D6.4 Use Cases settings and demonstration strategy

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List of Acronyms

Abbreviation / acronym	Description
AORP	Agriculture Operational Robotic Platform (Use Case 1)
CMD	Command Prompt
CPU	Central Processing Unit
DSO	Distribution System Operator
Dx.y	Deliverable number y, belonging to WP number x
ECU	European Currency Unit
EMDS	Energy Management and Decision Support system (Use Case 4)
ESBN	Electricity Supply Board Networks
EV	Electric Vehicles
FSTP	Funding Support to Third Parties (Open Call Use Cases)
GA	Grant Agreement
GNSS	Global navigation satellite system
GPS	Global Position System
IAIMM	In-car Advanced Infotainment and Multimedia Management system (Use Case 3)
IMU	Inertial measurement unit
IoT	Internet of Things
IT	Iteration
IUCP	Individual Use Case Plan
KPI	Key Performance Indicator
LoRa	Long Range
ML	Machine Learning
NUC	Next Unit of Computing
OS	Operating System
POI	Points of Interest
QoE	Quality of Experience
QoS	Quality of Service
RGB	Colour model red, green, and blue
ROS	Robot Operating System
RSAM	Railway Structural Alert Monitoring system (Use Case 2)
RTK	Real-time kinematic positioning
SUC	System Use Case
SW	Software

Abbreviation / acronym	Description
UC	Use Case
WP	Work Package
WPL	Work Package Leader
XR	Extended Reality

Executive Summary

This document is the deliverable D6.4 Use cases settings and demonstration strategy and it describes the set-up for the four internal project Use Cases, as well as the strategy and plan for further ICOS system validation.

The intention is to set up the environment for ICOS deployment in each Use Case and use the same methodology for additional Use Cases that will be selected via the ICOS open calls.

This deliverable elicits requirements for ICOS that each Use Case has established based on its deployment, and it underlines the added value that ICOS Meta OS should add to its operations. These details are included in the individual section for each Use Case called Individual Use Case Plan (IUCP).

Each IUCP document covers a description of the problem that each industry will solve thanks to ICOS and its initial requirements prioritization that ICOS functionalities should bring in. IUCPs will be revisited in each of the iterations to assess its feasibility and to introduce new outcomes or deviations from the original plan.

Finally, section 7 includes the general overview of the initial validation plan focused on Iteration 1 and the ICOS ecosystem set-up process that is the first step for the end users to install the ICOS in their testbeds to start testing its functionalities.

1 Introduction

1.1 Purpose of the document

This deliverable elicits ICOS functionalities requirements for each Use Case, considering expected outcomes from the technical WPs. The Use Cases that act as ICOS testbeds are described in detail in their Individual Use Case Plans (IUCPs) included in this document. These plans will be revisited in each iteration to assess their feasibility and to introduce new outcomes or deviations from the original proposal. The plan will include technical and business validation metrics, to assess technical requirements and ICOS business feasibility and impact. Adequate metrics will use quantitative and qualitative indicators to depict the degree of fulfilment of the requirements.

1.2 Relation to other project work

This deliverable is part of WP6 that is focused on ICOS deployment, validation, demo strategy and final ICOS Platform release. Therefore, the main goal of this document is to support Technical WPs in ICOS development by providing end-user feedback and validating ICOS functionalities in each iteration. Use Cases play a key role in exploitation being the first early adopters that will be able to show the added value of the final project results in a real environment and the benefits that they bring to potential future clients.

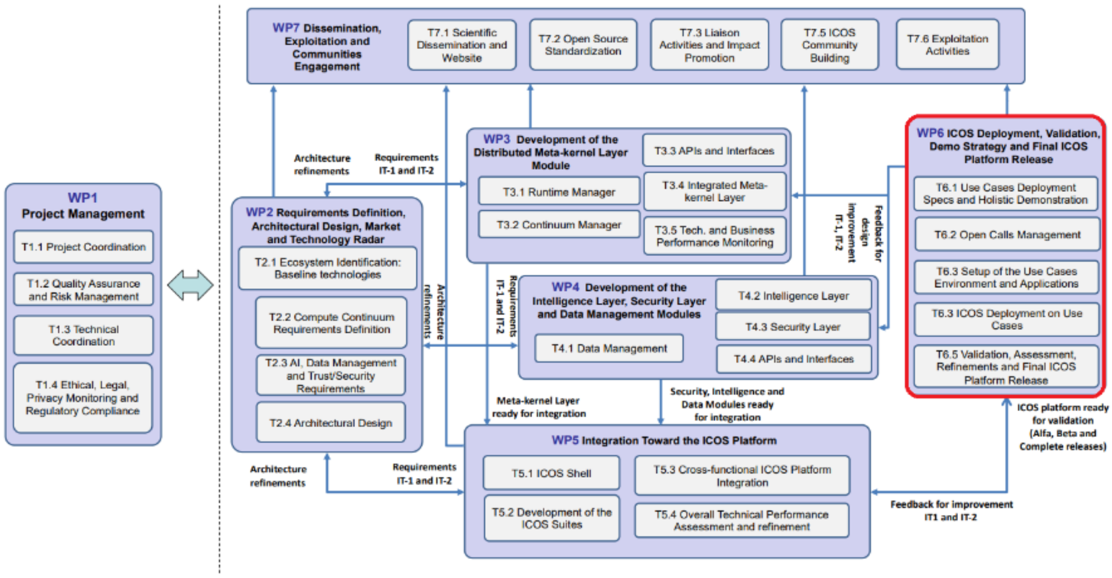


Figure 1 ICOS PERT Chart: WP6 relation to project work

Use Cases have been actively engaged in defining early requirements for the ICOS platform since the beginning of the project.

A dedicated face-to-face workshop was organized during the project's kick-off meeting in September 2022 (M1) to understand the Use Cases' architecture and define the initial approach towards validation.

Use Cases representatives have been actively participating in technical meetings and monthly WP6 calls to ensure alignment between the ICOS architecture and end-user requirements. The focus during this period was on identifying those requirements to structure pilot scenarios, including an evaluation framework for gap analyses, and expected future needs. Initial discussions for the ICOS validation methodology have also begun.

The results of the Functionalities Prioritization for IT-1 (ALPHA version) exercise, conducted by Use Cases, were presented during the 3rd consortium meeting in May 2023 (M9). These results are included in section 2.4 ICOS Use Cases Functionalities Prioritization and in the Individual Use Case Plans.

This information provides insight into the progress and activities related to ICOS project validation and the involvement of various stakeholders in shaping the project's direction. It highlights the project's commitment to aligning its activities with end-user requirements and its dedication to demonstrating and validating the ICOS operating system in real-world scenarios.

1.3 Structure of the document

This document is divided into four main sections:

- Chapter 1–2 – overview of WP6 (objectives, partners roles, actions done by M15, ICOS functionalities prioritization) and Introduction to Individual Use Case Plan concept.
- Chapter 3–6 – Individual Use Case plans of each Use Case.
- Chapter 7 – Introduction to validation strategy and initial ICOS ecosystem set up scenario.
- Chapter 8 – Next steps

2 Overview of WP6

2.1 ICOS Use Cases

In the context of the ICOS project, partners' roles within Work Package 6 (WP6) are divided into three distinct groups depicted in Figure 2 below, each with specific responsibilities and focus.

Figure 2 : ICOS Consortium partners engaged in WP6.

A) Four Internal Use Cases:

These Use Cases are brought by the consortium partners themselves and are used for internal testing and validation of the ICOS system. The roles within this group are further divided into:

a) Technology Provider: These partners play a role in providing the technology and infrastructure needed for the Use Cases. They will be responsible for setting up the technical aspects of the ICOS system in the Use Cases.
b) End User: These partners represent the end users of the ICOS system. They are the beneficiaries of the technology and are involved in validating how ICOS meets their specific needs and requirements.

The description of the four internal use cases can be found in the deliverable D2.1 [1] and below is a brief summary of the four internal Use Cases together with their challenges and benefits that they will impact their operations thank to the ICOS Meta OS.

- **UC1 Agriculture Operational Robotic Platform:**

  Concept: Further development of digital and robotic systems based on data exchange ecosystems and services based on their semantic processing to provide knowledge and tools that will increase efficiency, ensure safety, and confirm product quality in the supply chain, while reducing costs and providing valuable and up to date information to farmers.

  Challenges: Delays in accessing data, Efficient and optimal utilization of the available edge-to-cloud resources, and connectivity in real conditions.

  Expected Benefits: Reduction of decision-making latency, improved AI models, increased system availability, and predictive maintenance.

For more detailed information please refer to UC1 Individual Use Case Plan in section 3 of this document.

- **UC2 Railway Structural Alert Monitoring System:**

  Concept: The main challenge to be addressed by the use case is related to the continuous monitoring of critical infrastructure on rail tracks to ensure safety and improve maintenance activities.

  The railway line along an area select for the use case is where communications are limited in availability and bandwidth. ICOS Meta OS will make it possible to benefit from processing at the edge while sharing limited amounts of extremely relevant information to the upper layers of other applications.

  Challenges: Implementing energy-efficient solutions, improving wireless networking protocols, and Efficient and optimal utilization of the available edge-to-cloud resources.

  Expected Benefits: Reduced decision-making latency, increased overall system availability, and improved data security.

  For more detailed information please refer to UC2 Individual Use Case Plan in section 4 of this document.

- **UC3 In-car Advanced Infotainment and Multimedia Management System:**

  Concept: Multi-users and Multi-sites Virtual Sharing Experience to interact in sync with high-definition media contents (3D models, immersive videos, pictures, etc.) with in-car passengers and other users far away.

  The service provides and enriches multimedia functionalities for planning, enjoying trips and visiting touristic sites. Its deployment architecture includes edge nodes to host rendering and pre-processing and more powerful cloud nodes.

  Challenges: Ensuring seamless user experience, providing secure multi-user communication and interaction infrastructure.

  Expected Benefits: Optimized multimedia content distribution, enhanced quality of service, and privacy and security of shared data.

  For more detailed information please refer to UC3 Individual Use Case Plan in section 5 of this document.

- **UC4 Energy Management and Decision Support System:**

  Concept: This Use Case aims to deliver a secure and efficient energy system, based on advanced and reliable Machine Learning techniques for energy forecasting and home-to-home parameters sharing to avail of learnings obtained in other houses. The ICOS AI 'brain' will shape the future usage of the Prosumers with the aim of flattening the demand curve by removing demand on the grid at peak time and boosting energy usage at night-time.

  Challenges: Ensuring data protection and security, providing customized energy solutions, and ensuring real-time solutions in areas of poor connectivity.

  Expected Benefits: Secure and efficient energy management system, leveraging advanced machine learning techniques for energy forecasting, increased client satisfaction and retention.

  For more detailed information please refer to UC4 Individual Use Case Plan in section 6 of this document.

B) Technical Partners:

These partners are primarily engaged in the development and integration of the ICOS system. Their focus is on building and integrating the components and features of ICOS, ensuring it functions according to the project's objectives. They may also provide technical support to the Use Cases.

C) Partners responsible for Open Calls Management (External Use Cases):

These partners are responsible for managing the Open Calls process. They oversee the selection of new additional Use Cases, brought in through external projects or organizations, to run validation trials with ICOS. Their role includes identifying, onboarding, and supporting external Use Cases that contribute to a successful achievement of the project's goals.

This structure allows for a comprehensive approach to testing and validating the ICOS system. The internal Use Cases provide a controlled environment for initial testing, while external Use Cases, brought in through open calls, offer a way to validate ICOS in a wider range of real-world scenarios. Technical partners play a crucial role in ensuring the development and integration of ICOS to meet the needs of both internal and external Use Cases.

The ICOS project places significant importance on Use Cases (both, internal and external), each serving critical roles in the project's development and implementation. They are central to the project's success for 3 primary reasons:

Requirements Gathering and Refinement:

The Use Cases act as valuable sources of both functional and non-functional requirements for the ICOS system. Through their practical application and testing, they help identify the specific features and performance criteria that ICOS must meet to address real-world needs.

These requirements play a fundamental role in shaping the development and configuration of the ICOS meta operating system. They serve as the foundation upon which the system is designed, ensuring that it aligns closely with the demands of the Use Cases.

Early Adoption and Feedback Loop:

The Use Cases serve as early adopters of the ICOS system. They actively incorporate ICOS into their environments, deploying and managing applications using the platform.

By being at the forefront of ICOS adoption, the Use Cases provide essential feedback to the project. Their experiences and observations help identify areas for improvement, refinements, and optimizations in the ICOS system.

This feedback loop is crucial for enhancing the system's performance, reliability, and usability. It ensures that ICOS evolves in response to practical challenges and user needs.

Mutual Benefit:

Simultaneously, the adoption of ICOS significantly benefits the Use Cases. ICOS brings unique application deployment and runtime management features to their environments.

This adoption of ICOS enhances the capabilities of the pilot cases, making them more efficient and effective in their respective domains. The Use Cases gain access to cutting-edge cloud services and technologies, improving their operational performance.

In summary, the Use Cases in the ICOS project are not just passive participants; they are active collaborators. They help shape ICOS by providing essential requirements and offering valuable insights through their early adoption and feedback. This mutually beneficial relationship ensures that ICOS is finely tuned to meet real-world needs while enhancing the capabilities of the Use Cases, resulting in a win-win scenario for both sides.

The Use Cases alignment with the ICOS roadmap outlines the challenges and expected benefits for each Use Case, showcasing the diverse range of applications and industries that ICOS will impact. It demonstrates the project's commitment to addressing real-world needs and enhancing performance in various sectors. As ICOS progresses through these pilot cases, it aims to deliver tangible benefits, optimize operations, and overcome challenges in each context.

2.2 Objectives and KPIs

Information below gives an overview of the progress and activities related to Work Package 6 (WP6) in the ICOS project up to November 2023 (M15). It focuses on the objectives, expected outcomes, key performance indicators (KPIs), and the work done in this WP during the specified period. Here is a summary of objectives defined in Grant Agreement:

Objective 4: Demonstrate the project outcomes in key relevant scenarios.

Aim: Addressing challenges C1, C2 and C3, we plan to demonstrate and validate the ICOS meta operating system in the pilots brought in by the project (including defined use cases and open calls). This includes various ICOS releases, as well as application-scale ICOS demonstrations.

