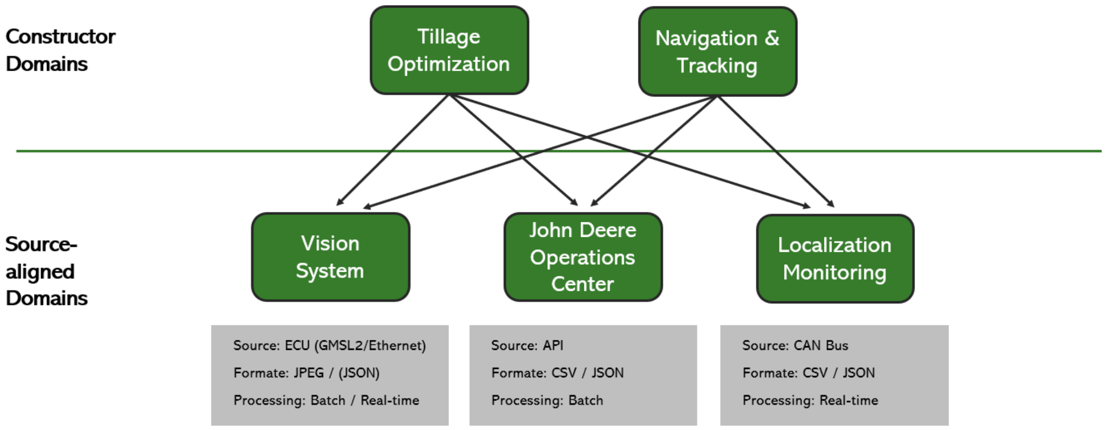

Figure 30. Relationship of Data Sources and Tasks Performed During Field Work in Scenario 1

The Pilot scenario 1 focuses on improving John Deere's fieldwork operations using the prototypes developed in the project to achieve substantial benefits in the overall performance. This innovative approach ensures a continuous drive towards elevated efficiency in field operations and becomes a benchmark for future advancements in the industry.

2.4.1.1 Setup and procurement activities

The HPCP platform by TTControl will be integrated inside the main control cabinet (IP67) of the vehicle of John Deere and it will support the following interfaces: Ethernet, Cameras, Virtual CAN, BroadR-Reach. We tested the following applications using this setup: Cameras‘ applications and the DetectNet recognition application with cameras.

- Sesam 2 vehicle loan to the project by John Deere
- HPCP Prototype Kit by TTControl provided on a loan to John Deere (incl. Camera)
- High resolution cameras

- GNSS Receivers with MRTK modems
- PC workstation

2.4.1.2 Development activities

HARDWARE / Middleware integration:

- Adaptation of the embedded software of both companies prototypes to support the future software integration

SOFTWARE:

- Preliminary tests of AI-supported application for secondary tillage optimization
- Preliminary tests of AI-supported application for row detection within the field
- Preliminary tests performed on ECU platform prototype using John Deere's internal datasets
- Preparation of software integration of ECU platform prototype into software of John Deere's prototype vehicle
- The prototypical Jetpack software compatible with the Xavier OS 1.0.4.0 with the latest NVidia Jetpack 5.1.2 implemented by TTControl

2.4.1.3 Integration activities

HARDWARE:

- The HPCP prototype HW integration support by TTControl to John Deere
- Afterwards, CAN integration between the HPCP prototype the John Deere hardware in a laboratory setup
- Starting the integration process of the hardware provided by pilot lead partner TTControl the several online integration sessions between the pilot partners and an in-person workshop at John Deere's premises in the European Technology Innovation Center in Kaiserslautern took place
- Ongoing integration of hardware into the vehicle of John Deere

SOFTWARE:

- Preparation, integration and the preliminary testing of the software infrastructure, such as e.g. API, interfaces, formats required for the data, etc.
- Integration of concepts for the containerized execution of the applications
- Definition of several datasets relevant for the use case

- Formalization of data
- Preparation of the software framework for the future deployment of the aerOS technical components

2.4.1.4 Validation activities

These activities include on-the-field actions and testing and evaluation of the KPIs. Details regarding validation of KPI 1 and KPI 2 as well as regarding the validation of the requirements related to Scenario 1, see in TH Ch 2.

2.4.2. Basis for CO_2 neutral intelligent operation

The foundation for CO2-neutral intelligent operations, including farming, construction, and forestry, relies among others on edge computing technology. By deploying tasks at the edge, one can drastically reduce latency and reaction time, especially when utilizing low-latency networks such as 4G or 5G. This innovative approach paves the way for more efficient and sustainable operations that minimize environmental impact while maximizing productivity.

John Deere electrified vehicles are the only way forward to reduce the CO2 footprint in the farming or other domains because the energy-saving aspect directly contributes to lowering CO2 emissions, thereby minimizing the ecological footprint of various industries. By usage of collaborative swarm vehicle scenarios, even further potential energy reductions will be possible. The operations and corresponding operation domains are presented in Figure 31 and Figure 32.

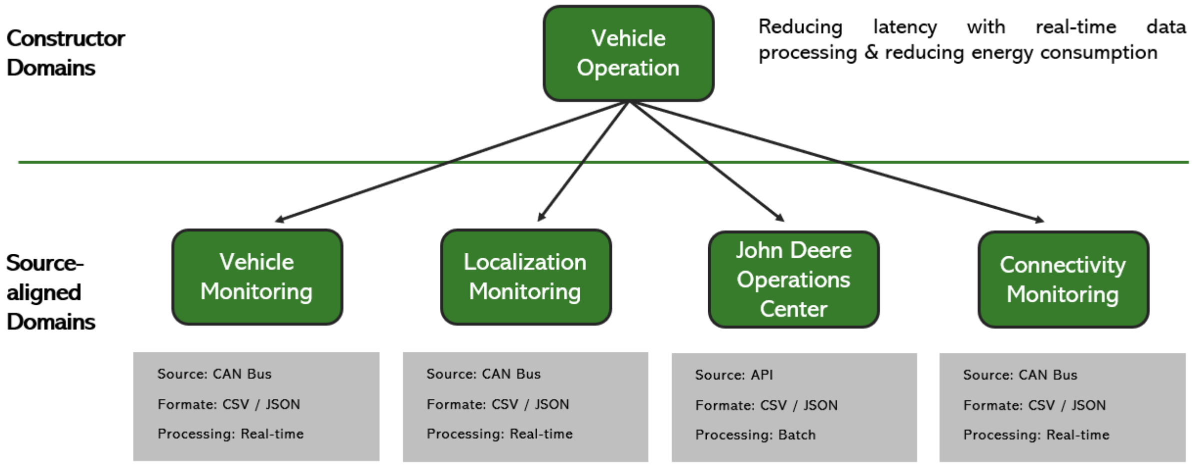

Figure 31. Data Sources Employed in Scenario 2 (Basis for CO2 neutral intelligent operation) to Optimize Vehicle Operation

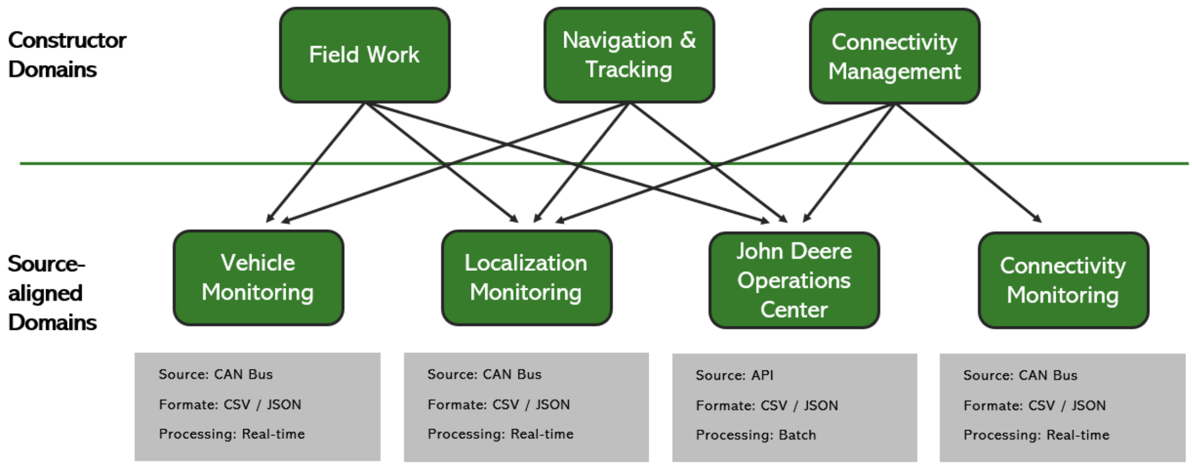

Figure 32. Relationship of Data Sources and Tasks Performed to Optimize Vehicle Operation in Scenario 2

In addition, the integration of AI-supported strategies has the potential to greatly enhance overall performance while adhering to sustainable and environmentally conscious practices. By leveraging the power of edge computing and low-latency networks, as well as applying the AI-supported and data-driven applications, the companies can work towards achieving CO2-neutral future for our planet. With these advanced solutions in place, organizations can simultaneously meet demands for higher efficiency while addressing the pressing need for environmental responsibility.

2.4.2.1 Setup and procurement activities

- GridCon vehicle loan to the project by John Deere
- The second HPCP Prototype Kit by TTControl to be provided on a loan to John Deere (incl. Camera)

2.4.2.2 Development activities

HARDWARE:

- Embedded SW integration: only minor development activities if needed to resolve for the execution of the aerOS technical components.
- From the today point of view, no further HW development activities planned.

SOFTWARE:

- Selections of the appropriate final datasets relevant for the use case
- Final tests of AI-supported application for secondary tillage optimization
- Final tests of AI-supported application for row detection within the field
- Final tests performed on ECU platform prototype using John Deere's internal datasets

2.4.2.3 Integration activities.

Deployment of the aerOS technical components will follow to illustrate the impact of the approach

2.4.2.4 Validation activities

Details regarding validation of KPI 3 and KPI 4 as well as regarding the validation of the requirements related to Scenario 2, see in TH Ch 2.

2.4.3. Pilot 3 Timeplan

The Figures below illustrate the Pilot 3 Time plan

Demonstrator related to Use Case Scenario 1

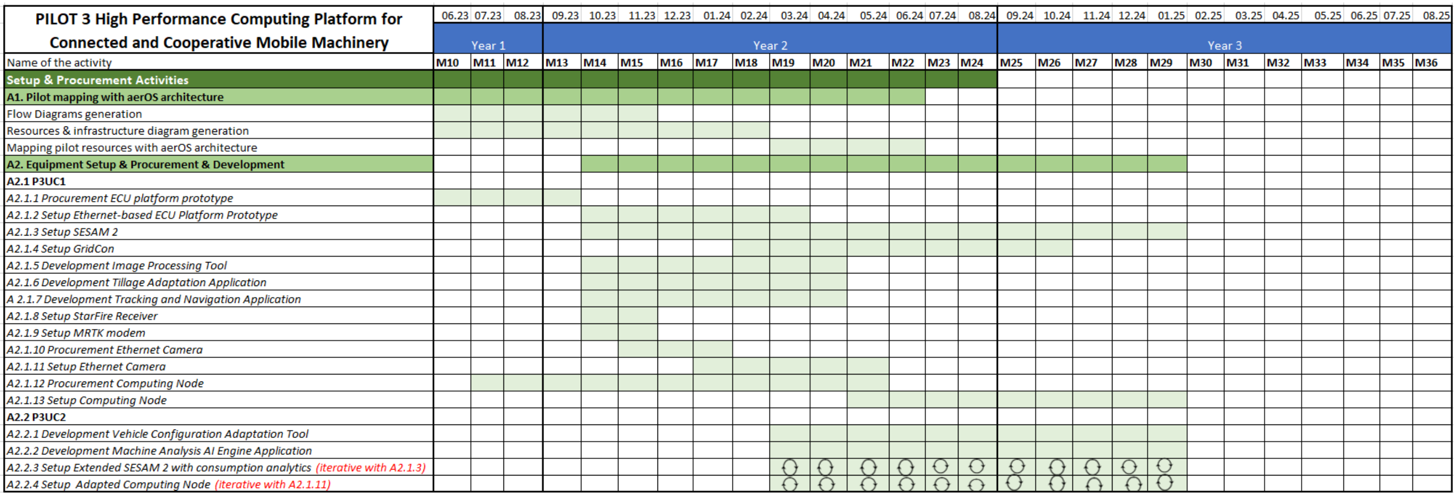

Figure 33. Pilot 3 Scenario 1 Planning of activities

Demonstrator related to Use Case Scenario 2

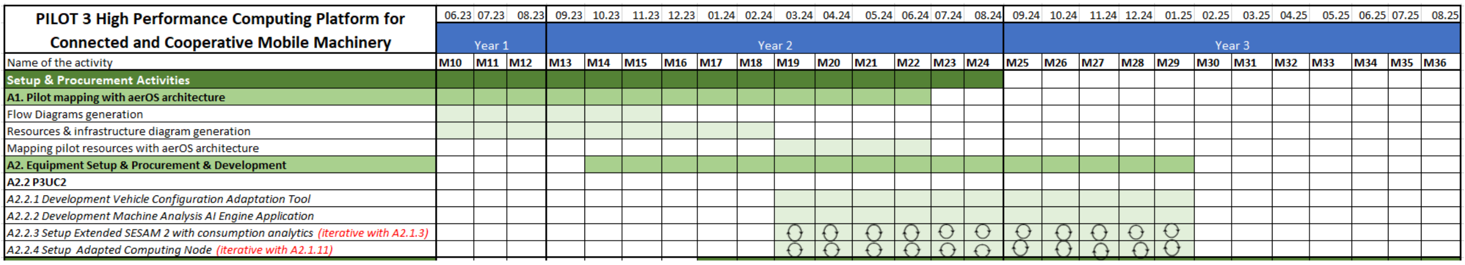

Figure 34. Pilot 3 Scenario 2 Planning of activities

This is monitoring / tracking activities table for the tasks defined above in the schedule. Tasks in the cooperation with the developers of technical components will be defined later, and the tasks between TTControl and John Deere (internal Pilot 3 tasks) are specified below.

Table 5– Pilot 3 – Scenario 1 - Overview of activities

ID	Topic	Activity	Who	Plan	Real	Status
P3UC1-A2.1.1	Procurement ECU platform prototype	*Set-up Activity*	TTControl	M13	M11	done
P3UC1-A2.1.2	Ethernet-based ECU Platform Prototype setup and integration	*Development Activity*	John Deere, TTControl	M19	N/A	ongoing
P3UC1-A2.1.3	Setup SESAM 2	*Set-up Activity*	John Deere	M29	N/A	ongoing
P3UC1-A2.1.4	Setup GridCon	*Set-up Activity*	John Deere	M26	N/A	ongoing

P3UC1-A2.1.5	Development Image Processing Tool	*Development Activity*	John Deere	M20	N/A	ongoing
P3UC1-A2.1.6	Development Tillage Adaptation Application	*Development Activity*	John Deere	M20	N/A	ongoing
P3UC1-A2.1.7	Development Tracking and Navigation Application	*Development Activity*	John Deere	M20	N/A	ongoing
P3UC1-A2.1.8	Setup StarFire Receiver	*Set-up Activity*	John Deere	M15	M15	done
P3UC1-A2.1.9	Setup MRTK modem	*Set-up Activity*	John Deere	M15	M15	done
P3UC1-A2.1.10	Procurement Ethernet Camera	*Set-up Activity*	John Deere	M17	N/A	ongoing
P3UC1-A2.1.11	Setup Ethernet Camera	*Set-up Activity*	John Deere, TTControl	M21	N/A	not started
P3UC1-A2.1.12	Procurement Computing Node	*Set-up Activity*	John Deere	M21	N/A	ongoing
P3UC1-A2.1.13	Setup Computing Node	*Set-up Activity*	John Deere	M29	N/A	not started

Tasks in the cooperation with the developers of technical components will be defined later, and the tasks between TTControl and John Deere (internal Pilot 3 tasks) are specified below.

Table 6– Pilot 3 - – Scenario 2 - Overview of Activities

D	Topic	Activity	Who	Plan	Real	Status
P3UC2-A2.1	Development Vehicle Configuration Adaptation Tool	*Development Activity*	John Deere, integration support by TTControl	M29		not started
P3UC2-A2.2	Development Machine Analysis AI Engine Application	*Development Activity*	John Deere	M29		Not started
P3UC2-A2.3	Setup Extended SESAM 2 with consumption analytics (iterative with A2.1.3)	*Set-up Activity*	John Deere, integration support by TTControl	M29		not started
P3UC2-A2.4	Setup Adapted Computing Node (iterative with A2.1.11)	*Set-up Activity*	*ibid*	M29		not started

2.5. Smart edge services for the Port Continuum (PRO/EGCTL)

The trials for the Pilot 4 are planned in three phases, with their corresponding milestones:

Pilot 4 - **Milestone 1** (P4M1): The first milestone is related to the procurement and acquisition of all the required HW and SW licenses for project's experimentation. It is estimated that all of them will be available before mid-term of the project (M18), i.e., February 2024.

Pilot 4 - **Milestone 2** (P4M2): The second milestone is related to the first tests with all the custom software components developed as well as initial aerOS layer and its core services deployed in the port. It is estimated that all of them will be deployed by M30, i.e., February 2025.

Pilot 4 - **Milestone 3** (P4M3): Finally, a third phase, ending with the final pilot's milestone, will be reached at the end of the project in M36 (August 2025). This phase is planned for further custom software refinement, bug fixing, and deployment of remaining aerOS auxiliary services of interest for the pilot 4.

The Pilot 4 has been divided in 2 scenarios:

Scenario 1 - Predictive maintenance of Container Handling Equipment: The goal is different ML algorithms will be trained in order to detect anomalies and test correlations while searching for patterns across the various data feeds from OT (sensors, PLCs), and IT (TOS, CMMS, weather condition) of Container Handling Equipment of the EUROGATE Container terminal

Scenario 2 - Risk prevention via Computer Vision in the edge: It will develop, integrate and validate different Computer Vision AI-based algorithms on the edge. IPTV cameras are installed at the terminal dock, next to the STS cranes. They record the loading and unloading of containers to or from vessels. This use case will allow the terminal to automatically identify containers with damages, and to check for the existence of container seals without the need of human intervention, avoiding subjective mistakes and reducing safety risks, by achieving a secure, and trustable environment for terminal staff.

The below diagram sketches the expected architectural deployment for the two Pilot 4 use case scenarios. As it can be seen, the pilot plans to differentiate up to 4 different aerOS domains. For use case scenario 1, both aerOS STS domain, as well as aerOS SC domain are expected to collect data from sensors and the machine's PLC, and performing basic pre-processing. Thus, they will be formed mainly by far-edge devices, which will perform local ML training and inferencing for identifying the need for predictive maintenance. In addition, aerOS STS domain will act as the entry domain, and will include all the distribution management and orchestration services from aerOS in the server being deployed in EUROGATE premises. Finally, cloud resources (CUT and Video domains) will be used for more intense ML training and testing, mainly for use case scenario 2.

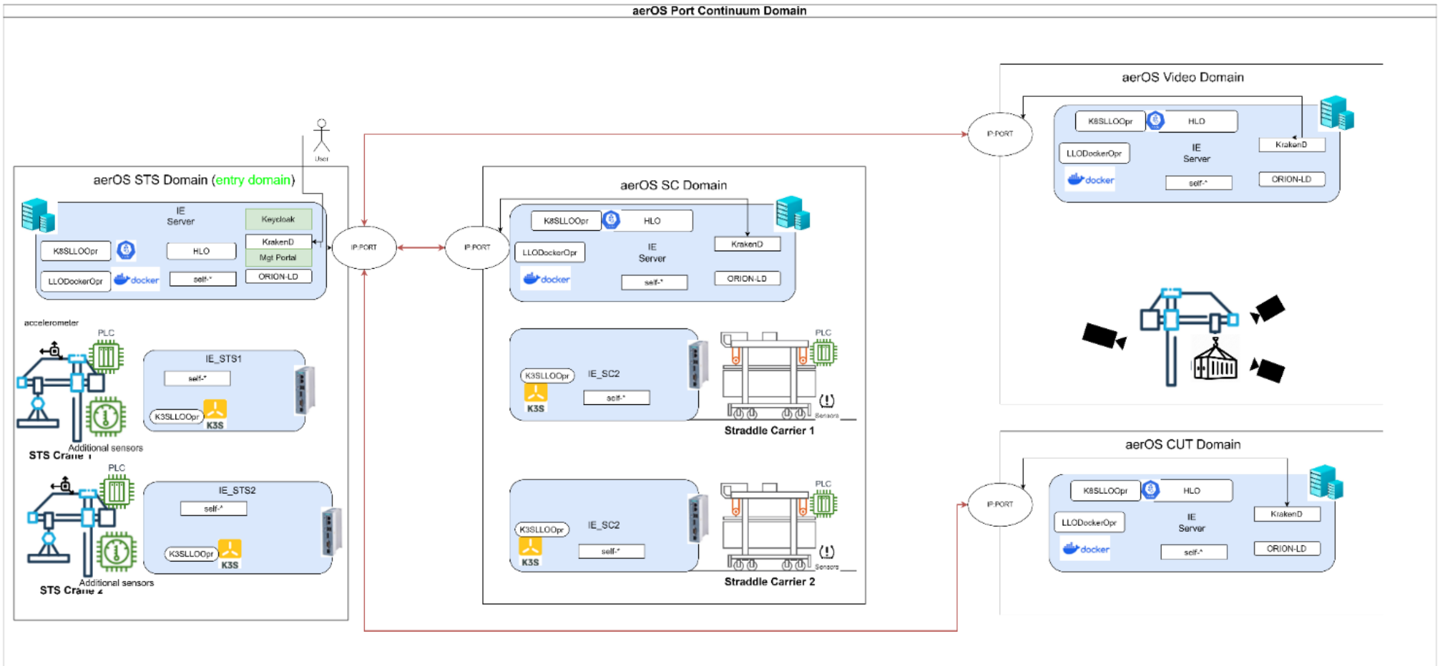

Figure 35. Pilot 4 – aerOS set-up

2.5.1. Predictive maintenance of Container Handling Equipment

The general objective of Pilot 4 - Scenario 1 is to validate different frugal AI model[1] to (i) predict remaining useful lifetime (RUL) of assets with regression models, and (ii) to predict failure within a given time window with classification models for STS cranes and straddle carriers. This can help to reduce downtime, increase efficiency, and save costs by reducing the need for regular manual inspections.

The overall planning for the Scenario 1 is presented in the 2.5.3 Timeplan, and the different activities foreseen for this scenario are listed below

2.5.1.1. Setup and procurement activities

P4.1 STS cranes PLCs (P4-S1-SA1). STS crane from OMG Bedeschi series M08140 is handled by a set of PLCs from Siemens model Simatic S7-1500. The Simatic S7-1500 is the basis for Industry 4.0, and IoT Automation by making use of the OPC-UA standard interface. They are equipped with 1516F-3 PN/DP CPU, with work memory 1.5 MB for program and 5 MB for data. It also supports PROFINET IRT protocols, with 2-port switch. ETHERNET and PROFIBUS are also interface supported. It runs jobs with speed up to 10 ns bit performance.