Pertinent to the topic: The project outcome is validated through the deployment of ICOS in the 4 internal Use Cases and 5 external Use Cases coming from the 1st open call[1], turning into 9 different verticals. Validation also includes a set of services (15) on the aforementioned verticals, selected through the 2nd open call.

The outcome of the WP6 should be:

i) ICOS performance validation (KPI 4.4 and KPI 4.5)

ii) demonstration of the benefits brought in by ICOS (KPI 4.4)

iii) the delivery of the final ICOS product (KPI 4.7)

Table 1 WP6 KPIs

KPI	Description	Deliverable related	Deadline
4.3	Specification of Use cases and pilots	D6.4	M15
4.4	ICOS validated in 9 project verticals (4 internal Use Cases +1st open call)	D6.9	M32
4.5	ICOS validated in at least 15 services (2nd open call) related to the project verticals	D6.9	M32
4.7	ICOS Final release	D6.11	M36

[1] https://www.icos-project.eu/first-open-call

WP6 objectives are also connected to **expected Outcome 5:** Demonstrators in key industrial and societal applications, which in future require more power at the edge. Nine (9) verticals will be validated to prove the added value that Use Cases (End Users) can get from using the ICOS continuum. The goal is to prove that thanks to ICOS, Use Cases can improve:

- Improve service availability between 10% and 20%
- reduce delay by 10% (e.g.., average time to response for the target application),
- reduce cyber-security threats by 10%.

It is important to underline that during the first year of WP6 work, partners agreed that KPIs in the ICOS validation process will be divided into 2 categories:

- **Functional (Technical):** specify the technical capabilities of the ICOS system - defined by technical partners.
- **Non-functional (Business):** specify end-user business needs of service availability, reducing delay, security, privacy etc. - defined by Use Cases

This division will be applied in each Use Case KPIs section in the updated Individual Use Cases Plans that will be a part of D6.5 Report on validation results - Initial version (to be delivered in February 2024).

2.3 Individual Use Case Plan (IUCP)

The IUCP (Individual Use Case Plan) is an essential document that provides key information about each Use Case and outlines the initial plan for the ICOS validation within that specific Use Case. It serves as a crucial reference point for how each Use Case will be integrated with the ICOS platform and validated. Here are the key points regarding the IUCP:

Content of the IUCP: The IUCP typically includes information about the Use Case's objectives, requirements, technical specifications, and expected outcomes. It outlines how the ICOS platform will be implemented and utilized within the context of the specific Use Case.

Updates and Reviews: Iterative Process: The IUCP is not a static document but rather an evolving one. It should be revised and refined during each ICOS platform iteration. The iterations, which include specific milestones such as M18, M22, and M32, allow for adjustments and improvements to the plan based on the progress and feedback received.

Alignment with ICOS Roadmap: The IUCP should align with the overall ICOS project roadmap and objectives. It needs to reflect how the Use Case contributes to the project's goals and how the ICOS Meta OS serves the specific requirements of that Use Case.

Stakeholder Involvement: Key stakeholders, including end users, technical partners, and those responsible for open calls management, should be involved in the development and review of the IUCP to ensure that it accurately represents the Use Case's needs and objectives.

By following these principles, the IUCP serves as a dynamic and evolving roadmap for the integration and validation of the ICOS platform within each Use Case. It allows for regular assessments, improvements, and alignment with the project's overarching objectives, ensuring the success of the ICOS project as a whole.

2.4 Use Cases Engagement and Progress Summary

Use Cases have been actively engaged in defining early requirements for the ICOS platform since the beginning of the project. Below is the overview of the WP6 timeline. Individual timeline might vary depending on the Use Case, please refer to sections with Individual Use Case Plans (sections 3-6) for more details.

Early Engagement (Since Kick-off Meeting):

- Dedicated face-to-face workshop during the project's kick-off meeting in September 2022.
- Active participation in technical meetings and monthly WP6 calls to align ICOS architecture with end-user requirements.

1st Year Focus - End-User Requirements:

- Identification of end-user requirements for pilot scenarios and evaluation framework.
- ICOS Functionalities Prioritization exercise results presented in May 2023.

Infrastructure and Devices Preparation:

- Use Case partners executed the preparation of infrastructure and devices.
- Identification, purchasing, and deployment of necessary equipment in the field.
- ICOS Testbed Environment - Fully Operational by M18: Cloud computing, edge computing, and IoT devices integrated into the network supporting ICOS interaction.

Short-Term Goal - IT1 Validation (11.2023 - 02.2024):

- ICOS ecosystem setup process in focus (Section 7.1).
- Use Case partners reviewing ICOS key requirements and preparing equipment for installation.
- Results incorporated into D6.5 Report on validation results - Initial version (Feb 2024, M18).

Post-M19 - Functionality Validation:

- Establishment of ICOS connection triggers functionality validation.
- Emphasis on individual KPIs validation, detailed in D6.5 deliverable.
- Technical partners will prepare ICOS set up toolkit based on ICOS set up process validation results. Toolkit will become a guide for future Use Cases (Open Call applicants) that will be invited to use ICOS Meta OS.

Table 2 : Gantt for Use Cases Engagement and Progress Summary

	Task	Reference in this document	M9 05.2023	M10 06.2023	M11 07.2023	M12 08.2023	M13 09.2023	M14 10.2023	M15 11.2023	M16 12.2023	M17 01.2024	M18 02.2024	M19 03.2024
0	*ICOS requirements elicitation*	*Section 2.4*											
1	*Individual Use Case Plan*	*Sections 3 - 6*		V1				final version	final version included in D6.4			updated version (individual KPIs) included in D6.5	
2	*Equipment purchase*	*Equipment listed in section 2.1 ICOS testbed environment of each IUCP*											
3	*Equipment components implementation*												
4	*Data Collection*	*Refer to section 2.2 Service data flow in each IUCP*											
5	*ICOS ecosystem set up*	*Section 7.1*											

2.5 ICOS Use Cases Functionalities Prioritization

The exercise in which Use Case partners assigned value (Low/Medium/High) to ICOS requirements included in D2.1 ICOS ecosystem: Technologies, requirements, and state of the art (IT-1) [1] and connected these requirements to System Use Cases (functionalities) in D2.2 ICOS architectural design (IT-1) [2].

System Use Case (SUC)
A System Use Case (SUC) represents a single functionality that the system can provide to one or more actors that results in an observable result that is of some value for those actors. The objective is to identify in a formal and structured way the set of all basic functionalities that ICOS should provide to its users. Given the complexity and the extension of the ICOS System, the System Use Cases are grouped based on the layer of the ICOS System and where they (functionally) belong to: Continuum Management (SUC_CC), Runtime Management (SUC_RT), Intelligence Layer in section (SUC_AI), Data Management (SUC_DM), Security Layer (SUC_SC).

Priorities list defined by Use Case partners was then compared to the list of expected time of functionalities in ICOS release included in D2.2 [2] to align the timeline of ICOS development with Use Cases validation. In some cases, the time for functionality development was not yet defined.

The exercise was a key step in ensuring alignment between individual Use Case requirements and ICOS development priorities. Figure 3 describes the process that internal Use Cases partners followed to define the ICOS functionalities list. Table 3 includes the final results of the exercise: ICOS functionalities prioritization.

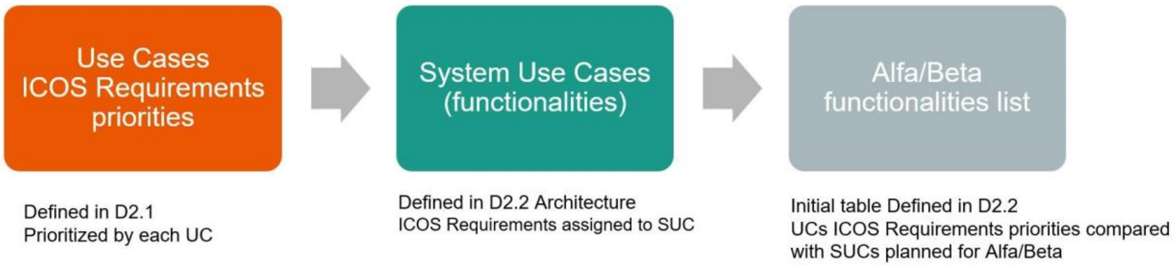


Figure 3 ICOS Use Cases Functionalities Prioritization process.

Here is a summary of the significance of this exercise and the outcomes:

Requirements Alignment: By assigning values to ICOS requirements, Use Case partners have provided a clear indication of the importance and relevance of each of those from the perspective of their specific Use Cases. This exercise helps prioritize which requirements are crucial for the success of each Use Case.

Use Case Prioritization: The assignment of Low, Medium, or High values to requirements allows Use Case representatives to communicate their needs effectively. It also helps identify areas where certain Use Cases may have higher or lower dependencies on specific ICOS features.

Development Prioritization: Connecting these prioritized requirements to System Use Cases in D2.2 [2] ensures that ICOS development aligns with the specific needs and priorities of the Use Cases. This connection helps the development team focus on the most critical features for the upcoming Iteration 1/Alpha (M18).

Transparency and Communication: This exercise fosters transparency and effective communication between the ICOS development team and the Use Case representatives. It ensures that both parties understand and agree on the priorities for the project.

Results Presentation: The presentation of the results during the face-to-face meeting in Barcelona in May 2023 (M6) further solidifies the alignment of priorities between Use Cases and the ICOS project. It provides an opportunity for discussion, clarification, and adjustments, if necessary.

Iterative Planning: The exercise sets the stage for an iterative planning process. As the project progresses, the priorities may evolve, and the alignment between Use Case requirements and ICOS development priorities can be revisited and adjusted accordingly.

System Use Cases (SUC) priorities defined by all Use Cases are listed in Table 3 below. Individual priorities per Use Case are included in section 3 of each Individual Use Case Plan included in this document (sections 3 -6).

Table 3 ICOS System Use Cases priorities.

SUC related	SUC Description	Expected time of functionalities in ICOS release
SUC_RT_5	Deploy in a different or multiple Controllers	BETA
SUC_DM_1	Access Data	ALPHA
SUC_DM_2	Allows to store data in an ICOS Node	ALPHA
SUC_DM_4	Allows to set permissions for data usage	Time Not defined
SUC_DM_5	Checks the permissions before a data operation	Time Not defined
SUC_DM_3	Execute Data Processing Functions	BETA
SUC_AI_7	Detect and Classify Anomalies	BETA
SUC_SC_6	Review Anomalies and Mitigations	Time Not defined
SUC_RT_4	Deploy Application	ALPHA
SUC_SC_10	Establish Secure Connections	ALPHA
SUC_CC_4	Join the Cloud Continuum	Time Not defined
SUC_CC_6	Install and Configure ICOS Discovery Service	Time Not defined
SUC_SC_2	Check Authorization	Time Not defined
SUC_AI_6	Classify Nodes	BETA
SUC_RT_6	See Application Logs and Status	ALPHA
SUC_CC_5	Visualize Continuum Topology	BETA
SUC_SC_8	Security Assessment	BETA
SUC_SC_1	Authenticate	Time Not defined

SUC related	SUC Description	Expected time of functionalities in ICOS release
SUC_SC_3	Audit Accesses and Actions	Time Not defined
SUC_SC_5	Execute Compliance Analysis	BETA
SUC_RT_3	Define Application Requirements and Policies	Time not defined
SUC_RT_7	See Application and Resources Performance Data	ALPHA
SUC_RT_8	Review Events and Alerts	BETA
SUC_RT_9	Apply suggested deployment optimizations	BETA
SUC_CC_1	Node On-Boarding	ALPHA
SUC_SC_7	Manage Roles	Time not defined
SUC_AI_1	Manage Model	ALPHA
SUC_SC_9	Establish Trust between Nodes	ALPHA
SUC_AI_2	Train Model	Time Not defined
SUC_RT_10	Apply recovery actions	BETA

3 UC1: Individual Use Case Plan: Agriculture Operational Robotic Platform (AORP)

3.1 Use Case description

The deployment of field robots in agriculture has witnessed significant development, driven by advancements in robotics, automation, and sensing technologies.

The emergence of field robots in agriculture has been notably shaped by the development of autonomous vehicles. This includes the creation of self-driving machines, tractors, and drones, representing a significant milestone in the deployment of field robots. These autonomous systems have the capability to execute tasks with minimal human intervention, enhancing efficiency and reducing the need for manual labour. Concurrently, the adoption of precision agriculture has become increasingly prominent. This approach uses cutting-edge technologies such as GPS, sensors, and data analytics to optimise the utilisation of resources such as water, fertilisers, and pesticides. In the realm of precision farming, field robots play a pivotal role, facilitating the implementation of targeted and data-driven agricultural practices.

One pivotal aspect of these technological advances lies in the paradigm of data-driven farming. Field robots now serve as prolific generators of extensive datasets encompassing crucial information on soil health, crop conditions, and meteorological influence patterns. Farmers, leveraging this wealth of data, can make judicious and informed decisions, thereby augmenting both productivity and resource efficiency within their agricultural operations.

Through the integration of these technologies, agriculture has witnessed a transformative shift towards more automated, precise, and resource-efficient methods, ultimately contributing to advancements in sustainable and technologically driven farming practices.

3.1.1 Problem definition

The primary challenge in this Use Case, which translates into a technological issue, lies in advancing digital and robotic systems based on data exchange ecosystems and services with semantic processing. This advancement aims to furnish knowledge and tools that enhance efficiency, ensure safety, and validate product quality within the food supply chain.

Simultaneously, the goal is to decrease costs and deliver valuable, up-to-date information to end users. This challenge mirrors several difficulties faced by the agricultural sector. Due to initial investment, high costs present a significant obstacle, particularly for smaller farms with limited financial resources, farmers have to deal with ongoing operational and maintenance costs. Regular maintenance, software updates, and repairs, further strain the budgets of farmers. A positive aspect of reducing investment costs is the multiplication of agbots' functionalities and the continuous linking of systems so that the solutions can work in environments with greater data availability (i.e., diverse crops, soil types, and weather conditions). An intelligent system to optimally manage the robot is a business-important solution to support the implementation of the technology into use.

Unfortunately, the technological complexity of robotic systems poses a hurdle, especially for farmers lacking technical expertise. Data security and privacy concerns arise due to the extensive data collected by field robots, raising worries about ownership and protection. The challenge is also the ease of access and the ability to use real-time data to make complex decisions as humans currently do. Another diagnosed challenge is interoperability issues hinder seamless integration with existing farm equipment, adding complexity to farm management.