Figure 36. Pilot 4 – PLC set-up

P4.2 Straddle carriers PLCs (P4-S1-SA2). Straddle Carriers from Kalmar series ESC 440W are equipped with PLC from Omron model CS1G-CPU44H, which are mounted with CPU Unit, with up to 40 Modules able to run 64K Words. They are provided with RS232C/USB interfaces for custom development.

P4.3 Straddle carrier sensors (P4-S1-SA3). Three main types of sensors are going to be used in the project. In particular

a. ***Danforss 060G1109 hydraulic Pressure Sensors.*** These sensors cover different output signals and include versions with absolute and relative pressure reference and measurement ranges between 0-1 and 0-600 bars.

b. ***IMUF99PL-SC3600-0KB20V1501 inclination and acceleration sensors.*** The IMUF99 is optimized to provide stabilized inclination and acceleration data as well as rotation rate data. The horizontal inclination can be reliably determined using the 3-measuring axis. The dynamic angle accuracy can be individually configured by selecting a compensation range to counteract the influence of external accelerations. Different output types are selectable for the angle definition (Euler angle, Euler vector, quaternions). In addition, accelerations and rotation rates are reliably measured in the 3-measuring axis. For further optimization of the measured value quality, filters can be set to suppress external vibrations.

c. ***VIM32PL-E1V16-0RE-I420V14 vibration sensors.*** It determines the vibration quantity using rms (root-mean-square) averaging. This form of quadratic averaging or pre-filtering enables precise trend statements about the condition of the application.

Figure 37. Pilot 4 Different sensors installed in the Straddle carriers under test in the project

P4.4 GPS (P4-S1-SA4). Different advanced analytics features associated to the Straddle carriers telemetry require the knowledge of their position. Commercial GPS will be installed, which will be appended to the timely synchronized telemetry data collected from the PLC. GPS will be installed on the straddle carriers.

Figure 38. Pilot 4 – PLC set-up

P4.5 HMI (P4-S1-SA5). The Kinco HMI GT070HE is going to be connected to the Straddle carrier PLCs, and has all the functionalities needed to access PLC. It will be then connected to the IoT Gateway explained next Features: 7" HD display, 16.77M true color; support Ethernet function; powerful script function, support edge calculation; built-in Iot function, support remote service.

Figure 39. Pilot 4 HMI set-up

P4.6 IoT gateways (P4-S1-SA6). The Siemens Simatic IoT2050 has been selected as the IoT Gateway for the pilot, due to its robustness, compact and flexibility, with special focus on the IoT environment and round off the SIMATIC IPC product range. IoT2050 will be in charge of reading, extracting, pre-processing and publishing data from the STS PLCs, Straddle Carrier PLCs, Straddle Carrier Sensors, and GPS. All these steps of data acquisition are programmed into its embedded NodeRed open-source software service on Linux. The connexion with the IoT2050 is done by ethernet through the internal ethernet network of the straddle carriers. The data once processed by the IoT2050 is published through an external 4G modem explained next. Features: Intel 1.1GHz CPU, RAM 2GB, 16GB eMMC, 2xRJ45 Ports, 1xSerial Port.

P4.7 4G-WiFi routers (P4-S1-SA7). The Teltonika RUT240 is an industrial M2M/IoT 4G router that supports two Ethernet ports and a wireless interface with Hotspot functionality. It will permit to publish the straddle carrier data, i.e., the internal data from the Straddle Carrier domaing, to the EUROGATE and/or CUT domains. Features: 4G/LTE (Cat 4), 3G, 2G; Atheros, MIPS 24Kc, 400 MHz; 64 MB RAM; TCP, UDP, IPv4, IPv6, ICMP, NTP, DNS, HTTP, HTTPS, FTP, SMTP, SSLv3, TLS 1.3, ARP, PPP, PPPoE. It runs over RutOS wich is based on Linux.

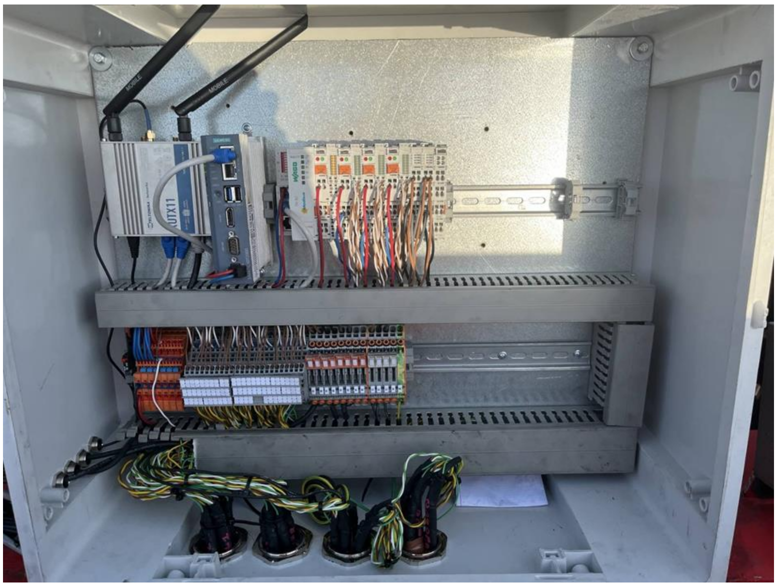

Figure 40. Pilot 4 - RUTX11 and IoT Siemens 2050 gateway installed in Straddle Carrier PLC room (top left of the figure).

P4.8 EUROGATE server (P4-S1-SA8). The EUROGATE server will act as the main edge element of the pilot. It will be split into different Virtual Machines running in VMware environment for the project. As initial plan, it will provide one VM that collects all the PLCs, sensors, and GPS data acquired from STS cranes and Straddle Carriers. In addition, it will also provide the IE associated to the different Pilot 4 domains, namely STS domain, SC domain, and Video domain (as described in the diagrams provided in TH Chapter 5).

P4.9 CUT server (P4-S1-SA9). The data acquired from the different Pilot 4 domains, and subject of ML development will not only be stored at EUROGATE premises, but also at CUT domain. To do so, a Dell PowerEdge R6525 has been acquired. It is equipped with 48 AMD physical cores 2.3GHz-3.2GHz turbo, 256MB L3 Cache, 128GB DDR4 RAM, 6 HDDs (10K SAS 1.2 TB each), and an NVIDIA Tesla T4 16GB GPU.

Figure 41. Pilot 4 CUT server of CUT domain

2.5.1.2. Development activities

D4.1 PLC data gathering (P4-S1-DA1). This activity can be split in two-fold sub activities. On the one hand, STS crane PLC data is retrieved by the use of specific Siemens libraries running under node-red environment within the IoT Gateways. On the other hand, the straddle carrier PLC data is going to be firstly acquired by the HMI, which will send the data to the IoT2050 by the installation of an MQTT client. An MQTT broker (probably EMQx) will then be deployed in the IoT2050, which will be in charge of managing the different MQTT topics and allow new EUROGATE and CUT servers' MQTT clients to subscribe to them.

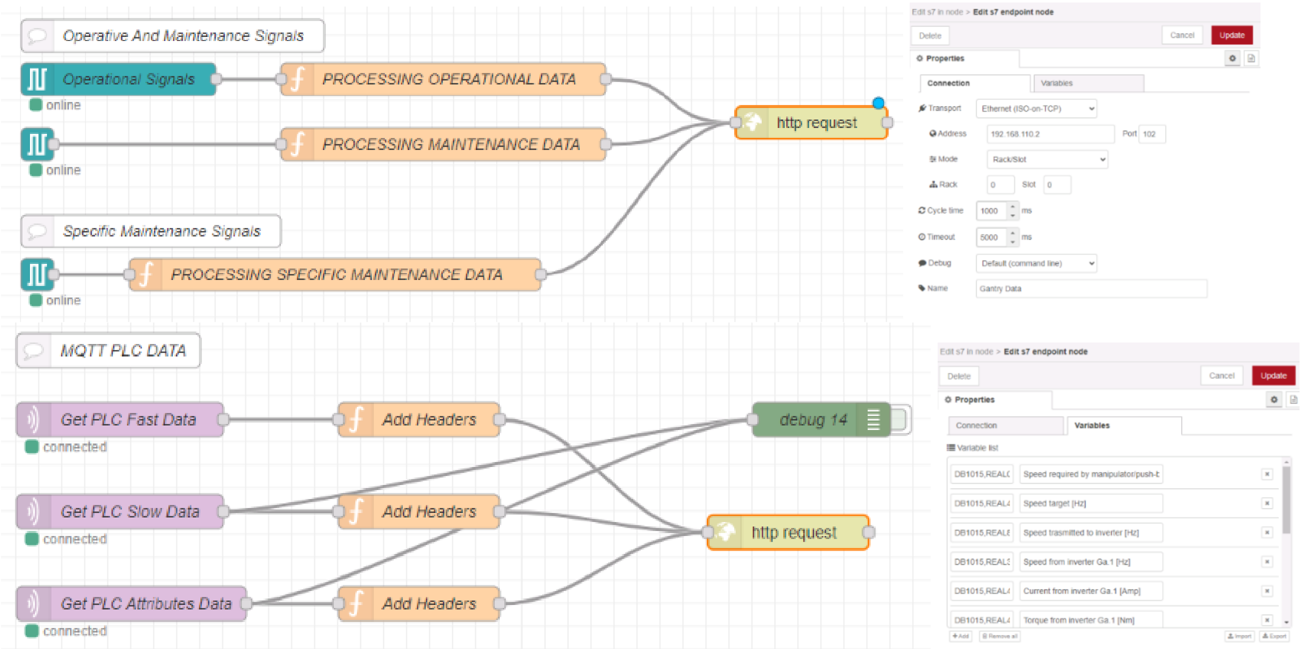

Figure 42. Pilot 4 - STP PLC Data acquisition (top) and Straddle carrier PCL Data acquisition (bottom)

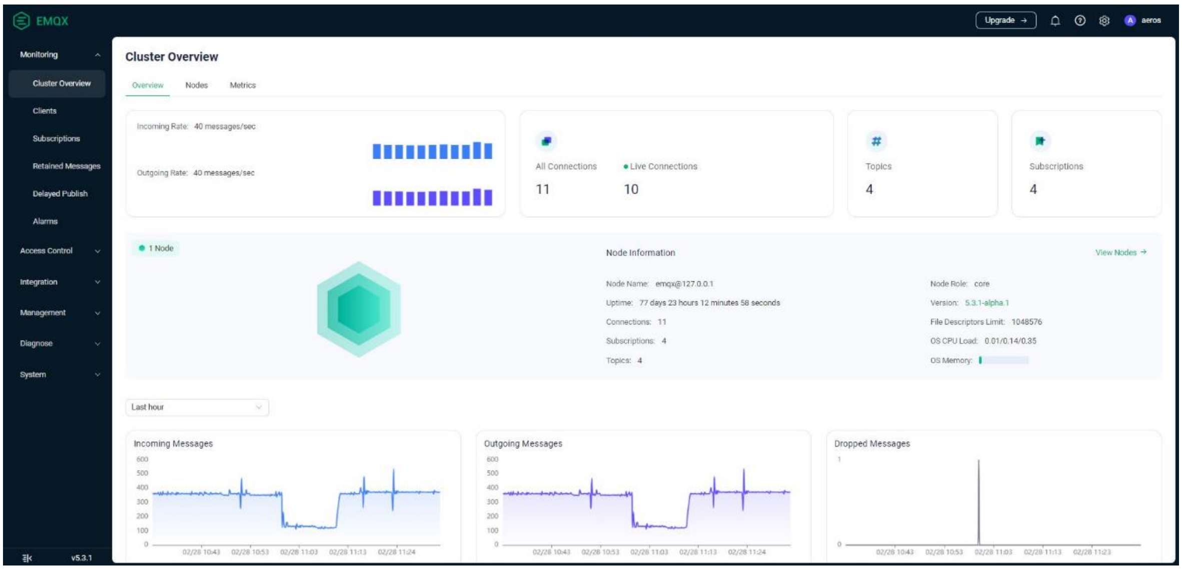

Figure 43. Pilot 4 - Straddle carrier data collection in MQTT broker

D4.2 GPS and sensors data gathering (P4-S1-DA2). A custom component will be developed and deployed at the edge IEs of the pilot. Likewise D4.1 activities, this component will be in charge of retrieving the data generated by the sensors and GPS mounted on the straddle carriers, and will be appended to the corresponding time-series register from the PLC data. It will be probably based on node-red code, but the final details are still under discussion among pilot 4 partners.

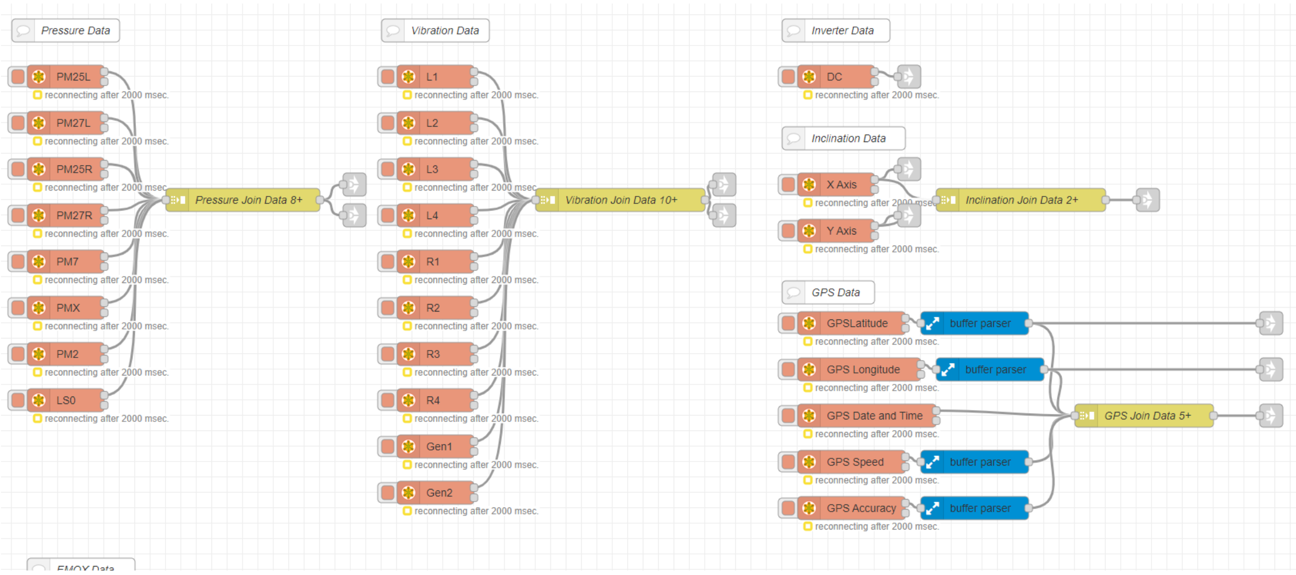

Figure 44. Pilot 4 Straddle carrier sensors and GPS data acquisition

D4.3 TOS data acquisition (P4-S1-DA3). TOPX is the true real-time and state-of-the-art terminal operating system used by EUROGATE. It aims at increasing efficiency of the terminal by providing among others integrated solutions for crane planning as well as real-time automated vessel planning. This TOS data is considered relevant for an in-depth analysis of the root-cause of predictive maintenance features. Thus, different operational information data, such as number of daily working hours per CHE, total weighed containers, terminal block location under work will be acquired for the pilot. A custom API request (or a recursive SQL query) is going to be developed. Not started yet

D4.4 CMMS data acquisition (P4-S1-DA4). Like TOS data, periodic queries to the CMMS system of EUROGATE, namely Limble, is needed for correlating the AI-based predictive maintenance models with the actual maintenance tasks. A custom API endpoint is also going to be developed. Not started yet

D4.5 STS AI models training (P4-S1-DA5). Different AI models shall be trained, tested, and validated in order to provide the most accurate predictions for CHEs maintenance. As explained in D2.2, the following predictive maintenance use cases are planned for STS components: (i) Trolley Wire Rope Enlargement Warning, (ii) Motor Filter Condition, (iii) Motor Bearings Condition, (iv) Motor load sharing from Hoist, and (v) Motor load cell.

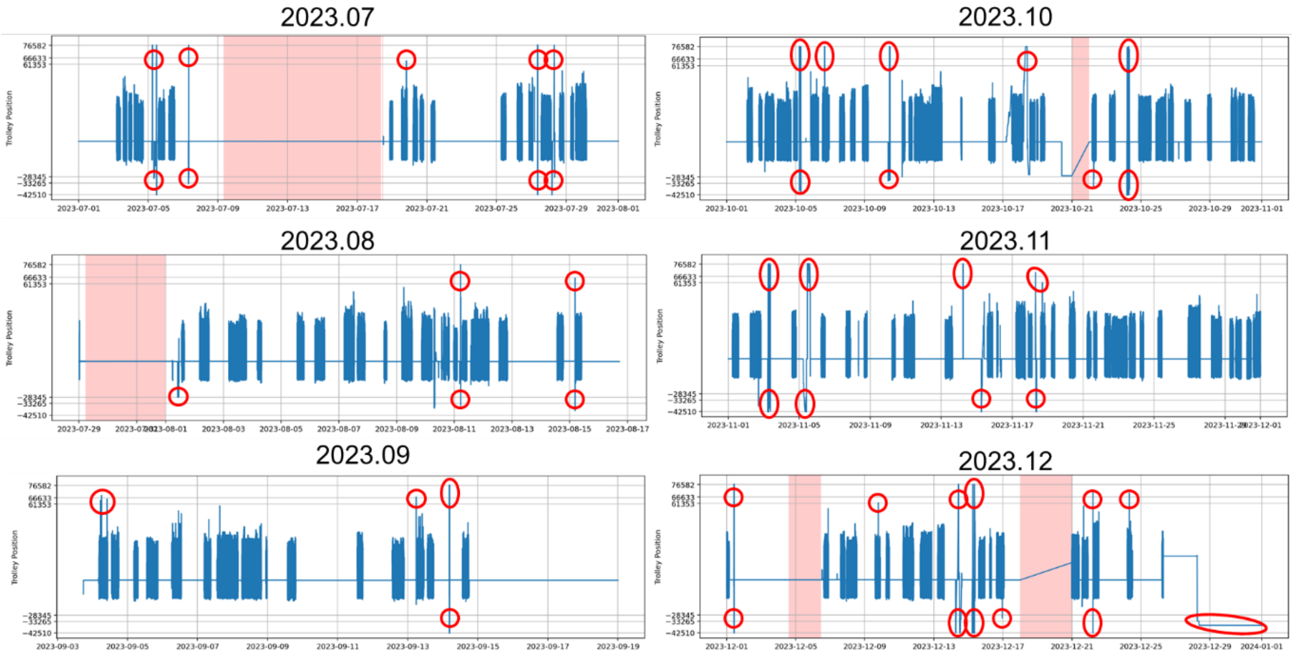

Figure 45. Pilot 4 Data exploratory

D4.6 Straddle carriers AI models training (P4-S1-DA6). Different AI models shall be trained, tested, and validated in order to provide the most accurate predictions for CHEs maintenance. As explained in D2.2, the following predictive maintenance use cases are planned for straddle carriers components: (i) Generator engine efficiency, (ii) Genset vibrations, and (iii) Inclination issues. Not started yet

D4.7 GIS cartography generation (P4-S1-DA7). The generation of a web-based cartography is considered as extremely relevant for the graphical interface of the pilot. EUROGATE already possesses a digital geo-referenced cartography of the terminal, so the GIS cartography generation activity refers to the export of the AUTOCAD information into a PostGIS compliant component, which will be connected to the different data collected from the assets in the terminal.

Figure 46. Pilot 4 EUROGATE CTL GIS cartography generation

2.5.1.3. Integration activities

These actions have not been started yet, but they will be as described below:

I4.1 Data fabric integration (P4-S1-IA1). In order to be compliant with aerOS architecture, the different data pipelines as outcomes of the previously described development activities of the pilot shall be integrated with the data models identified in the data fabric. In addition, the contemplated domains, and IEs that will form part of the pilot should also be accessible by the HLO, and the different LLOs.

I4.2 Self-awareness integration (P4-S1-IA2). The discovery processes of new domains and IEs along an aerOS pilot require the need of integrating as a core service the self-awareness tool of the project. They will be then integrated on all the IEs of the pilot.

I4.3 Context Broker integration (P4-S1-IA3). The communication between the different IEs of every domain will be provided by the ORION-LD context broker of aerOS.

I4.4 HLO task collector and topology manager integration (P4-S1-IA4). The new custom AI models for predictive maintenance, as well as the data collection pipelines can be susceptible to changes. Their potential changes, as well as the introduction of new services and tasks shall be coordinated by the HLO and LLOSs that are going to be integrated across all the IEs of the pilot.

I4.5 Management portal integration (P4-S1-IA5). The access to the pilot infrastructure is going to be provided by the management portal. It will also serve as the graphical engine for the additional and specific graphical interfaces of the pilot.

I4.6 Embedded analytics and benchmarking tool integration (P4-S1-IA6). All the IEs of the Port Continuum will support the embedded analytics functionalities that are going to be developed in the project. They will allow for setting up potential alerts from all the devices deployed in the pilot. In addition, the benchmarking tool will permit to EUROGATE administrators to visualize in a user-friendly way the performance of all the planned IEs in terms of processing, memory, or storage needs, connectivity, security, etc.

I4.7 AAAintegration (P4-S1-IA7). The Authentication and Authorization components of aerOS will provide the security needs for avoiding malfunctions or undesired hacking attacks to the platform. They will be fully integrated not only for the aerOS infrastructure management, but also for the roles and user managements of EUROGATE.

2.5.1.4. Verification activities

These actions have not been started yet, but they will be as described below:

V4.1 Data acquisition verification (P4-S1-VA1). Different test benches will be performed for the verification of the data acquisition from the different data sources, i.e., PLCs from STS and straddle carriers, GPS, and straddle carrier sensors.

V4.2 Data storage verification (P4-S1-VA2). Different data pipeline test benches will be performed for the verification of the data collection at the EUROGATE and CUT servers.

V4.3 Model verification (P4-S1-VA3). This activity refers to the verification of the correct execution of the trained ML models for STS and straddle carriers.

2.5.2. Risk prevention via Computer Vision in the edge

The general objective of use case scenario 2 is to provide a CV (computer vision) solution that can be inferred from the edge without requiring very high bandwidths. The aerOS orchestration will manage when these functionalities can be carried out in the edge devices dynamically, according to the actual IEs capabilities. This general objective can be split into small specific objectives:

1. To use existing and install additional (if needed) IPTV cameras at the quay side of the port.
2. To capture and record video streams to be used as data set for annotation and training.
3. To train, test, and validate different frugal AI models for object detection (wrong seals, and containers' surfaces damages). Different classifications Neural Networks will be tested (Very Deep Convolutional Networks (VGG-16), Inception / GoogLeNet, ResNet50, EfficientNet, to name a few). Since, higher number of parameters in any model increase the complexity and vice-versa, the selection of the most efficient model for this use case scenario will be done according to the trade-off between higher accuracy versus lower computational complexity.