Lack of sufficient knowledge, easy-to-use tools and resistance to technology adoption, weather dependency affecting robot usability, and concerns about job displacement further contribute to the multifaceted challenges in the deployment of field robots in agriculture.

Addressing these issues based on business and user-friendly rules to develop processes on farms reducing operating costs, improving awareness of technology potential impact, digital competences, improves effective use of resources as well as reduces the amount of used plant protection products is crucial for the successful integration of agbots in the agricultural landscape.

3.1.2 Proposed solution:

As outlined in deliverable D2.1[1], the Agriculture Operational Robotic Platform (AORP) is an independent running platform prepared for aggregation with different working tools to create task configurations which performance will be verified within UC1. AORP field tasks and missions include sowing and tending crops, removing weeds, monitoring crop development, and identifying threats. The platform moves autonomously through the field, performing the assigned missions. The robotic platform consists of control and driving modules. In addition, it is equipped with interchangeable tools - a seeder and a sprayer. The accuracy of the tasks is controlled by an RTK GPS, while the working environment is monitored using a camera on the front of the robot and ultrasonic sensors. Besides the robotic platform there is a transport platform that could act as a gateway.

The mobile platform takes advantage of four independent steerable wheels; each wheel's rotational speed can be controlled separately. With such a mobile platform, advanced manoeuvres in the field, such as skid steering and ackermann steering, are possible. The diesel engine on the mobile platform provides the power for hydraulic pumps and alternators to generate enough electricity to charge the batteries. These batteries are connected to a power inverter to provide electricity to external electronic equipment. The capacity of the fuel tanks is sufficient for 88 hours of continuous operation.

On the robot, a rugged embedded industrial computer (Neousys Nuvo) is providing computational power to processes on the robot, where an Ubuntu server is installed as the operating system, and on top of that, ROS2 is functional. A ROS2-CAN bridge node is responsible for low-level communication with the robot's ECU through a USB-CAN adaptor. The robot is equipped with RGB and RGB-D cameras, lidar, IMU, encoders, a GNSS system, etc., and its data is being processed in ROS2.

Cameras and lidar together are used for segmentation, object detection, navigation, and mapping, while taking advantage of two GNSS receivers beside global positioning provides global heading information. The data from GNSS is fused with IMU and encoders to provide more accurate state estimation.

With the raw sensor data and navigation stack on ROS2, the robot can simultaneously localize itself on the map and navigate to the destination while avoiding obstacles. The communication channels to the driving platforms (local) and the internet (cloud) would allow the robot to be controlled and/or monetised, as well as receive mission plans and transfer data to and from the cloud. To this end, communication with the AORP will be upgraded to LoRa, WIFI, and xG modems.

Functionalities. Three main functionalities have been selected for implementation that will profit from and make use of the ICOS:

- Predictive Maintenance of the machinery and remote steering
- Crop management analytics (weed map) - main focus in ICOS.
- Validation and Improvements of the ML models for robot operations and steering

Predictive maintenance of the machinery and remote steering. Data from cameras, logs, and information from all other devices installed on the robotic platform will be stored using ICOS as raw data on the cloud. Data size per day can reach 100 GB. During operation of the AORP, the maintenance algorithm (cloud) will carry out a prediction analysis on the basis of vibrations and signal control information. In the event of any issue, it will send back the control signals to the robotic platform. The data should be stored using data management tools in long-term storage.

There is a need to create a user interface for maintenance management, and parameters storing and control. As the robots are expensive devices, particular focus should be put on securing the connection. There should also be a way to define in ICOS the policy to limit access from the ICOS Meta OS.

Crop management analytics (weed map): During the first pass of the robot in the field, using the predefined mission, machinery will take field images that will be used for the purpose of creating a weed map. During the second pass the robot should already make a precision treatment based on the location on maps. The expected accuracy is 2-3 cm.

Figure 4 : Development of an algorithm for automatic plant identification

The computation will start on the edge but will need in short time any possible processing power and be able to send input images. The data management tools should allow for transparent management in the continuum. Depending on the constraints (e.g., connectivity) and on the requirements (e.g., precision, e2e delay) the ICOS system will optimise the use of ICOS Elements (computing, storage, network resources) along the Cloud Continuum.

Validation and improvements of the ML models for robot operations and steering. The data will be sent from the devices to the cloud to train, validate and improve AI models that will be used for further missions, and for improving the robot capabilities. Usually, predefined missions are being used. From a computational perspective the robot will use mostly the edge due to the requirements related with movement speed and the management of the unexpected obstacles or events (e.g., obstacle detection).

3.2 ICOS testbed environment

The main location for the testing tasks will be the L-PIT test field in Poznań. Due to the ICOS first iteration implementation outside the agro-technical season (January-March 2024), the main scope of testing IT-1 will concern communication (including lack of mobile connectivity) and the proper implementation of tasks by the robot platform using the ICOS Meta OS (autonomous operation, monitoring and control, data collection, data transmission). The ease and procedure of software deployment and ICOS ecosystem set up process will be tested by 03.2024.

3.2.1 IoT devices and SW included in Use Case:

The main two devices, considered to function as testbeds, hosting ICOS are described as Robot(s) and User Panel(s). As shown in Figure 5, Robot is equipped with an industrial boxed computer. This computer is connected to the robot's internal control board using a CAN-USB adapter to send control commands to the robot's actuators and read their statues. Additionally, the onboard computer is connected to a WIFI LTE guarantee connectivity to the local network and Internet. Imagery sensors, for instance, RGB and RGB-D cameras are utilised for image processing tasks and other sensors such as IMU and GNSS modules are used for precise localization.

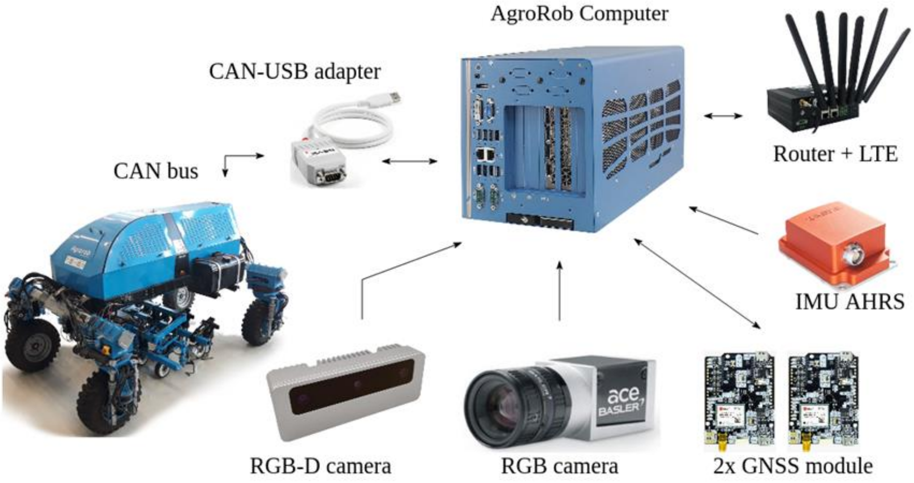


Figure 5: IoT devices in Use Case 1

User Panel, defined as a portable computer equipped with a screen is considered to be used as the hardware for hosting user panel SW, as illustrated in Figure 6.

3.2.2 Service data flow

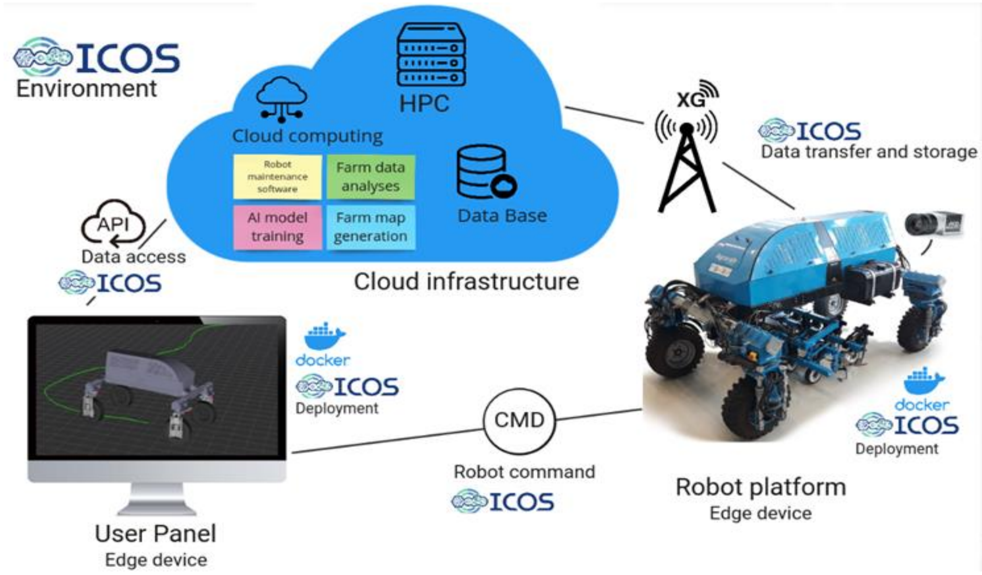


Figure 6 ICOS connectivity environment for UC1

As presented in Figure 6, the execution of processes and control tasks takes place using the control computer of the robotic platform (Edge). In the first instance, planned missions are determined by the user via the user panel (Edge) and existing data of the farm from a system located in the cloud. Mission information is being sent to the robot, the robot's software generates paths for the robot to follow and tasks to execute based on the data of the mission. Having tasks and generated paths, the control software, operating on the on-board computer, can now operate the robot on the field taking advantage of localization data received from devices such as GNSS and IMU. Considering the declared tasks and checkpoints.

Status information and signals from individual sensors and measuring points are continuously transmitted to the system for maintenance control. The data is collected in the cloud PSNC repositories. Similarly, the data from the tasks performed (position data, video data, maps) are transferred to the server as long as the connection speed (3G+) permits. When the connection speed drops or is lost, data is stored in internal storage until a stable connection to the cloud server is regained. The ICOS system, through the data management layer and Zenoh protocols, should provide lossless support for data transfer (robot-cloud data storage), cloud and robot data transfer to upper layers (integrity and synchronisation) and control of robot's operational data transfer. In addition, the ICOS system allows data to be presented in real time on a user panel, enabling the user to take control of the vehicle and terminate currently running tasks (CMD) at any time.

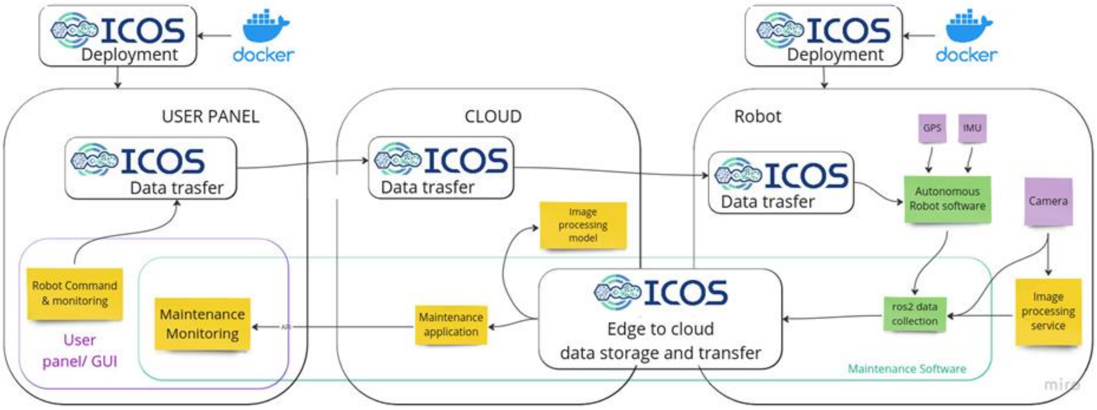


Figure 7 . ICOS architecture configuration for UC1

3.2.3 Applications executed with ICOS support and requirements (challenges) for ICOS:

Use Case 1 is expected to test the ICOS ecosystem set up process (described in section 7 of this document) by 03.2024.

Next step for IT1 will concern communication (including lack of mobile connectivity) and the proper implementation of tasks by the robot platform using the ICOS Meta OS (autonomous operation, monitoring and control, data collection, data transmission). Depending on the ICOS development, the key applications are expected to be validated in IT2.

Table 4 Use Case 1 requirements for ICOS.

Priority	Application name	Problem	Requirement for ICOS	Expected Validation date
1	**User panel software, Real time Monitoring and commanding**	Data integrity and synchronisation if there are connectivity problems between Edge-Cloud (Use Case is located in remote, rural area)	ICOS should ensure data synchronisation when connectivity is recovered.	IT2
2	**Maintenance software, Edge to cloud data transfer and storage**	Data generated as the result of performing tasks in the field must be sent and stored to the cloud, imagery files, database, and edge device (user panel) should be able to access these data.	When connectivity is available, ICOS should make sure that edge devices sync throws local data with the cloud	IT2
3	**Robot control software**	Remote deployment	ICOS should provide tools to orchestrate the deployment of control software on the edge devices.	IT2 (optional)

3.3 ICOS Requirements Elicitation

Table 5 Use Case 1 ICOS Requirements Elicitation [1]

	ID	Requirement Name and Description	SUC related	SUC Description	Expected time
1	CM_FR_02	**Workload Offloading:** The ICOS MUST be able to distribute the workload of the application components offloading part of their computation onto other nodes of the infrastructure, and coordinate the offloaded components	Not connected to any SUC		
2	CM_FR_03	**Function execution request:** ICOS COULD provide a mechanism to request the execution of a function on the continuum being totally transparent of the device that will host the execution	Not connected to any SUC		
3	CM_FR_10	**Data Management:** ICOS MUST be able to maintain the data sources topology as well as data source types (metadata) for proper application data assignment. This includes data source selection, data source-application binding, and data access	SUC_DM_1 SUC_DM_2	Access Data Store Data	ALPHA
4	CM_FR_11	**Data Access:** ICOS MUST be able to provide different data access methods, including selective access as well as streaming access, according to flexible high level data access application program interfaces	SUC_DM_1 SUC_DM_2	Access Data Store Data	ALPHA
5	DRT_FR_02	**Transparent data access:** ICOS MUST be able to provide location and format transparent data access methods through flexible high level data access application program interfaces (API)	SUC_DM_5	Check Permissions	Time Not defined
6	DRT_FR_04	**Support for distributed/parallel execution:** ICOS SHOULD provide the integration of data management with the execution runtime to support efficient scheduling and execution of the required tasks.	SUC_DM_3	Execute Data Processing Functions	BETA
7	DRT_FR_05	**Failure recovery mechanism/management:** ICOS MUST provide the capability to restart the failing transfers of the data in case of the failures (e.g., losing the connectivity)	Not connected to any SUC		
8	DRT_FR_06	**Secure data exchange:** ICOS SHOULD support data preserving communication techniques between modules (interfaces) for secure data exchange.	SUC_RT_7	See Application and Resources Performanc e Data	ALPHA

	ID	Requirement Name and Description	SUC related	SUC Description	Expected time
9	SST_FR_03	**Tenant Isolation:** ICOS SHOULD provide mechanisms that allow for isolation of resources across multiple tenants	SUC_SC_2	Check Authorization	ALPHA/BETA
10	SST_FR_07	**Secure API:** ICOS MUST provide API supporting AuthT/AuthZ and Audit capabilities	SUC_SC_1 SUC_SC_3	Authenticate Audit Accesses and Actions	ALPHA/BETA Not defined

3.4 Short term timeline

Table 6 Use Case 1 progress summary.

Task		M10 06.2023	M11 07.2023	M12 08.2023	M13 09.2023	M14 10.2023	M15 11.2023	M16 12.2023	M17 01.2024	M18 02.2024	M19 03.2024
1	Equipment procurement and purchase										
2	Equipment components implementation										
3	Data Collection										
4	ICOS set up process: system installation on IoT device										

4 UC2: Individual Use Case Plan: Railway Structural Alert Monitoring system (RSAM)

4.1 Use Case description

As outlined in deliverable D2.1 [1] Ferrocarrils de la Generalitat de Catalunya (FGC) infrastructure includes metro and commuter lines in and around the city of Barcelona, tourist mountain railways, and rural railway lines which serve more than 90 million passengers per year. Whilst most lines are conventional adhesion railways, the FGC also operates two rack railways and four funicular railways.

On all these railway lines, the massive deployment of sensors along different parts of the infrastructure is essential for the optimization and improvement of service and safety. The increasing number of sensors and their specific, and typically siloed solutions, present an increasing complexity related to the management and operations of such solutions.

Today, the railway monitoring process to improve the maintenance cycle is basic, and for most railway operators it is done preventively (once every fixed period) through a special train with sensors which runs through the whole rail system. This special train can measure several key parameters of the railway system, such as the height difference and width between the rails, and thus identify where, potentially, corrections in the track geometry is needed. However, this measurement is only taken once or twice a year; in the remaining months, nobody knows what happens (only physical inspections are available: very costly and uncommon), and there is no established procedure to evaluate the cost-effectiveness of the actions taken to address the identified rail tracks' issues. Indeed, digital technology, such as IoT, aims to minimize the monitoring and maintenance costs by gaining knowledge of the status of key aspects of the railway infrastructure in real-time: rail tracks geometry, slope, surrounding areas settlements and falling elements, overhead lines maintenance, etc.

The main challenge to be addressed by the Use Case is related to the continuous monitoring of critical infrastructure on rail tracks to ensure safety and improve maintenance activities.

The initial area to deploy and validate the Use Case for the Railway Structural Alert Monitoring system (RSAM) is the line in Lleida-La Pobla due to its difficult access to several of the areas of the line and its orography generating possible geological incidents.

Figure 8 Lleida-La Pobla Railtrack and train circulation

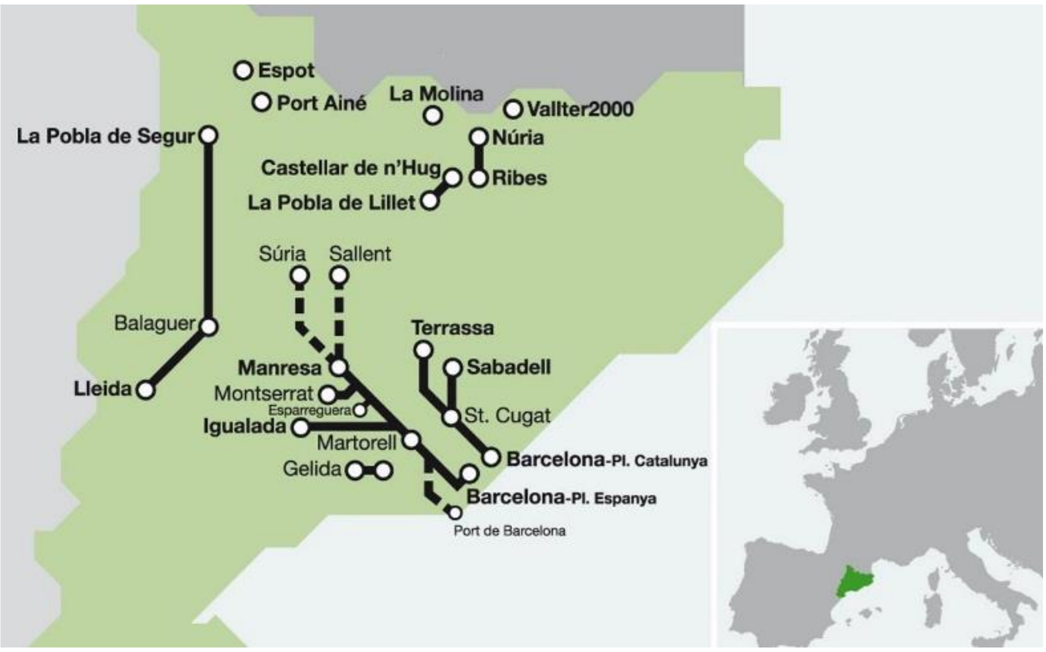


Figure 9 Lleida-La Pobla rail track location in Catalunya, Spain

4.1.1 Problem definition

The line is along an area where connectivity may be limited in availability and bandwidth, making it possible to benefit from processing at the edge while sharing limited amounts of extremely relevant information to the upper layers of other applications. There has been an identification of different applications relevant to the Use Case.

Figure 10 Safety problem on the rail track

Summary of Use Case location characteristics and needs:

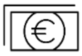
- Mountain rail line (16 train circulations per day)
- The only train connection for this region
- Non-stable area in Gerb of 4km
- Water flow below the rail track
- Non-compacted layers
- Presence of small caves
- In 2020 two big holes appeared
- Need for general repair (80m long, 8m wide, 3m depth)
- Safety problem, due to unpredictable rail track movements

Main impacts

- Time: Visual inspections weekly/bi-weekly
- Repairs: Several times per year, works to correct track geometry
- Quality: To reduce safety consequences, train circulation is limited to 30 km/h in 350m. And is also limited to 30 km/h in 4km for the first train.

End User added value for the Use Case implementation:

Time saving through continuous monitoring: limit intensive personnel inspections that are done every day before train circulations



Cost saving: implement corrective actions in advance to avoid reparation costs.

Improve safety: establish velocity limits to avoid risky situations when with quality of the operation decreases.

4.1.2 Proposed solution

Track geometry IoT monitoring for the following measurements:

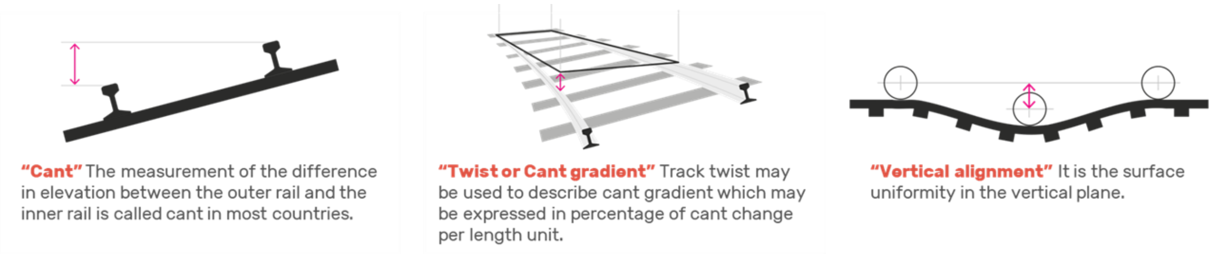


Figure 11 UC2 Railway track measurements to be monitored.

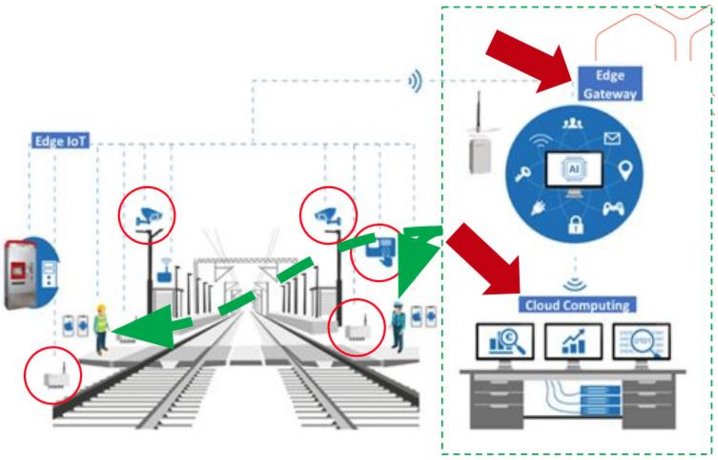


Figure 12 ICOS UC2_testbed

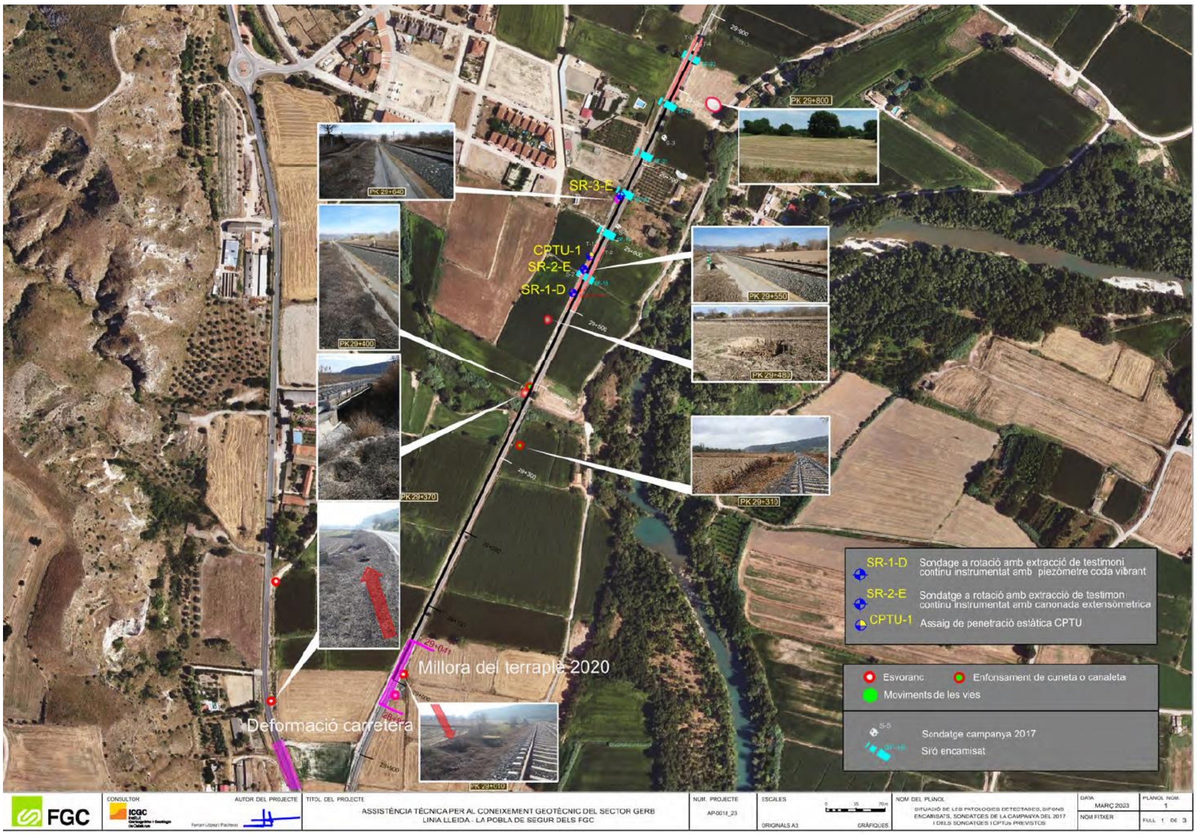


Figure 13 UC2 Railway Lleida-La Pobla_Gerb sensors location

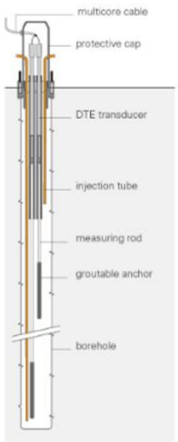
4.2 ICOS testbed environment

4.2.1 IoT devices and SW included in Use Case:

In the given context, IoT devices from Worldsensing, including sensors, IoT nodes, and gateways, play a crucial role in the Use Case 2 scenario. Here is how these IoT devices might be utilized:

Sensors

These sensors are designed to capture specific data points related to the Use Case requirements. Thus, sensors are responsible for collecting real-time data from the physical environment, enabling continuous monitoring and feedback.



Use Case 2 will cover different types of sensors to monitor track geometry and subsurface. This includes sensors like Tiltmeters, Extensometers and Piezometers.

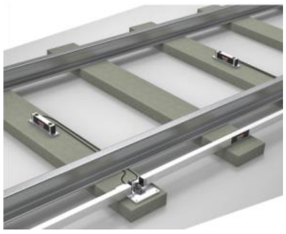


Figure 14 UC2 Devices: Different types of sensors

IoT Nodes:

The Worldsensing IoT Nodes are robust, low-power, long-battery life devices that allow data collection from analogue and digital sensors. It transforms manual and sporadic data collection to a more regular and automatic process, making it the most cost-efficient way to capture data from any environment. It is capable of transmitting data via long range radio to a gateway up to 9 miles / 15 kilometres away.

The data collected is stored in the logger and shared wirelessly to the closest Worldsensing gateway.

Figure 15 UC2 Devices: IoT Nodes (left vibrating wire node, right: digital node)

IoT Gateway:

The gateway serves as a communication hub between the IoT devices (nodes) and the central cloud-based system. It facilitates the transfer of data from the field devices to the central cloud, enabling real-time analysis, decision-making, and feedback.