2.5.2.1. Setup and procurement activities

P4.10 Cameras (P4-S2-SA1). Currently, two IP cameras are installed that capture the loading/unloading work instructions to/from ships from/to straddle carriers through STS cranes. A third camera will be procured (HIKVISION DS-2XM6756G0-IS/ND) and strategically placed at opposite angle compared to the other two cameras so that all sides of the containers are captured.

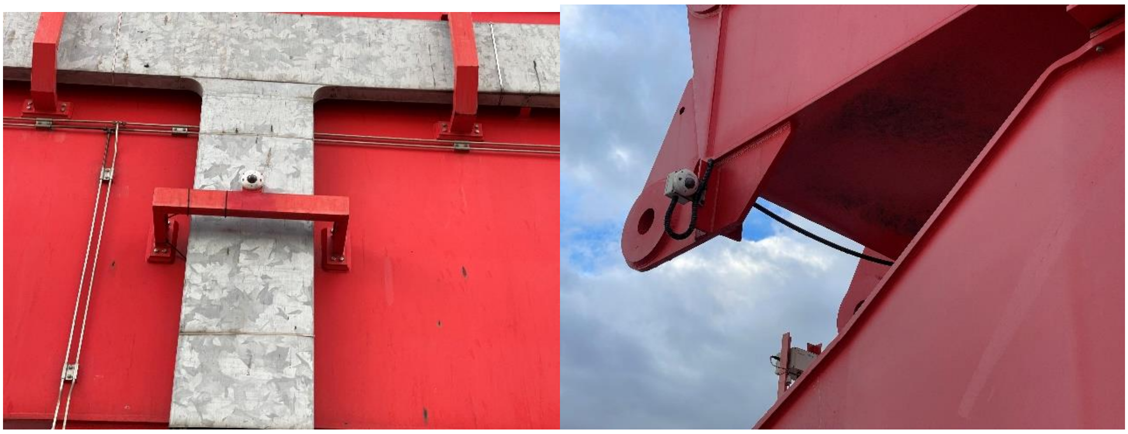

Figure 47. Pilot 4 IP Cameras installed at the STS crane gantry legs

2.5.2.2. Development activities

D4.8 Video Collection (P4-S2-DA1). The management of video streams collection is twofold. In a first stage, they will be stored for later preproccessing, labeling, and training. Once the ML models are considered accurate enough, real-time streams will be inferred without the need for additional storage beyond the 1-month EUROGATE's retention policies.

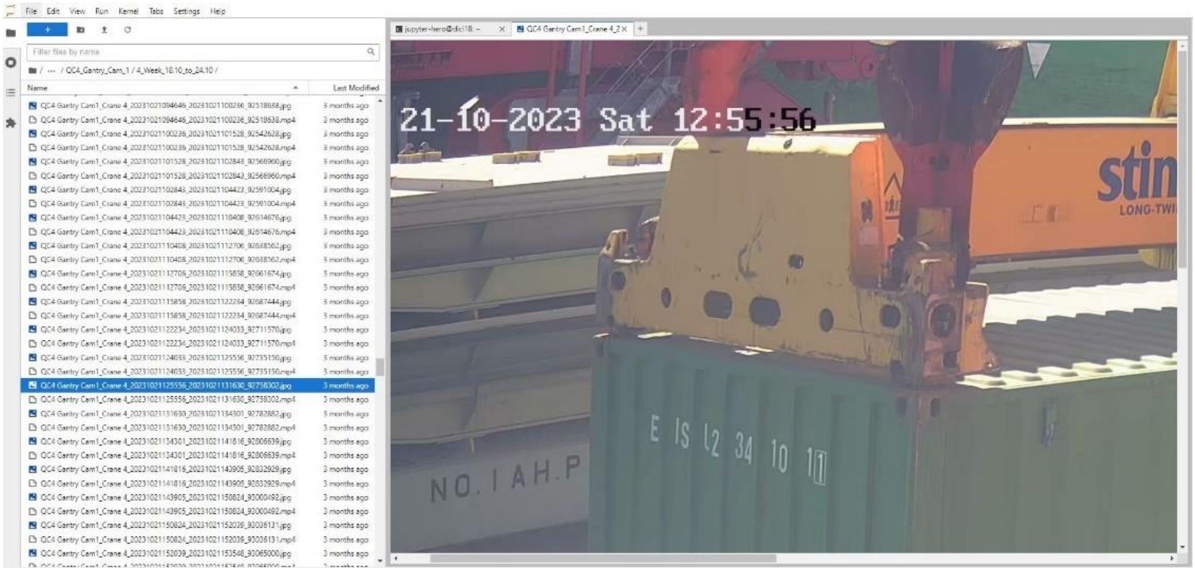

Figure 48. Pilot 4 AV service with current videos collected from cameras

D4.9 Container ID recognition model training (P4-S2-DA2). Different AI models shall be trained, tested, and validated in order to provide the most accurate predictions for first identifying the containers in the video feed while they are loaded/unloaded and second for recognizing the container ID. Not started yet.

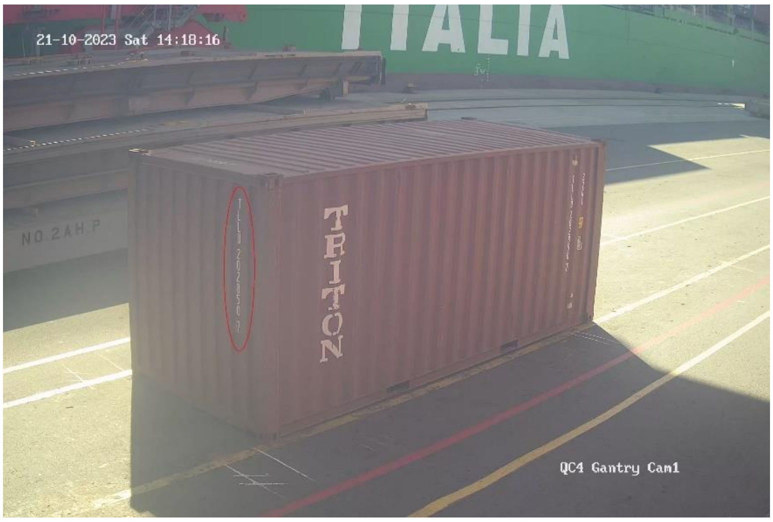

Figure 49. Pilot 4 Video frame with the Container ID labelled

D4.10 Container damage recognition model training (P4-S2-DA3). Different AI models shall be trained, tested, and validated in order to provide the most accurate predictions for detecting different types of damages on the container surfaces (e.g., dents, cracks, etc.). Not started yet.

Figure 50. Pilot 4 Video frame with the Container ID labelled

D4.11 Seal recognition model training (P4-S2-DA4). Different AI models shall be trained, tested, and validated in order to provide the most accurate predictions for detecting whether the seal on a container is closed, missing, or damaged. Not started yet.

2.5.2.3. Integration activities

The integration activities for Scenario 2 are the same as the integration activities for Scenario 1 described in the previous section.

2.5.2.4. Verification activities

The integration activities for Scenario 2 are the same as the integration activities for Scenario 1 described in the previous section.

2.5.3 Pilot 4 Timeplan

A single demonstrator planning is presented for this pilot, given that most of the different planned activities are common to both use cases.

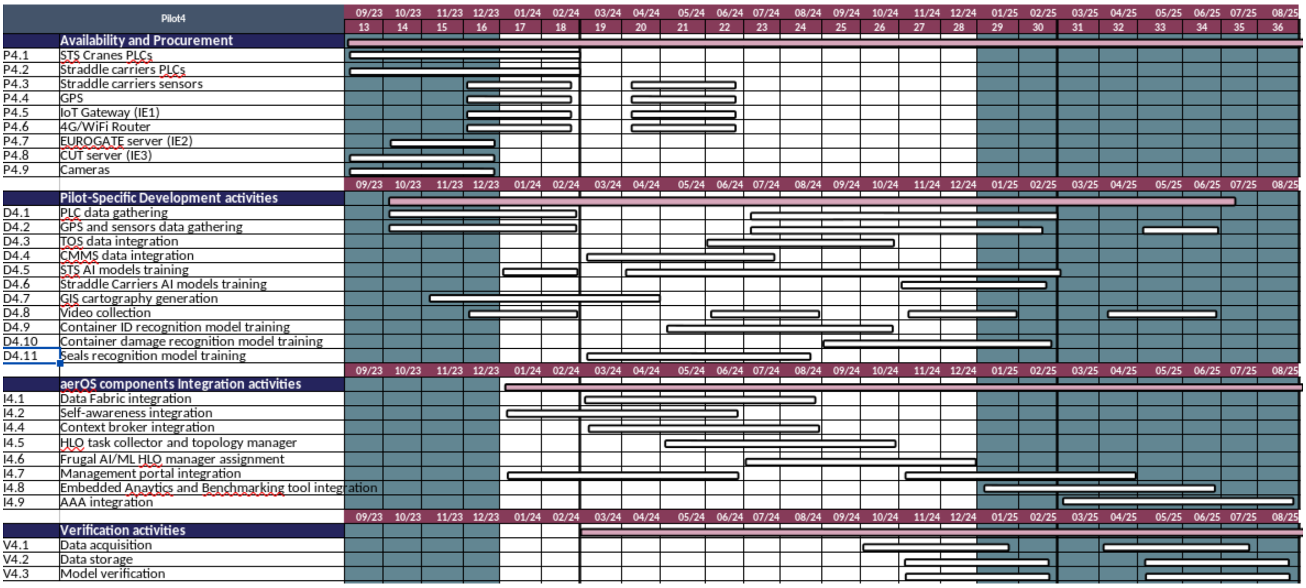

Figure 51. Pilot 4 Time Plan

2.6. Energy Efficient, Health Safe & Sustainable Smart Buildings

Pilot 5, driven by partners COSM, NCSRD, FOGUS, INF and UPV, aims to demonstrate gains of the aerOS architecture in an edge deployment for energy efficient, sustainable, flexible, and health-safe smart buildings. The use case considers deployment and validation in an office enterprise building of COSMOTE (Athens, Greece). The Pilot supports two scenarios, that while built on the same infrastructure focus on two different aspects:

Scenario 1 focuses on the achieved benefits for ‘Intelligent Occupational Safety and Health’
Scenario 2 addresses ‘Cybersecurity and data privacy in building automation’

Scenario 2 expands horizontally to the Scenario 1 deployment, with focus on the security, trust, and niche communication capabilities (5G) and as such shares the same planning path with Scenario 1, with only difference on the Testing and Evaluation of Results.

Pilot5 builds around the transformation of an existing IoT application (COSMOTE Leonar&Do) and its adaptation and incorporation of the aerOS principles and modules, to showcase the edge-cloud continuum benefits for Energy and Health-safe smart buildings. The IoT application is furnished with AI capabilities and user interactions to deliver the smart objectives of the project, which are developed as part of Pilot5 WP5 activities.

According to the project-wide methodology, the high-level plan is built around (i) procurement (ii) development (iii) aerOS modules integration and (iv) field validation activities.

Pilot 5 consists of four (4) different systems, the IoT Application, the health & energy AI system, the recommendation system, and the end-user interaction web application. Each need to be developed and integrated through the aerOS context broker capabilities, with each own implementation plan as depicted below.