The ICOS Meta OS agent will be installed on the IoT Gateway allowing it to act as an edge device in the Edge-to-Cloud continuum. Consequently, the final model of the IoT gateway deployed in the ICOS project will depend on final Meta OS requirements.

Figure 16 UC2 Devices: different models of Worldsensing IoT Gateways

Key characteristics of the Gateway integration with ICOS Meta OS are:

- IoT Gateway needs to be onboarded as a processing device at the ICOS continuum.
- IoT Gateway will be available as a processing node at the ICOS Meta OS
- IoT Gateway will offer API endpoints to a limited number of configuration features of the IoT devices.

CMT Cloud:

The data collection and management layer are an existing solution based on the Connectivity Management Tool (CMT) provided by WSE. The platform supports the processing and storage from sensors deployed on the FGC railway.

CMT Cloud is based on microservice architecture with applications such as Monitoring, Safety and Maintenance that will be orchestrated by ICOS Meta OS.

CMT Cloud needs a specific cloud computing environment to run its components. The usual cloud environment uses several Virtual Machines and a Kubernetes cluster on Google Cloud. But it can be adapted to the general cloud processing availability in ICOS based on Virtual Machines and Containers. An ICOS agent will also run on the cloud resources allocated to execute the whole CMT Cloud system, to ensure the management of its microservices according to the requirements of the Use Case.

4.2.2 Service Data flow

For the Railway Structural Alert Monitoring system, ICOS will be managing the Edge and Cloud processing environments. Edge will be supported by the IoT Gateway with limited resources for computing and 4G connectivity through commercial mobile services to the Cloud computing environment. The cloud computing environment used by Worldsensing is provided by Google Cloud Platform. Both the Edge device and the Cloud environment should have the ICOS agent deployed to be able to onboard such elements to the continuum.

The onboarding of both compute services will allow the orchestration of services through ICOS Meta OS according to specific requirements for the Monitoring, Safety and Maintenance applications available in the CMT Cloud solution.

Out of the scope of the ICOS managed environment, data from the IoT sensors and nodes will be aggregated at the IoT gateway through a LoRaWAN radio communication. The data collected from the IoT sensors (tiltmeters) is related to geometry parameters of the rail track, while IoT nodes collect data from geotechnical sensors (extensometers and piezometers) to geological parameters.

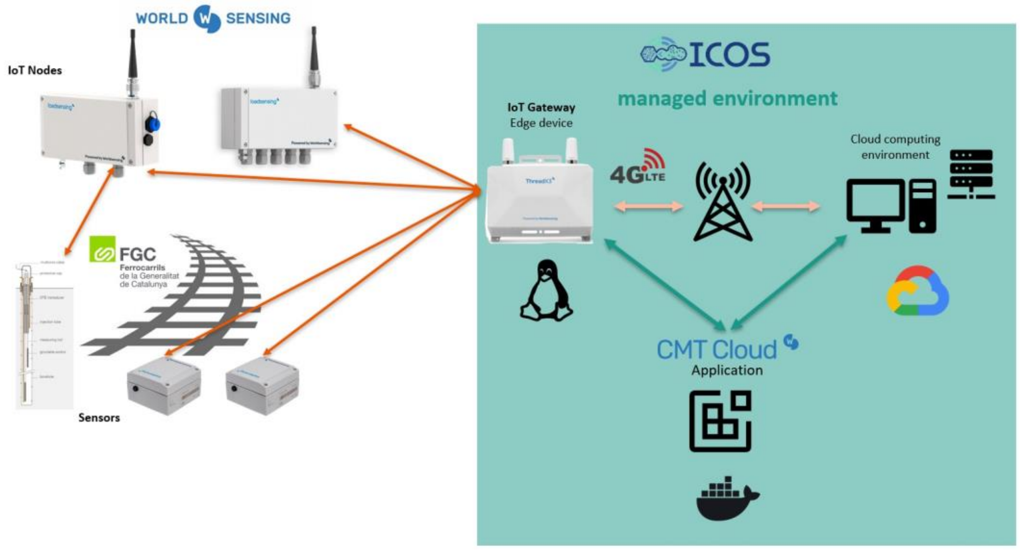


Figure 17 : ICOS Use Case 2 testbed.

4.2.3 Applications executed with ICOS support and requirements (challenges) for ICOS:

The following applications were identified in the deliverable D2.1[1] as relevant to the use case

1) **Real-time Monitoring:** the application will support safe operations by deploying a digital and wireless monitoring system that will collect and deliver real-time information regarding the quality parameters to monitor critical infrastructure status to support the decision makers and to timely detect possible anomalies or physical threats regarding the railway track.
2) **Critical event detection for Safety**: The alarm detection module is connected to the deployed devices, and it allows the detection and acquisition of possible alarms. The detection of alarms and response actions can be required to be processed at the edge to ensure safe operations even if connectivity with upper layers is not fully available. Such response to events detected might also include the request for additional information to the physical devices to collect additional contextual data about the possible incidents and thus to better design or select a response plan.
3) **Prediction for maintenance planning**: To optimize the decision-making process and exploit all the available resources, the maintenance application will also be onboarded within the ICOS architecture. The objective of the application is to identify the trend and predict the moment when the condition where quality parameters would not be met, and therefore plan maintenance activities to mitigate such risk. The proposed application will request available resources at the edge and cloud level based on connectivity and data transfer requirements and will run appropriately.

As for IT1 validation, Use Case 2 is expected to test the ICOS ecosystem set up process (described in section 7 of this document) by 03.2024. After that, the ICOS validation will concern communication (data synchronization when connectivity is recovered) and critical event detection for safety that are expected to be validated in IT2.

Table 7 Use Case 2 requirements for ICOS.

Priorit y	Application name	Problem	Requirement for ICOS	Expected Validation date
1	**Real time Monitoring**	Data integrity and synchronisation if there are connectivity problems between Edge-Cloud (Use Case is located in remote, mountain area)	ICOS should ensure data synchronization when connectivity is recovered.	IT2
2	**Critical event detection for safety**	Operate regardless of connectivity (taking local decisions)	When connectivity is not available, ICOS should make sure that edge devices process data and execute rules. Critical applications should operate regardless of connectivity availability.	IT2
3	**Prediction for maintenance planning**	Identify the trend and predict the moment when quality parameters would not be met	ICOS should make decisions when data transfer should be done from Edge to Cloud. Relevant monitoring parameters should be calculated at the edge using raw data collected by IoT devices.	IT2 (optional)

4.3 ICOS Requirements Elicitation

Table 8 Use Case 2 ICOS Requirements Elicitation [1]

ID		Requirement Name and Description	SUC related	SUC Description	Expected time
1	CM_FR_01	Smart resources first allocation and migration: ICOS MUST be able to find a near-optimal match (considering different metrics, such as response time, energy footprint, monetary cost) in terms of nodes to run one business application taking into account nodes performance, reliability and availability	Not assigned		
2	CM_FR_02	Workload Offloading: The ICOS MUST be able to distribute the workload of the application components offloading part of their computation onto other nodes of the infrastructure, and coordinate the offloaded components	Not assigned		
3	CM_FR_10	Data Management: ICOS must be able to maintain the data sources topology as well as data source types (metadata) for proper application data assignment. This includes data source selection, data source-application binding, and data access	SUC_DM_1 SUC_DM_2	Access Data Store Data	ALPHA
4	DRT_FR_02	Transparent data access: ICOS must be able to provide location and format transparent data access methods through flexible high level data access application program interfaces (API)	Not assigned		
5	DRT_FR_04	Support for distributed/parallel execution: ICOS SHOULD provide the integration of data management with the execution runtime to support efficient scheduling and execution of the required tasks.	Not assigned		
6	DRT_FR_05	Failure recovery mechanism/management: ICOS MUST provide the capability to restart the failing transfers of the data in case of the failures (e.g., losing the connectivity)	Not assigned		
7	DRT_FR_06	Secure data exchange: ICOS SHOULD support data preserving communication techniques between modules (interfaces) for secure data exchange.	SUC_DM_4	Set Permissions to Move/Access/Process Data	Not defined
8	DRT_FR_07	Data Recompilation: Control Nodes must be able to recollect data in a scheduled or periodic way from the nodes it orchestrates	Not assigned		
9	SST_FR_03	Tenant Isolation: ICOS SHOULD provide mechanisms that allow for isolation of resources across multiple tenants	SUC_SC_2	Check Authorization	ALPHA/BETA
10	SST_FR_09	Anomaly detection: ICOS MUST provide a mechanism for the detection of anomalies (e.g., any kind of abnormal situations, including potential security threats, which is recorded in application, system or network logs) in the applications/services on the cloud/network/edge provider	SUC_AI_7	Detect and Classify Anomalies	BETA

ID		Requirement Name and Description	SUC related	SUC Description	Expected time
11	SST_FR_10	Anomaly mitigation and recovery: ICOS MUST be able categorize anomalies and recommend specific mitigation actions or recovery process	SUC_RT_10	Apply recovery actions	BETA

4.4 Short term timeline

Table 9 Use Case 2 progress summary.

		M10 06.2023	M11 07.2023	M12 08.2023	M13 09.2023	M14 10.2023	M15 11.2023	M16 12.2023	M17 01.2024	M18 02.2024	M19 03.2024
1	Equipment procurement and purchase										
2	Equipment components implementation in FGC railway										
3	Data Collection										
4	ICOS set up process: system installation on IoT device (gateway)										

5 UC3: Individual Use Case Plan: In-car Advanced Infotainment and Multimedia Management system (IAIMM)

5.1 Use Case Description

As outlined in deliverable D2.1 [1], in-car services are crucial for establishing a positive business case for the development of connected and autonomous vehicles. Mobility is changing, making vehicles an integral part of the customer digital world (or life): as vehicles become increasingly tech forward, the experience will expand beyond the screen to delight all the senses. The rise of autonomous and connected cars will also generate new demand for in-car infotainment and entertainment.

The IAIMM Use Case will offer innovative media content and services focused on tourism to enhance the user experience while travelling in a car and getting to know and explore new places.

This service will provide the user with an in-depth tailored experience about the place they are visiting, showing the tourist extra information and knowledge around that new area in an immersive way. The possibilities of this technology will be exploited not only for interaction between users inside the car but also for others remotely. The service will use real-time and dynamic information from the Car System to determine when the car will be in a specific location, considering factors such as traffic and weather. Lastly, the service will also be linked with car devices and sensors, allowing for events triggered by the car to impact the operational of the Service.

5.1.1 Problem definition

Considering the fact that the proposed multimedia service should be able to operate in mobility context using real time and dynamic information, it's important to avoid any delay in the provision of the expected content to the final user that should impact heavily in the perceived quality of the service and its consequent usability. Moreover, the service has to provide high-quality multimedia functionality even in low connectivity situations and support multi-user interaction through multiple sites ensuring data security and privacy minimizing the energy consumption.

5.1.2 Proposed solution

The ICOS solution, as described in deliverable D2.1 [1], will be indeed designed to provide the user with a mixed reality interaction service by optimizing the distribution of multimedia content (such as Videos, Interactives 3D models, Audio) and maintaining high levels of Quality of Service (QoS) and Quality of Experience (QoE). The solution also shall provide a secure multiuser communication and interaction infrastructure able to ensure privacy and security of shared data. This will be achieved through a multilevel resource and data management system that utilizes cloud, edge, and device resources to provide location-aware services. The service aims to provide high-quality multimedia functionality for planning and enjoying trips and visiting tourist sites (Points of Interest - PoI), even in low connectivity situations. The service architecture includes nomadic edge nodes for hosting rendering and pre-processing services that ensure high quality content with low latency. Cloud nodes are used for hosting complex analytics modules, an Extended Reality (XR) manager, and a media content repository for large datasets.

Additionally, the ICOS System will prepare in advance for when the service will be used, allowing for seamless and efficient operation. One of the key features is the Automatic Retrieve of 3D Models and Media Contents by Location (or Search). This feature allows for fast downloading of large data on-the-fly and on-demanding, making it easy to access and utilise. Additionally, the service also allows for the Visualization and Interaction of the 3D Models and Media Contents, with the capability for remote offloading at the Edge.

The following picture introduces the high-level architecture of the IAIMM service highlighting functionalities provided and software modules and where the components will be executed in a three layers deployment Cloud, Edge and End-User device.

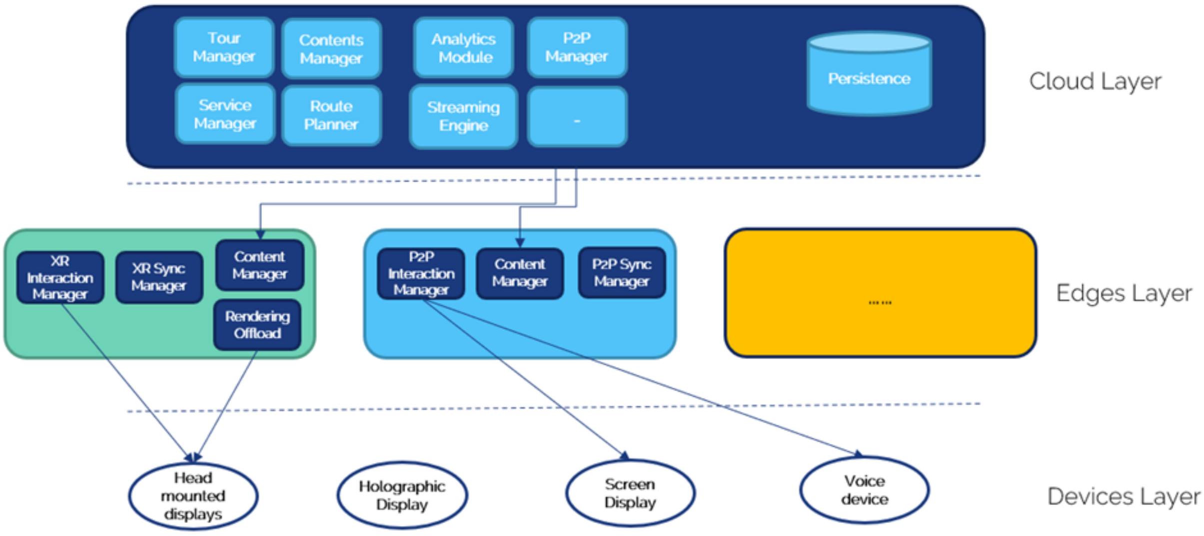


Figure 18 IAIMM High Level Architecture

5.2 ICOS testbed environment

5.2.1 Test site and IoT Devices

The main test site of the automotive Use Case will be in Turin close to the Politecnico of Turin where one node used for deploying the application is site. The Turin test site will involve one vehicle running in the proximity and at least one other user with its own mobile device acting as simple user that join an available service session from home.

A secondary test site will be in Barcelona involving only users joining the service from home using as IoT device the own smartphone.

In the IAIMM use case the main IoT devices are represented by the vehicles that ingest own position to the service. In order to enable the use of the IAIMM use case the vehicle setup showed in the Figure 19 below has been implemented.

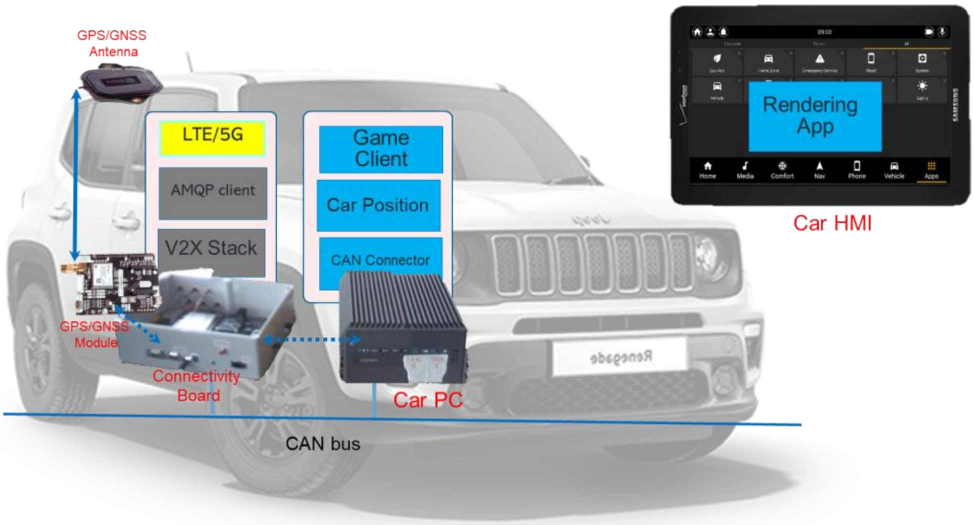


Figure 19 Vehicle Architecture

In the initial stage of the project the prototype vehicle set up to demonstrate the Automotive Use Case consists of a Jeep Renegade vehicle equipped with the following HW components needed to integrate and demonstrate the IAIMM functions:

- **Connectivity Board:** provided by Politecnico of Turin (APU2E4): provides the 5G connectivity to the vehicle, host the V2X stack able to manage standard messages between vehicle and infrastructure and an AMPQ module for exchange messages with the correspondent server broker; the connectivity board is connected to the vehicle can bus and is able to read and write can signals managed inside v2X messages.
- **Precise Positioning:** the module that provides vehicle position and vehicle dynamic data is constituted by an Ardusimple GNSS device (GPS/GNSS Module) and the related antenna (GPS/GNSS Antenna) placed on the vehicle roof.
- **Car HMI**: the vehicle HMI is provided using a Lenovo Tablet that emulates the vehicle radio for both visualizing the services output onboard and managing the interaction with the vehicle occupants.
- **Onboard Computational node:** a CAR - PC (NUC) is used for hosting any customized software components needed onboard; in particular, for the first stage of the project, it will host the GameClient component that manages the onboard part of the IAIMM application and the car position component that uses the information provided by the precise positioning module for feeding the GameClient with the vehicle latitude and longitude coordinated needed for the IAIMM App;

The vehicle has been modified according to the electric schema shown in Figure 20 in order to host the equipment just described as highlight by the four grey boxes.

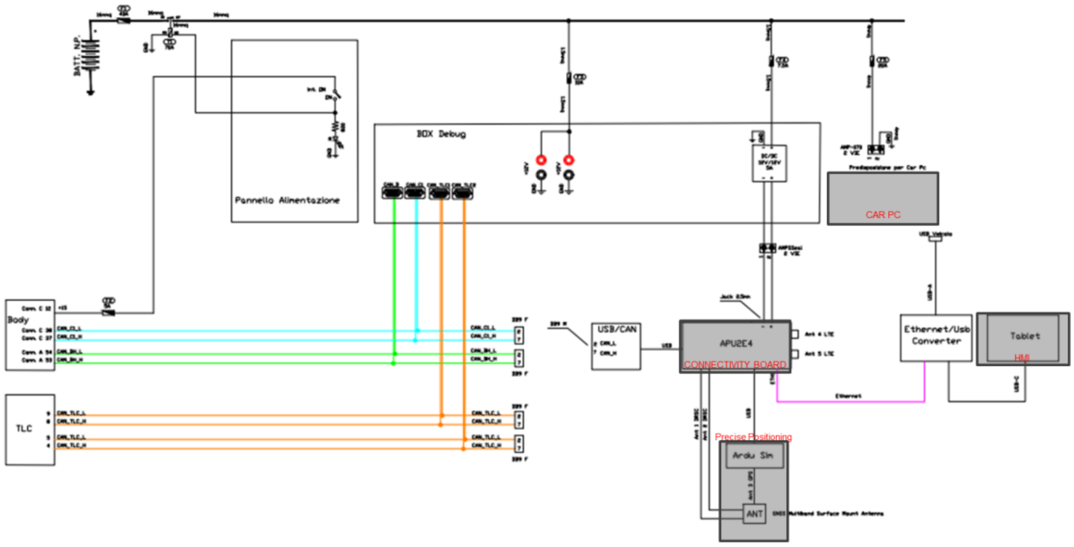


Figure 20 Vehicle Electric Schema

5.2.2 Service Data flow

The IAIMM service may be used from either the vehicle (POI based) or Home (session sharing). The dataflow is described as follow and shown in the Figure 21 below:

1. The vehicle checks and sends the required positioning data to the Lobby Manager.
2. The Lobby Manager gets the information from the car; based on car position it calculates the closest PoI and requests to the ICOS cloud database the related content available.
3. A new Lobby is created regarding that POI, and other users can join it.
4. If relevant content is available, the 3D Model rendering manager, the XR manager and/or the session sharing manager start to generate the infotainment content getting the required data from the Cloud database.
5. The generated content is shared with the users in the Lobby and session starts.
6. The users interact with the infotainment content, which is constantly updated according to their inputs.

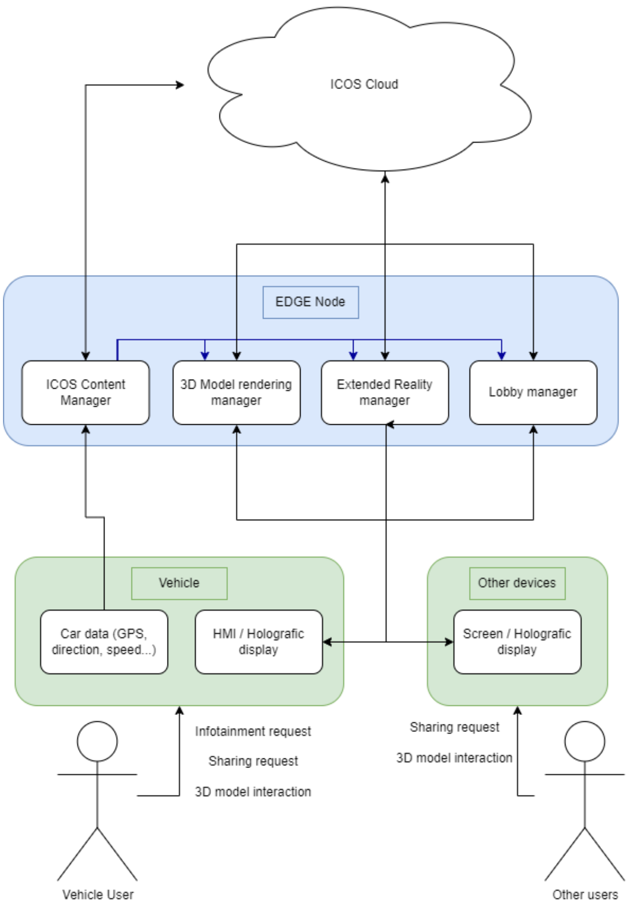


Figure 21 High Level Service Components

In ICOS first iteration, the ICOS Agents and Controller might be installed in the far and near edge (one controller per test site) where the vehicle will act as IoT feeding the service with the information of the vehicle location collected by the GPS/GNSS onboard device. Further releases of ICOS will include several improvements.

Figure 22 represents how the IAIMM service components will be deployed and orchestrated considering the three levels, far edge/ IoT, Near Edge and Cloud and highlighting the main interactions between the main components.

The vehicle and the end user devices, smartphone and tablet will feed the core components of the application with the input for the creation of a new lobby or the request to join an existing one.

At the Near Edge, the lobby manager is in charge of creating a new lobby providing a proper game server where the Multimedia content is properly managed.

At the Cloud side, the media content is managed in the proper library along with all the eventual Analytics requested for optimising the application.

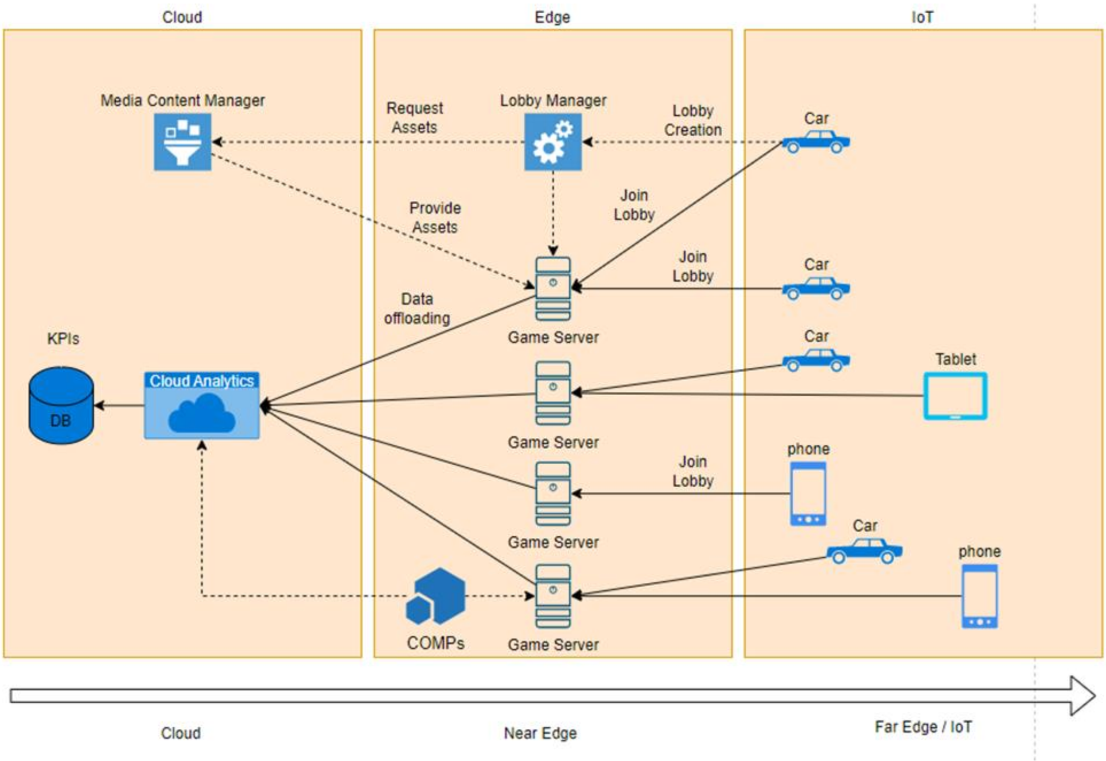


Figure 22 IAIMM components deployment

The IAIM Service sequence diagram in Figure 23 shows in more detail the interaction between the application components.

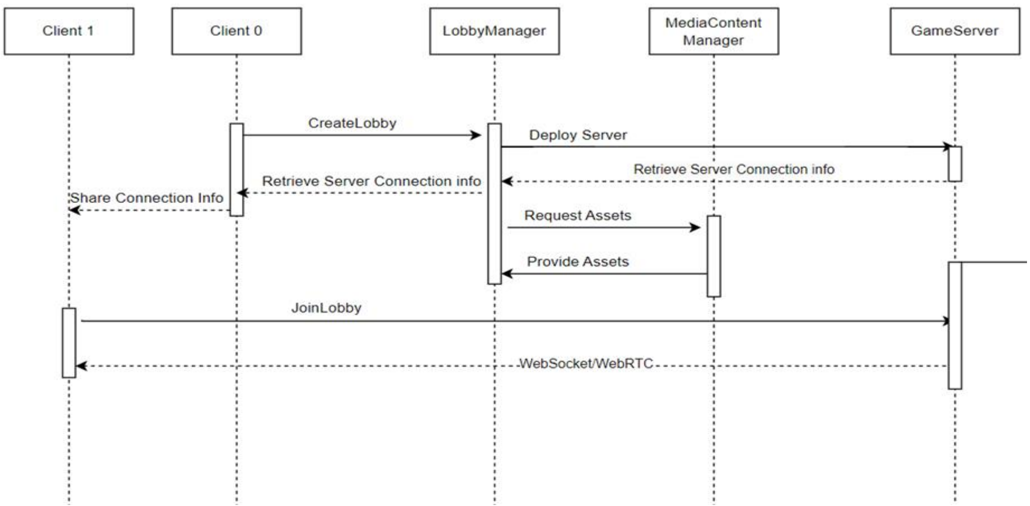


Figure 23 IAIMM Service Sequence Diagram

5.2.3 Applications executed with ICOS support and requirements (challenges) for ICOS:

1. Offer a Novel infotainment service (immersive multi-sensor experience providing a seamless integration between vehicle and digital ecosystem) providing Multi-users and Multi-sites Virtual Sharing Experience to interact in sync with high-definition media contents (3D models, immersive videos, pictures, etc.) with in-car passengers and other users far away.
2. Simplify complexity of new vehicles architecture enabling us to build quick simple services – Simplify our user experience.
3. Improve QoS & QoE: Service continuity in low connectivity situation, effectiveness.