Some early proof-of-concepts (POCs) are targeted as the systems get developed and unit tested, with the first end-to-end delivery, integrating aerOS capabilities planned for M28. Details on the gradual integration of AerOS MVP components and the respective plan is presented in the 2.6.3 Pilot 5 Timeplan

2.6.1. Intelligent Occupational Safety and Health

2.6.1.1 Setup and procurement activities

Pilot5-Scenario1-SetupActivity-1(P5-S1-SA1): Kubernetes (version 1.24.17) and kubeedge (version 1.15.1) are deployed in a ubuntu 22.04.2 LTS VM deployed on an Esxi hypervisor. There are 3 gateways added as edge nodes on the cluster (1 GW for room 105 and 106, 1 GW for room 208 and 1 GW for room 209).

Pilot5-Scenario1-SetupActivity-2 (P5-S1-SA2): HomeAssistant (version 2023.7.0) has been deployed and 52 sensors were deployed and integrated. There is a HomeAssistan pod running on each edge node.

Pilot5-Scenario1-SetupActivity-2 (P5-S1-SA3): TICK framework installed in a K8s node of the cluster.

Pilot5-Scenario1-SetupActivity-2 (P5-S1-SA4): MQTT: 2.0.18 installed in a K8s node of the cluster.

Pilot5-Scenario1-SetupActivity-2 (P5-S1-SA5): Context Broker OrionLD (1.5.1) installed in a K8s node of the cluster.

Pilot5-Scenario1-SetupActivity-2 (P5-S1-SA6): MetalLB (v0.14.3) installed in K8s cluster.

Pilot5-Scenario1-SetupActivity-2 (P5-S1-SA7): KrakenD (v2.5.1) installed in K8s cluster.

Pilot5-Scenario1-SetupActivity-2 (P5-S1-SA8): SelfAwareness::Monitoring are deployed with helm charts with the latest version.

Currently the versions running are the bellow:

2.6.1.2 Development activities

Pilot5-Scenario1-DevelopmentActivity-1 (P5-S1-DA1): DataFabric::OpenDataAccess Semantic Annotator, Data mapping done for the datasets that are going to be used, in order for them to be transformed into NGSILD.

Pilot5-Scenario1-DevelopmentActivity-1 (P5-S1-DA2): HVAC/Plugs Actuator component development started.

Pilot5-Scenario1-DevelopmentActivity-3 (P5-S1-DA3): End User Interface

The design phase was commenced with the creation of mock-ups to visualise the user interface and workflow. Leveraging Figma, an industry-standard design tool, a few prototypes that encapsulated the application's intended look were developed. Iterative feedback loops were implemented to refine the mock-ups. The resulting mockups will serve as an initial blueprint for the subsequent development efforts.

Building upon the foundation established in the previous phase, the development of a first prototype which will implement the main functionalities has been initiated. The fig. 1 (Left) depicts the login page of the application while fig. 1 (Right) presents the landing (main) page. The "Set Preferences" page is shown in fig. 2 (Left) while fig. 2 (Right) depicts the "Recommend Desks" page. At the moment the development was focused on the web application's front end.

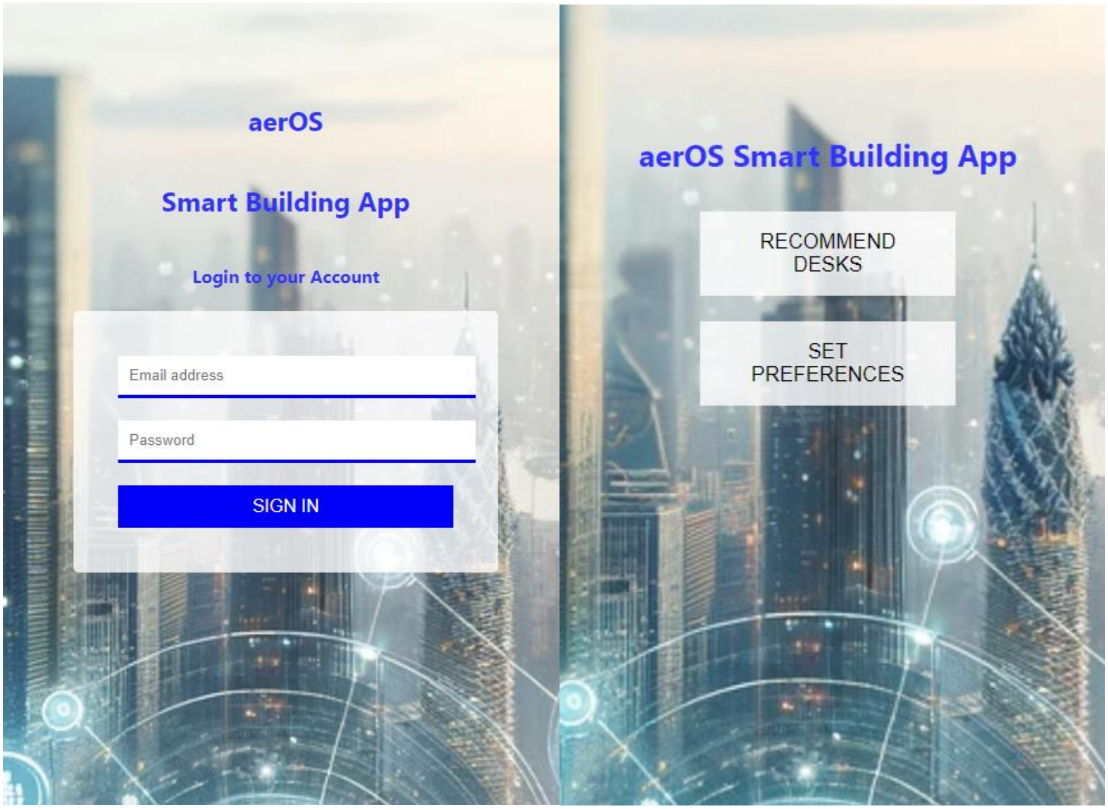

Figure 52. Pilot 5- Web app Login page (Left) and Landing page (Right)

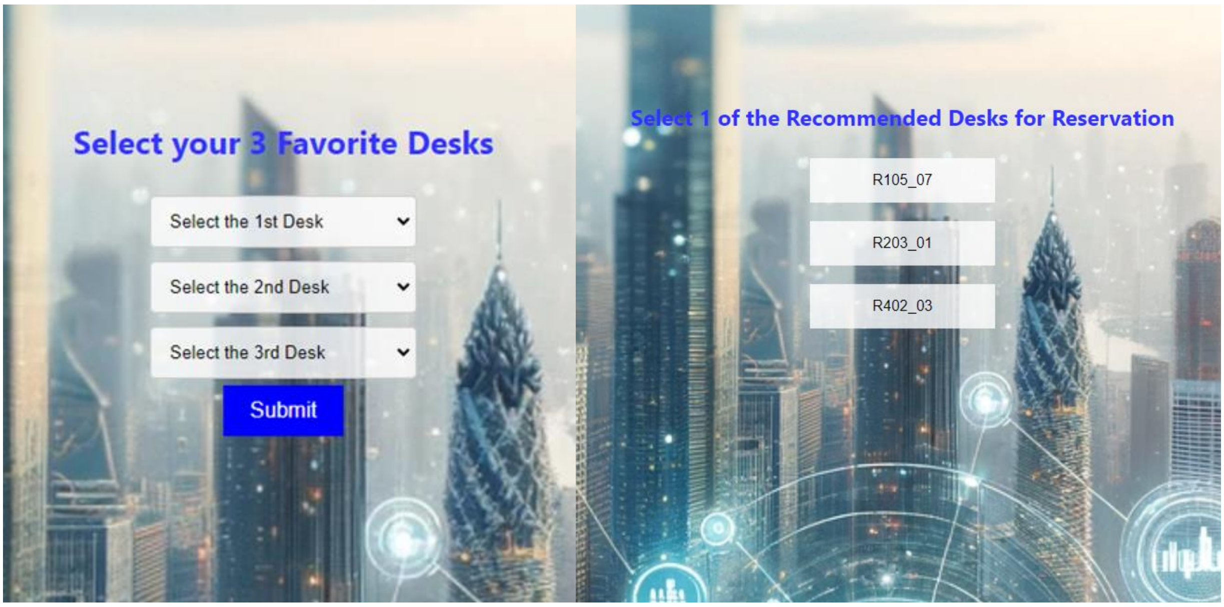

Figure 53. Pilot 5- Web app "Set Preferences" page (Left) and "Recommend Desks" page (Right)

Pilot5-Scenario1-DevelopmentActivity-4 (P5-S1-DA4): Data Retrieval from Context Broker using NGSI-LD.

The process initiates by extracting essential room metrics, including time, date, temperature, humidity, CO2 levels, PM2.5, and energy consumption, from the context broker. This retrieval employs NGSI-LD standards, utilizing specific room identifiers (room ID) to construct the query. Following the assembly of this query, we engage the context broker to obtain the relevant data, which is then stored locally for further processing.

Pilot5-Scenario1-DevelopmentActivity-5 (P5-S1-DA5): Data Preprocessing.

The initial phase of data preprocessing involves the cleaning of the retrieved data to address any instances of missing values. Subsequent to this, we engage in the computation of occupancy levels within the room, inferred from the status of desks (desk occupancy states). This step is crucial for analyses that require an understanding of room usage patterns. The final step in the preprocessing phase is the chronological ordering of the dataset, ensuring that the data is sequenced by time. This temporal sorting facilitates more efficient analyses and data management practices.

Pilot5-Scenario1-DevelopmentActivity-6 (P5-S1-DA6): AI Models.

A series of machine learning models have been developed. We use the XGBoost open-source library which provides a regularizing gradient boosting framework for python in order to solve a regression problem. We are able to predict future values of temperature, humidity, CO2, and PM2.5 for a room with specific volume, specific occupancy of people and in a specific time. Individual models have been built for each one of the environmental values that we are interested in monitoring and predict. The algorithms have satisfying results, but we are looking on ways to enhance their performance. Facebook Prophet models are considered to enhance our application in the future, and we are doing research on how we can combine the two models (XGBoost and FBProphet) in a way that can add value to our scenario.

Pilot5-Scenario1-DevelopmentActivity-7 (P5-S1-DA7): Health Score.

A script has been developed using python that is able to calculate the health score of a room based on temperature, humidity, CO2 and PM2.5. You specify the range of acceptable values and can add specific weights on the metrics that are believed to be more important than others in the health score of a room. The outcome of the script is a percentage of health score in a room. The script can take as input the values from the AI models in order to be able to predict future health score.

Pilot5-Scenario1-DevelopmentActivity-8 (P5-S1-DA8): Energy Consumption.

Based on the XGBoost, a model has been developed that is able to predict future energy consumption for a room with specific volume, specific occupancy of people and in a specific time. The algorithm has satisfying results, but we are looking on ways to enhance their performance and accuracy of prediction.

Pilot5-Scenario1-DevelopmentActivity-9 (P5-S1-DA9): Optimization.

A Bayesian optimization algorithm has been developed in order to extract the optimal environmental conditions of a room with the goal to minimize the energy consumption. There specific bounds that allow to limit the outcome of the optimizer in a range acceptable for a healthy room. The algorithm can use as input values outputted by the machine learning models mentioned above in order to be able to suggest optimal conditions in the future. The algorithm performs well but its accuracy is limited by the accuracy of the above-mentioned machine learning models.

Pilot5-Scenario1-DevelopmentActivity-10 (P5-S1-DA10): Deployment process.