The **benefits** expected by the introduction of ICOS will be:

1. Ensure seamless user experience by optimizing the distribution of multimedia content and maintaining high levels of quality of service (QoS) and quality of experience (QoE) also in case of low connectivity.
2. Provide secure multiuser communication and interaction infrastructure able to ensure privacy and security of shared data.
3. Ensure viable and sustainable real-time solutions in all settings including areas of poor connectivity.

Table 10 : Use Case 3 requirements for ICOS

Priority	Application name	Problem	Requirement for ICOS	Expected Validation date
1	Seamless experience	Increase latency / reduce delay maintaining high quality (QoS and QoE) and fluidity in the content provision	ICOS Edge processing capabilities should ensure a reduction of latency ensuring that it will be adequate for the consumption onboard of the multimedia content.	IT1 and IT2
2	Data security and privacy	Ensure high level of data security and data privacy is maintained at all data processing/collection and storage stages including data synchronization and integrity.	ICOS security and data management layer feature implementation should ensure the proper management of data shared by the application according with security and privacy policies	IT1 and IT2
3	Service availability	Ensure the availability of the service optimizing the use of available resource.	ICOS should be able to make the right decision allowing that the application could operate regardless of connectivity and poor resources availability.	IT2 and IT3

5.3 ICOS Requirements Elicitation

Table 11 Use Case 3 ICOS requirements elicitation [1].

	ID	Requirement Name and Description	SUC related	SUC Description	Expected time
1	CC_FR_01	Resources Catalogue: The ICOS MUST support a resource registry to record (publish) available resources to operate application workloads.	SUC_RT_4	Deploy Application	Alpha
2	CC_FR_02	Discovery: ICOS MUST support methods to discover registered infrastructures	SUC_CC_4 SUC_CC_6 SUC_RT_5	Join the Cloud Continuum Install and Configure ICOS Discovery Service Deploy in a different or multiple Controllers.	Beta
3	CC_FR_03	Topology Awareness: ICOS should be able to monitor and maintain the topology of the created Cloud Continuum.	SUC_CC_4	Visualize Cloud Continuum Topology	Beta
4	CC_FR_04	Controller Communication: ICOS should allow the communication of multiple ICOS controllers in order to exchange local views, policies and information.	SUC_RT_5 SUC_CC_1	Deploy in a different or multiple Controllers. Node On-Boarding	Beta
4	CM_FR_01	Smart resources first allocation and migration: ICOS MUST be able to find a near-optimal match (considering different metrics, such as response time, energy footprint, monetary cost) in terms of nodes to run one business application taking into account nodes performance, reliability and availability	Not assigned		
5	CM_FR_02	Workload Offloading: The ICOS MUST be able to distribute the workload of the application components offloading part of their computation onto other nodes of the infrastructure, and coordinate the offloaded components	Not assigned		
6	CM_FR_10	Data Management: ICOS must be able to maintain the data sources topology as well as data source types (metadata) for proper application data assignment. This includes data source selection, data source-application binding, and data access	SUC_DM_1 SUC_DM_2	Access Data Store Data	Alpha
7	CM_FR_18	MLOps frameworks: ICOS MUST allow the storage, retrieval and modification AI models available to be used by clients and AI-as-a-Service (AIaaS) providers from ICOS.	SUC_AI_1 SUC_AI_5	Manage Model Deploy Model	Alpha Beta

	ID	Requirement Name and Description	SUC related	SUC Description	Expected time
8	DRT_FR_02	Transparent data access: ICOS must be able to provide location and format transparent data access methods through flexible high level data access application program interfaces (API)	Not assigned		
9	DRT_FR_03	Minimization of data transfers: ICOS MUST avoid unnecessary data movements to increase performance, reduce network congestion, and favour privacy by exploiting near-data processing	SUC_DM_3	Execute Data Processing Functions	Beta

5.4 Short term timeline

Table 12 Use Case 3 progress summary.

Task		M10 06.2023	M11 07.2023	M12 08.2023	M13 09.2023	M14 10.2023	M15 11.2023	M16 12.2023	M17 01.2024	M18 02.2024	M19 03.2024
1	Equipment procurement and purchase										
2	Equipment components integration in the vehicle										
3	Data Collection										
4	ICOS set up process (system installation)										

6 UC4: Individual Use Case Plan: Energy Management and Decision Support system (EMDS)

6.1 Use Case Description

6.1.1 Problem definition

As outlined in deliverable D2.1 [1], the increase in economic and social activity following the emergence of the COVID-19 pandemic and the humanitarian crisis in Ukraine has generated a unique and challenging energy situation across Europe. The steep increase in the price of fossil fuels (oil and gas) has impacted the wholesale price of electricity generation, leading to a large increase in retail prices. The need to reduce fossil fuel consumption has increased demand for the production and distribution of renewable energy. The Republic of Ireland, together with many other European countries, is on a journey to reduce emissions by 51% by the end of this decade and reach net-zero emissions no later than 2050. For an island nation like Ireland, the intermittency of renewable generation, low levels of grid energy storage, and limited interconnection with other power grids are key factors that raise the importance of demand-side management. Furthermore, with government incentives in place for electricity microgeneration and electric vehicle purchases, the ability to manage these prosumer and grid-level renewable assets in a way that satisfies the needs of the consumer, the grid operator, and the energy retailer is critical to reaching the 2050 zero emission goal. Artificial intelligence and smart connected devices can play an important role in allowing customers to lower their energy costs by deciding when to buy, sell, use, or store energy, while at the same time helping the grid by providing power during peak demand and mitigating curtailment.

SSE Airtricity (SSEA) is the largest provider of wind energy in the Republic and Northern Ireland, with a large number of onshore and offshore wind farms generating more than 720 MW of renewable energy. SSEA is enabling the transition to smart homes through active participation in the smart metering program promoted by the national network operator, Electricity Supply Board Networks (ESBN). Time-of-use tariffs and Distribution System Operator (DSO) flexibility scheme payments will further drive uptake in smart meter services, especially for customers with the capacity to supply power and/or shift usage (i.e., customers with microgeneration, home energy storage, EVs, heat pumps, etc). In addition, SSEA supports the green energy transition with the installation of solar PV, home energy retrofit and EV chargers.

6.1.2 Proposed solution

The SSEA Use Case (UC4) aims to provide an Energy Management and Decision Support System (EMDS) using the ICOS continuum on data collected from five smart homes, including the use of Machine Learning models, Edge computing and Cloud capabilities.

Figure 24 UC4 EMDS solution

The energy management system will generate personalised and optimised energy suggestions tailored to customer needs based on AI models and sustainable solutions. The AI will provide recommendations on when energy will be used/stored, with hyperparameters adapting or updating through reinforcement and/or federated learning. The customers should be able to track improvements between actual costs vs optimized costs (or CO2 emissions) to build their trust in the ICOS decision-making.

6.2 ICOS testbed environment

The ICOS homes (location shown in Figure 25) used in UC4 are equipped with smart technologies including microgeneration, home energy storage, electric vehicles (EVs) and heat pumps.

Customers with SMART technologies like the ICOS participants (the prosumer of tomorrow) will play a fundamental role in the transition towards a net zero emission energy system. The ICOS AI 'brain' will shape the future energy usage of the prosumer to reduce generation curtailment and costs and flatten the demand curve by removing demand on the grid at peak time and boosting energy usage at night-time.

A potential deployment of ICOS to manage the overall infrastructure in the continuum and the specific energy management services, will improve demand flexibility (e.g., the capacity of demand-side loads to change their consumption patterns on a time scale) making the electric grid more reliable (avoiding grid loss) and increasing the usage of renewable energy sources.

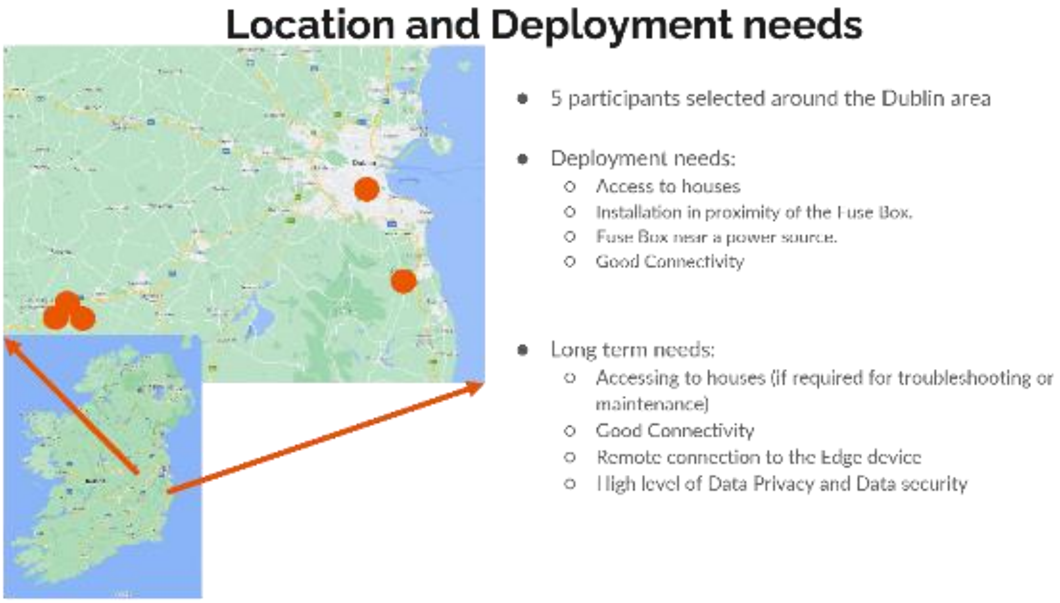


Figure 25 UC4 Smart Home location and deployment needs

6.2.1 IoT devices included in Use Case

The IoT sensors, installed in the house or linked to the EV chargers and solar panels, include:

- Inductive Power Monitoring Clamps,
- Smart meters,
- Occupancy sensors, and
- Thermostat controllers.

Consumption data is generally recorded by a smart meter and available on a day +1 basis, where the data is collected every 30 minutes by the DSO and shared with the energy provider the following day. To increase data granularity down to tens of seconds, an energy clamp can be connected to the electricity meter to share data in real time. The use of five sets of energy clamps is envisaged in each home, for the microgeneration, the EV charger, the electricity meter, the Heat Pump and the main grid. The setup of the IoT sensors can be seen in Figure 26. The IoT sensors will be built with open-source technologies freely available on the market. The IoT device is composed of a six-channel board (expandable 6 channel ESP32) and a microcontroller with Wi-Fi capabilities. The clamps will be connected to the board through jake connections. An ESP32 microcontroller, fully compatible with the board, will be connected to ensure conversion from analogical to digital format. A dedicated case will host the IoT device. Examples of data for UC4 are:

- Consumption,
- Power export,
- Power storage,
- EV charging, Market price data.

The deployment needs to include availability to access the houses, with the IoT sensors and Edge devices located close to the fuse box and a source of power.

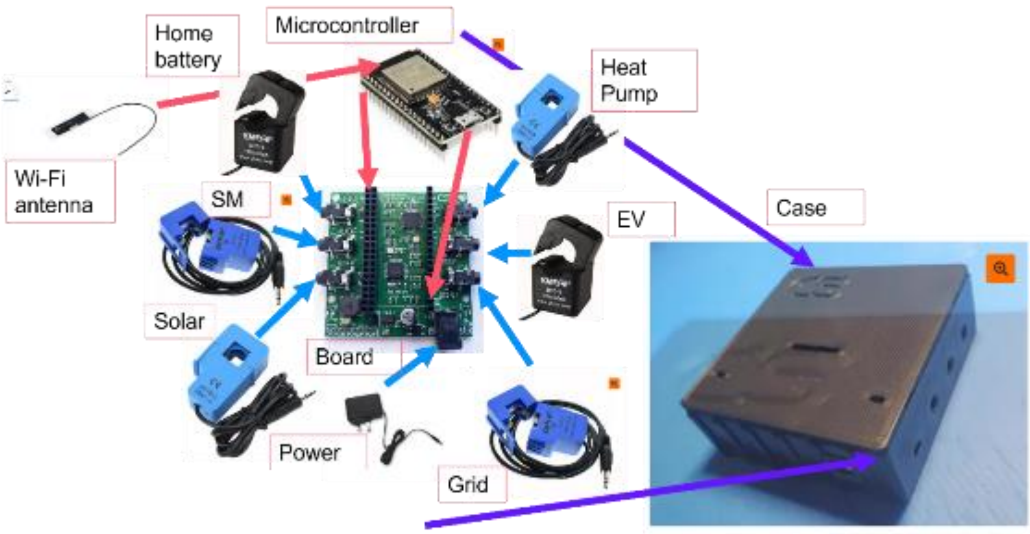


Figure 26 : UC4 IoT devices

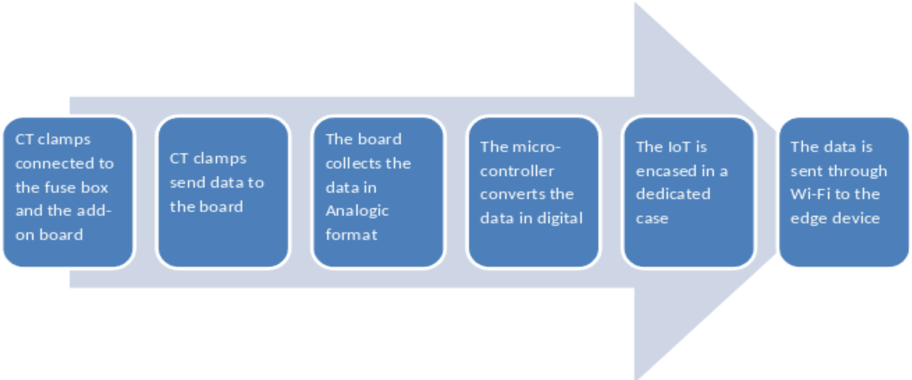


Figure 27 IoT configuration for UC4

6.2.2 Service Data Flow

The data collected will be sent by the IoT to an Edge device located in the house through fast and secure connectivity (Wi-Fi or 4/5G). Good connectivity levels will be required throughout the entire lifespan of the UC. See Figure 28 for IoT and Edge device communication setup.