A Dockerfile was designed to build an image for the application using a Python runtime environment. Key steps include setting up a non-buffered Python output, creating a virtual environment for dependency isolation, installing system and Python dependencies, exposing the necessary port, and specifying the command to run the application. Also, a Makefile was created to automate the processes of building a Docker image, pushing it to a registry, uploading the corresponding Helm chart, and deploying the application. Additionally, it includes targets for cleaning up builds and deployments.

2.6.1.3 Integration activities

Pilot5-Scenario1-IntegrationActivity-1 (P5-S1-IA1): Integrate MetalLB with KrakenD.

Pilot5-Scenario1-IntegrationActivity-1 (P5-S1-IA2): Integrate MetalLB with MQTT.

Pilot5-Scenario1-IntegrationActivity-3 (P5-S1-IA3): Security Components.

We are in the process of integrating the security components developed for the aerOS MVP in the scenario 2 of pilot 5

2.6.1.4 Validation activities

Pilot1-Scenario1-ValidationActivity-1 (P5-S1-VA1): Validated kubeedge functionality operation at the edge (edge autonomous operation).

2.6.2. Cybersecurity and data privacy in building automation

The second scenario builds upon de foundation of the first one. As mentioned, it expands horizontally focusing on security and trust, and differing mainly on testing and validations phases. This means procurement and setup are covered by the previous scenario, and the development requires certain amount of progress to be initiated.

2.6.3 Pilot 5 Timeplan

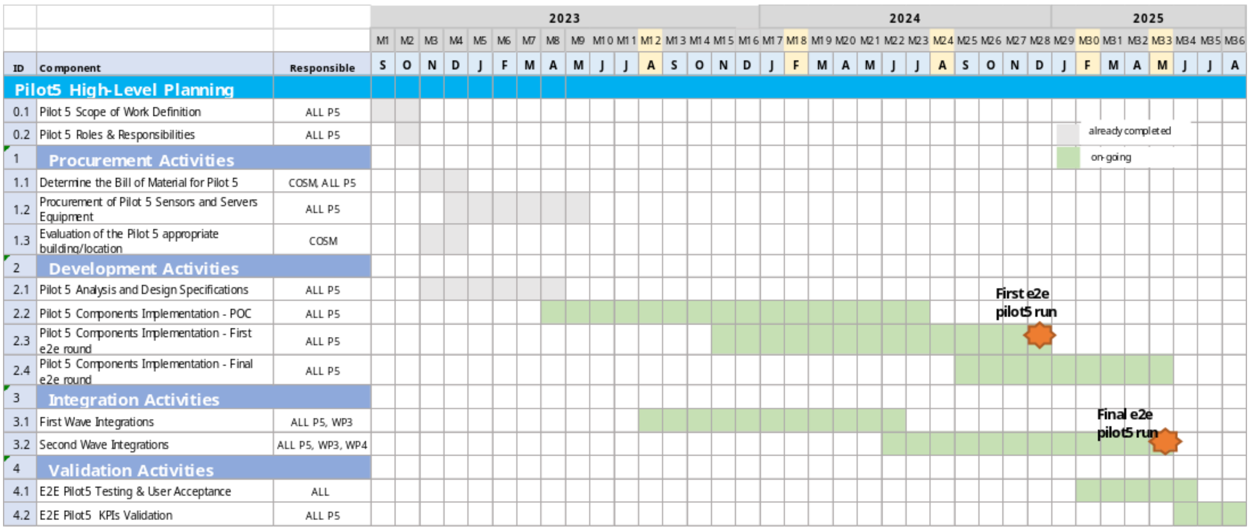

Figure 54. Pilot 5- High-Level Implementation Plan

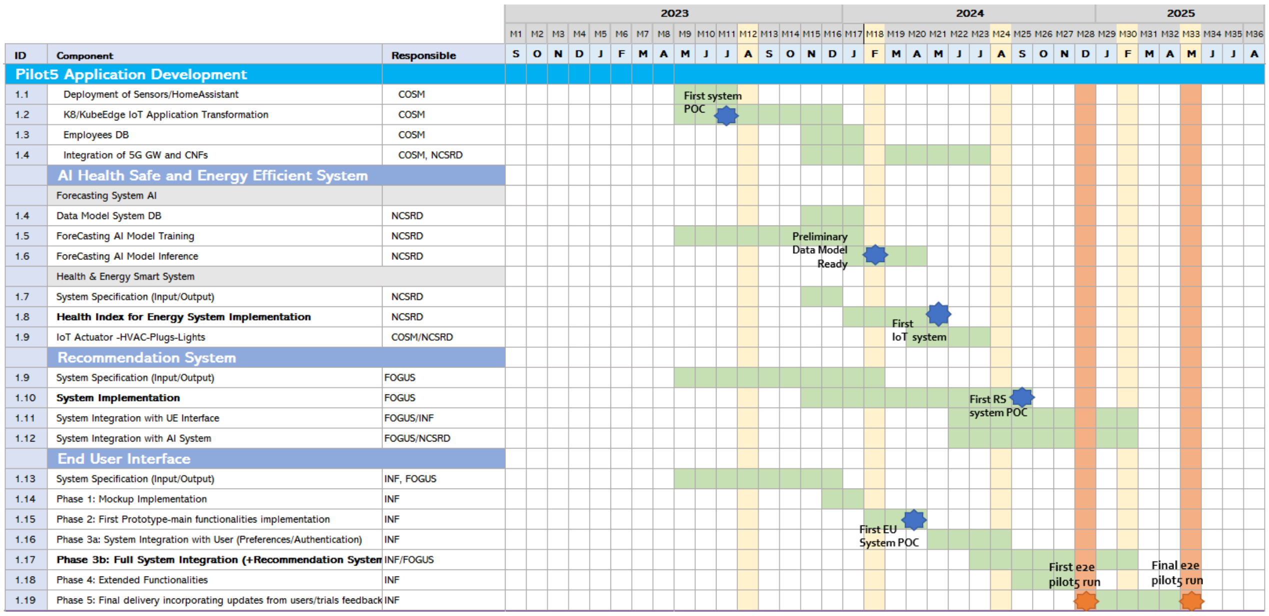

Figure 55. Pilot 5- Application Components Implementation Plan

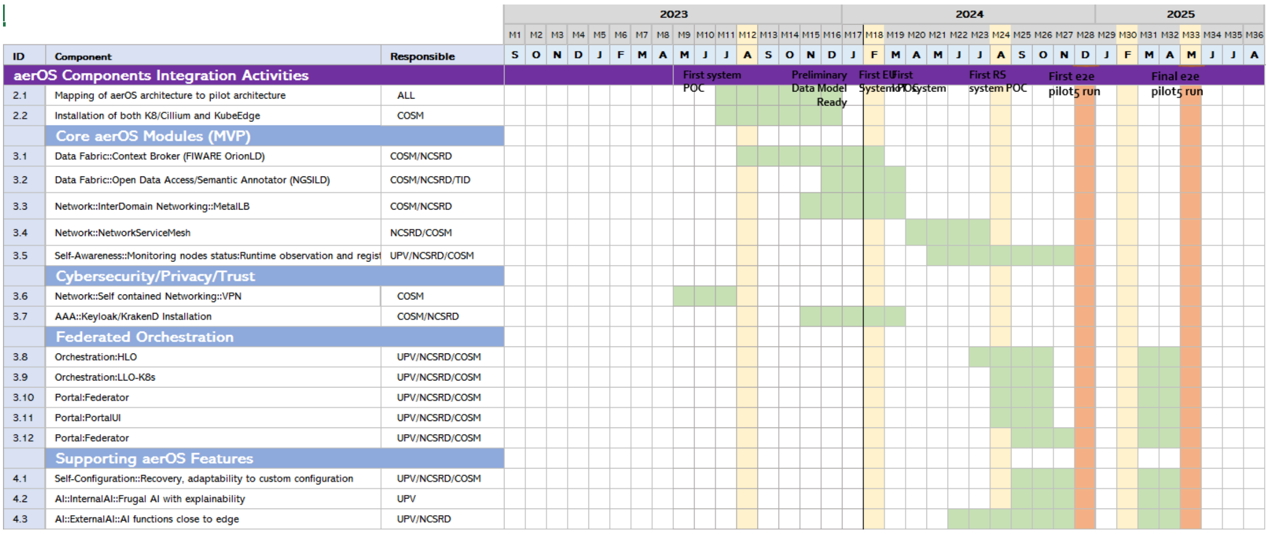

Figure 56. Pilot 5- aerOS Adaptation and Integration Plan

3. First Open Call (UPV)

Description and technical objectives of the project

The transition to software-based components and systems requires the efficient integration of new technologies and services. This involves data strategy, reliable data sharing systems, use of frugal AI, containerisation and virtualisation, decentralised decision making and federation of systems and networks for data exchange in the IoT edge-cloud continuum. The meta operating system provides orchestration mechanisms to efficiently utilise the IEs that compose the computing continuum. aerOS will drive the development of hyper-distributed applications and services, closer to the data sources, will leverage the concept of services across multiple infrastructure domains and service levels, supporting federation, and will use self-* capabilities mechanisms in the nodes to provide them with a degree of automation.

aerOS is being carried out by a Consortium of 27 partners from 11 European countries, specialised in IoT, edge and cloud technologies and in the verticals in which the solution will be tested. The goal of aerOS is to design a virtualised, platform-independent meta operating system for the IoT edge-cloud continuum. aerOS will enable orchestration, virtual communication, the use of frugal and explainable AI, maximum availability and will include robust systems to ensure security and reliability. Furthermore, aerOS will allow distributing software task execution requests, supporting intelligence as close to events as possible, running services across virtual machines and containers connected through an intelligent network infrastructure, allocating and orchestrating resources and supporting scalable data autonomy.

aerOS will be used in five real-world Pilots with various scenarios, in order to validate the results and demonstrate its viability in the future of IoT: (i) manufacturing; (ii) computing near renewable energy, (iii) mobile agricultural machinery, (iv) smart seaports and (v) energy efficient buildings. To achieve these goals, seven technical objectives have been set out in the project, which are:

1. Design, implementation and validation of aerOS for optimal orchestration.
2. Intelligent realisation of smart network functions for aerOS.
3. Definition and implementation of decentralised security, privacy and trust.
4. Definition and implementation of distributed AI components with explainability.
5. Specification and implementation of a Data Autonomy strategy for the IoT edge-cloud continuum.
6. Definition, deployment and evaluation of real-life use cases.
7. Global ecosystem creation, maximisation of impact and Open Call conduction.

Open Calls

In order to support Research centres (RTOs), European SMEs, Universities and individuals to extend the scope of the project, submitting proposals through two rounds of Open Calls, aerOS has set aside a total of 900.000 euros. The objectives of the Open Calls are:

- Validate and improve aerOS components.
- Attract more developers, domain experts, entrepreneurs, etc., to create new solutions that leverage aerOS.

- Promote the visibility of the project and the results obtained.
- Gather new input and insights from IoT, edge, networking and industry experts.
- Extend the application base to other verticals outside of those included in the proposal (domain agnostic).

Open Call #1

The goal of the first Open Call is to fund proposals to improve the aerOS targets in one of its five Pilots. As mentioned above, only Research centres (RTOs), European SMEs, Universities and individuals may submit proposals. Proposals must be no longer than 15 pages (excluding the cover page and the last page) and must follow the template included in the Application Package, with a minimum font size of 10 points and respecting the format provided in the template, including the same page margins. If the maximum length is exceeded, excess pages will not be taken into account. Furthermore, the content must include (at least, but not limited to) the following information:

1. Administrative information.
2. Idea.
3. Relevance to aerOS.
4. Impact and sustainability.
5. Implementation.
6. Team.
7. Other relevant aspects.

The proposals submitted by the participants will go through a first selection process, in which they will be accepted or rejected if they meet or fail to meet a series of criteria, which are:

- Proposals may only be submitted by one entity (Consortiums are not allowed) and must be written in English.
- Proposals must conform to the aerOS technology principles and contribute to the aerOS paradigm.
- Each proposal must be contextualised in one of the five Pilots of the project and must address one of the objectives of the Open Calls.
- Participants do not need to be located at the Pilot sites (Navarre or Basque Country in Spain, Germany, Milano in Italy, Biel in Switzerland, Poland, Kaiserslautern in Germany, Limassol in Cyprus or Athens in Greece).
- Candidates must base their proposals on original work and any intended development must be free of third party rights, or be clearly indicated in the appropriate section of the proposal.
- Only one proposal per participant may be submitted. If a participant submits more than one proposal, only the first one will be considered.

- Proposals from entities with financial interests, family or emotional ties, or any other shared interest ("conflict of interest") with the partners of the aerOS Consortium will not be accepted. All cases of conflict of interest will be assessed on a case-by-case basis, based on the relevant EU provisions.

Once the proposal has been drafted (in PDF format), it has to be submitted through a three-step procedure. The steps in the procedure are as follows:

1. Complete an online form with the data related to the proposal. This form will be open from October 1st, 2023 until January 31st, 2024 at 17:00 CET.
2. Attach the PDF document with the proposal, according to the available template.
3. Email the proposal (the same PDF file uploaded through the form) to opencall-aeros-project-eu@aeros-project.eu and iglaub@upv.es as a password-protected ZIP file (aerosopencall1) including all relevant material. Participants should also include a copy of the form (in PDF format) as proof of registration which they will receive after submitting the form.

Of all the proposals received, a maximum of 7 will be selected and funded, with a maximum subsidy of 60.000 euros each. The duration of each project may not exceed 8 months. Funding will be provided to each participant after the achievement of the different milestones, which will be verified through the submission of technical and financial reports. Payments will be divided into: (i) pre-financing, (ii) interim payment based on the results achieved and (iii) final payment. A table to indicate the budget of the proposal is included on the last page of the "Proposal Template" within the Applicant Package.

On the one hand, for costs to be eligible, they must meet the following criteria:

- They must be incurred within the period set out in Article 9.4 of the Collaboration Agreement (see Application Package), with the exception of costs related to the submission of the technical report and financial statement (see Article 9 of the Collaboration Agreement).
- They must be identifiable and verifiable, in particular recorded in the applicant's accounts in accordance with the accounting rules applicable in the country where the applicant is established and with the applicant's usual cost accounting practices.
- They must comply with applicable national tax, labor and social security legislation.
- They must be reasonable, justified and comply with the principle of sound financial management, in particular with regard to economy and efficiency.

On the other hand, the following costs shall not be considered eligible:

- Those not complying with the conditions set out above (see Article 7.1 of the Partnership Agreement).
- Those reimbursed under another EU or Euratom grant (including grants awarded by a Member State and financed by the EU or Euratom budget and grants awarded by bodies other than the European Commission for the purpose of implementing the EU and Euratom budget).

All proposals received will be evaluated and will receive a score on the basis of which they will be accepted or rejected for funding. The evaluation process is summarised in four steps:

1. The proposals received will be pre-selected by a group of aerOS members to check that the eligibility criteria are met.

2. Two external expert evaluators (with experience in related fields) and one observer will be selected for each proposal to ensure impartiality. Each expert will give a score for each of the evaluation criteria, which are: relevance to aerOS (min. 3 out of 5), impact and sustainability (min. 4 out of 5), technical excellence (min. 4 out of 5), quality of implementation (min. 4 out of 5) and quality of the team (min. 4 out of 5). The minimum score to be selected must be 19 out of 25.

3. For each proposal, both experts will make an agreed assessment based on their independent evaluations. The result will be reflected on the Evaluation Summary Report (ESR).

4. ESRs will be ranked and will go through a final evaluation by a committee formed by PCC (Project Coordination Committee) members of aerOS and two external observers to guarantee impartiality.

Participants will receive notifications of funding or rejection before March 31st, 2024 (there may be slight delays in the deadline). Following the evaluation of the Open Call, representatives of the selected proposals will be invited to sign a Collaboration Agreement with Universitat Politècnica de València (partner UPV), the Project Coordinator, on behalf of the aerOS Consortium in order to be able to receive the funds. Selected entities will thereof enter the Consortium of aerOS as third parties of the Project Coordinator.

The following is a summary of the most important dates of the first Open Call:

- Opening of Open Call application submission window: October 1st, 2023.
- Closing of Open Call application submission window: January 31st, 2024.
- Communication of the results: March 31st, 2024.
- Expected start of action: 3rd/4th week April 2024.
- Expected end of action: 3rd/4th week November 2024.

The first OpenCall results are represented on the following figures:

The challenges that have been more extensively addressed are those posed by Pilots 1, Pilot 4 and Pilot 5. The challenge that has received more submissions is P5 with 8 submissions.

Most of the participants of the open call are SME (27), with a lower participation on the academic and research communities.

The pilots received an even distribution of submissions although P1 and P5 are the ones with a higher submission rate (above30%). Pilot 2 is the one that was more difficult for participants to address, maybe due to the intrinsic characteristics of the domain.

Spain, Greece and Italy are the countries that have submitted a higher number of proposals to addressed the challenges posed by the pilots.

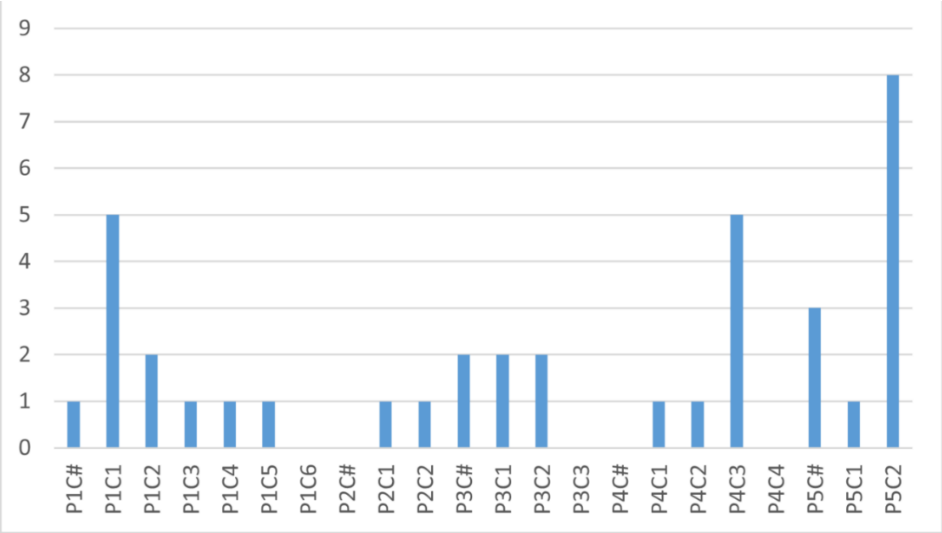

Figure 57. Proposals per challenge for the First Open Call

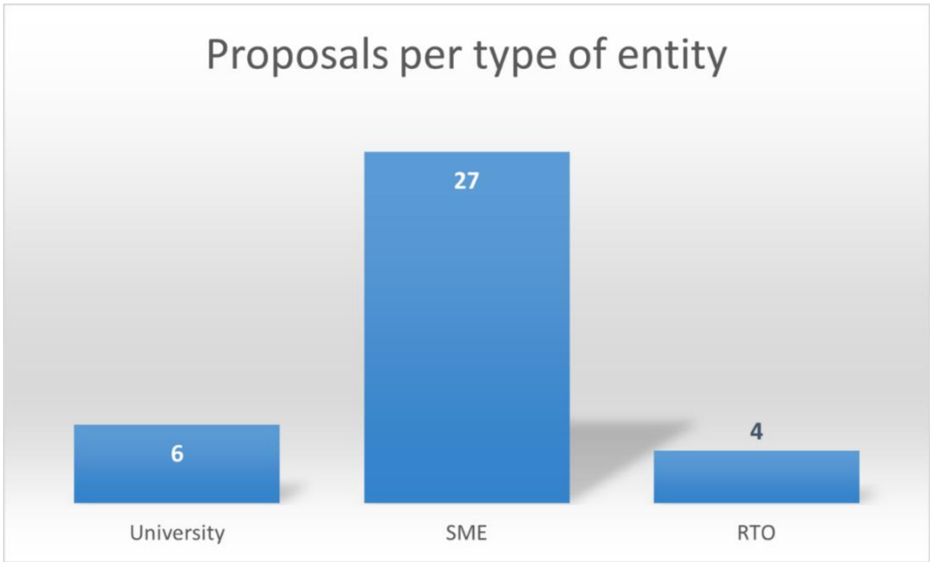

Figure 58. Proposals per type of entity for the First Open Call

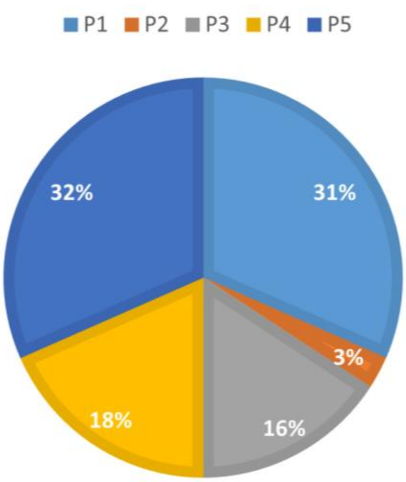

Figure 59. Proposals received per Pilot for the First Open Call

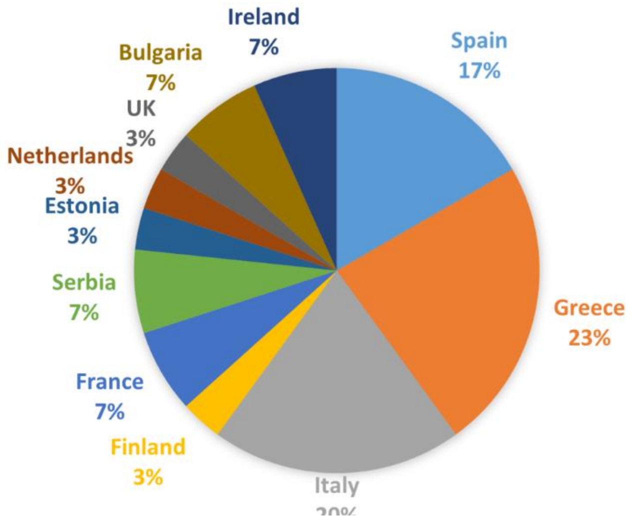

Figure 60. Proposals received per Country for the First Open Call

5. Conclusions and Future Work

This document has provided compelling evidences that the aerOS metaOS reference framework is open enough to meet the challenges of a high diversity of pilot business processes, use cases and verticals. The aerOS metaOS has been set up in a number of scenarios and it is now proven that the basic services can support the baseline operation of the processes addressed. On the other hand, we can conclude that applications and services that could benefit from the aerOS continuum may require a significant revision of their architecture to support the operation of distribute workflows. The pilots so far have demonstrated that the aerOS metaOS can be successfully deployed in brownfield scenarios and that aerOS metaOS digital enablers can extend current digital infrastructures and devices across the continuum.

Future work will be driven on one hand to achieve a full integration of the aerOS framework beyond the initial phase that is based on the MVP release of the metaOS. Future development and integration work at the pilots should facilitate the application of advanced metaOS systems and a full assessment of technical and business KPIs as new releases become available.