In the first ICOS iteration, the data will be managed through an SSE-dedicated Cloud repository which can be used for scalability purposes for future releases of ICOS. In subsequent releases, the data management capabilities of the ICOS management layer will be explored and adopted. MQTT protocols will be set up to ensure seamless communication allowing the synchronization and data flow through the continuum (IoT to Edge to Cloud). Jetson devices (8 GB of RAM, Wi-Fi, GPU processing capabilities and fast network connectivity) will be used as Edge devices for data storage, transfer, or processing. An ICOS node will be installed into the Edge device using an ICOS Shell. As UC4 involves the use of personal data at a very granular level, data security, data privacy and data integrity are of fundamental importance. Restricted access with authentication procedures, the implementation of security measurements in the ICOS Security Layer along with ICOS Edge processing capabilities will ensure a high level of security. Figure 28 shows the ICOS architecture applied to UC4.

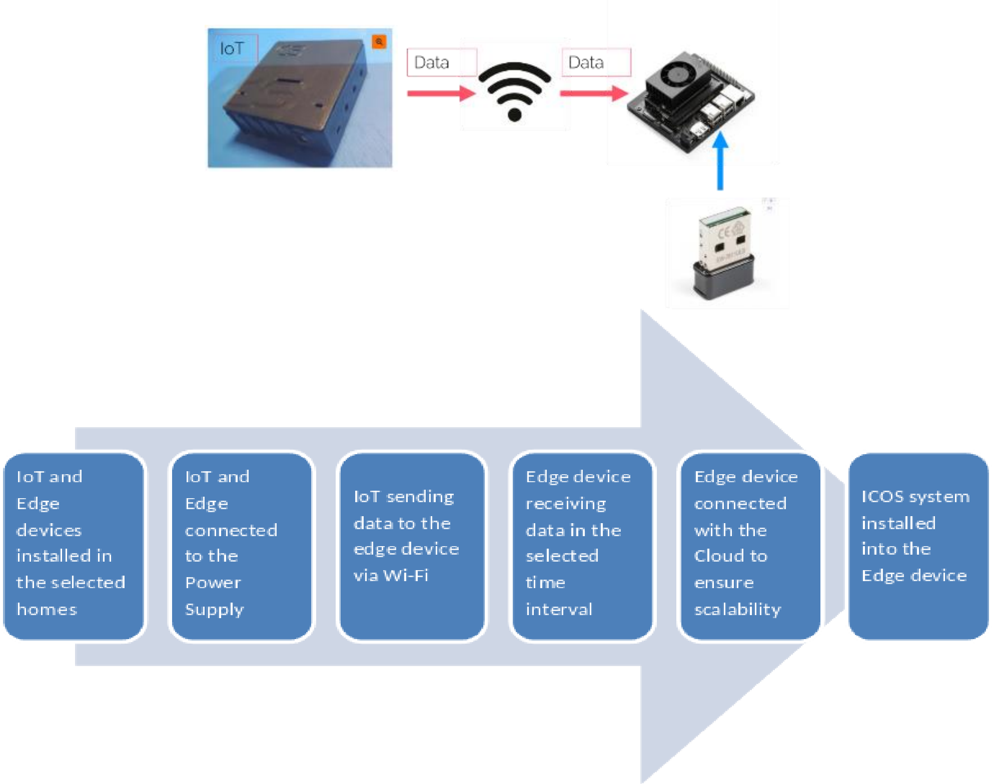


Figure 28 IoT and Edge device configuration

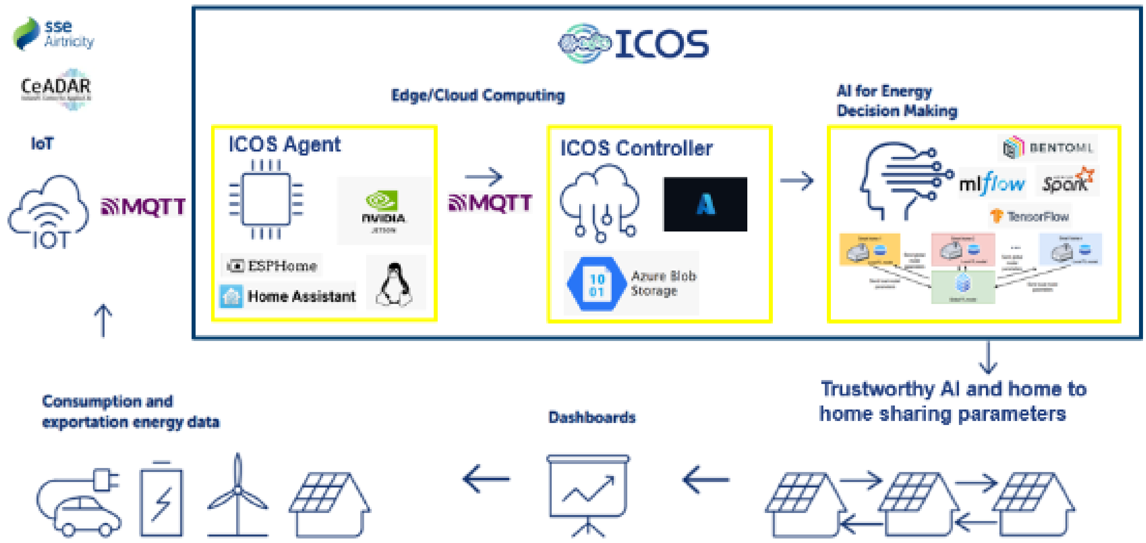


Figure 29: ICOS architecture configuration for UC4

In ICOS first iteration, the ICOS Agent and Controller might be installed in the edge device located in the house (one controller per house). Further releases of ICOS will include several improvements with one controller for the five houses at the Cloud level and AI models including Reinforcement and Federate Machine Learning techniques, with home-to-home model parameters sharing to avail of learnings in other houses.

6.2.3 Applications executed with ICOS support and requirements (challenges) for ICOS:

The **challenges** expected to be addressed in this pilot by ICOS are:

1. Provision of secure solutions, where data protection and data security must be ensured throughout all stages, including data collection, analysis, storage, and processing.
2. Provision of customised, innovative solutions for optimal energy usage, and increase of self-consumption to pave the path towards households' net zero emissions.
3. Ensure viable and sustainable real-time solutions in all settings including areas of poor connectivity.

The **benefits** expected by the introduction of ICOS will be:

1. Delivery of secure and efficient energy management systems based on advanced and reliable Machine Learning techniques for energy forecasting and home-to-home parameters sharing to avail of learnings obtained in other houses.
2. Ability to leverage Cloud and Edge capabilities for real-time solutions, with latency reduction, increased security and flexibility to tailor to customers' specific needs, increasing client satisfaction and retention.

Table 13 Use Case 4 requirements for ICOS

Priority	Application name	Problem	Requirement for ICOS	Expected Validation date
1	Data security and data management	Ensure a high level of data security and data privacy is maintained at all data processing/collection and storage stages including data synchronization and integrity.	ICOS security and data management layer feature implementation should ensure the detection and mitigation of malicious activity and optimal data management and storage.	IT1 and IT2
2	Latency reduction and real-time prediction	Real-time demand-supply predictions are vital to understand electricity usage and consumption to ensure reliable and interrupted services.	ICOS Edge processing capabilities should ensure a reduction of latency and an increase in security and operate in all connectivity areas (rural/poor connectivity).	IT2
3	Automated decisions for energy consumption.	Identify the trend and predict optimal usage of energy to flatten the demand curve by removing demand at peak time and boosting energy usage at nighttime	ICOS should provide automated decisions tailored to customer needs by implementing Trustworthy AI models including reinforcement learning and federated learning at the EDGE level with home-to-home model parameters sharing to avail of learnings in other houses.	IT2

6.3 ICOS Requirements Elicitation

Table 14 Use Case 4 ICOS requirements elicitation [1].

	ID	Requirement Name and Description	SUC related	SUC Description	Expected time
1	CC_FR_01	Resources Catalogue: ICOS MUST support a resource registry to record (publish) available resources to operate application workloads.	SUC_RT_4	Deploy Application	Alpha
2	CC_FR_02	Discovery: ICOS MUST support methods to discover registered infrastructures	SUC_CC_4 SUC_CC_6 SUC_RT_5	Join the Cloud Continuum Install and Configure ICOS Discovery Service Deploy in a different or multiple Controllers.	Beta
3	CC_FR_04	Controller Communication: ICOS should allow the communication of multiple ICOS controllers in order to exchange local views, policies and information.	SUC_RT_5 SUC_CC_1	Deploy in a different or multiple Controllers. Node On-Boarding	Beta
4	CM_FR_01	Smart resources first allocation and migration: ICOS MUST be able to find a near-optimal match (considering different metrics, such as response time, energy footprint, monetary cost) in terms of nodes to run one business application taking into account nodes performance, reliability and availability	Not assigned		
5	CM_FR_02	Workload Offloading: The ICOS MUST be able to distribute the workload of the application components offloading part of their computation onto other nodes of the infrastructure, and coordinate the offloaded components	Not assigned		
6	CM_FR_10	Data Management: ICOS must be able to maintain the data sources topology as well as data source types (metadata) for proper application data assignment. This includes data source selection, data source-application binding, and data access	SUC_DM_1 SUC_DM_2	Access Data Store Data	Alpha
7	CM_FR_18	MLOps frameworks: ICOS MUST allow the storage, retrieval and modification AI models available to be used by clients and AI-as-a-Service (AIaaS) providers from ICOS.	SUC_AI_1 SUC_AI_5	Manage Model Deploy Model	Alpha Beta
8	DRT_FR_02	Transparent data access: ICOS must be able to provide location and format transparent data access methods through flexible high level data access application program interfaces (API)	Not assigned		

	ID	Requirement Name and Description	SUC related	SUC Description	Expected time
9	DRT_FR_03	Minimization of data transfers: ICOS MUST avoid unnecessary data movements to increase performance, reduce network congestion, and favour privacy by exploiting near-data processing	SUC_DM_3	Execute Data Processing Functions	Beta
10	DRT_FR_04	Support for distributed/parallel execution: ICOS SHOULD provide the integration of data management with the execution runtime to support efficient scheduling and execution of the required tasks.	Not assigned		
11	DRT_FR_05	Failure recovery mechanism/management: ICOS MUST provide the capability to restart the failing transfers of the data in case of the failures (e.g., losing the connectivity)	Not assigned		

6.4 Short term timeline

Table 15 Use Case 4 progress summary.

	Task	M10 06.2023	M11 07.2023	M12 08.2023	M13 09.2023	M14 10.2023	M15 11.2023	M16 12.2023	M17 01.2024	M18 02.2024	M19 03.2024
1	Equipment procurement and purchase										
2	Equipment components integration in the vehicle										
3	Data Collection										
4	ICOS set up process (system installation)										

7 Introduction to ICOS Validation Methodology

ICOS employs a dynamic and adaptable Use Case validation methodology that allows for continuous development, effective integration of external projects, and a strong focus on communication and collaboration. The approach is designed to address challenges, meet user needs, and deliver a robust and effective ICOS operating system.

Validation approach includes 9 Use Cases in total: 4 internal Use Cases (consortium partners) and 5 external Use Cases selected through 1st Open Call.

The validation methodology outlined in the ICOS Grant Agreement is described below.

The outcomes should be:

i) ICOS performance validation.
ii) demonstration of the benefits brought in by ICOS and
iii) the delivery of the final ICOS product.

ICOS proposes an incremental and iterative approach to both facilitate a fast reaction to any deviation, problem or issue that may drive additional work in the project, as well as to guarantee that development efforts and validation trials start as soon as a preliminary release is developed. ICOS proposes a two-iteration methodology, partially overlapping in time, monitored through a continuous partners' interaction and clear definition of target achievements, each running all methodology focus areas.

As a result of the continuous development strategy proposed by ICOS, different releases are envisioned, to accommodate early processes of testing, feedback, debugging and refinements. Thus, the first release, an Alpha version is delivered in M15, which would be the preliminary outcome of IT-1, including a limited set of core functionalities and components of ICOS, for this period the validation will be focused on setting up the ICOS ecosystem into the Use Cases environment. The deliverable D6.5 Report on validation results - Initial version expected for M18 (February 2024) will include detailed description of this process and initial results of ICOS set up in Use Cases.

Then, a Beta release is produced in M22 that will improve the Alpha version by considering the feedback coming from the validation trials (Use Cases in IT-1) along with the preliminary work done in IT-2 on implementation and integration tasks to include most of the expected functionalities and components in ICOS. This Beta version will be extended toward the ICOS Complete Release in M32, being the result of the continuous development done in IT-2. Finally, in M36 the ICOS Final Product is delivered.

The ICOS methodology is also tailored to properly accommodate the Open Calls process (FSTP), aimed at facilitating the integration of the selected projects. In short, ICOS FSTP will support 5 large coordinated projects starting in M18 till M28, including infrastructure and services providers in 5 additional sectors (different than those appointed in the ICOS Use Cases) that may contribute to all ICOS areas, particularly on the research and validation activities, as well as short individual projects, aimed at fuelling technology uptake by SMEs, that will be oriented to facilitate the deployment and testing of the ICOS solution to SMEs services or technology providers working within the 9 sectors covered by ICOS.

Certainly, the project should also consider that some challenges may arise when developing the proposed methodology, summarized at this stage as:

i) successful requirements collection from end-users and Use Cases (to overcome this challenge ICOS organized the workshops during Kick Off meeting and engaged technical partners in WP6 meetings).
ii) proper feedback from the validation activities (Use Cases and open call projects) must be properly gathered.

iii) lack of sufficient data collection, which may strongly impact on the proposed AI-strategies (to overcome this challenge, data processes will be set to continuously monitor what the actually collected data is), and.

iv) poor consortium interaction hindering the proposed iterative and continuous development strategy (to overcome this challenge ICOS coordinator has established a set of communication processes to monitor activities, progresses and partners interaction).

7.1 ICOS Ecosystem set up.

The ICOS set up process is the very first step that each Use Case will need to take to start using ICOS. It is considered as completed whenever ICOS is able to consider the device for interactions like reading data or deploying applications.

The process will be divided into two stages:

1) Preparation of infrastructure and devices

In this phase, cloud computing, edge computing, and IoT devices are integrated with the network that supports their interaction. Vertical solution operators who wish to adopt ICOS should be mindful of several key requirements to ensure the solution can deliver the expected functionalities:

- **Interoperability**: The computational infrastructure and devices must be capable of seamless integration. This necessitates standard protocols, a shared network infrastructure, and interfaces.
  - ICOS is engineered to allow its control plane to operate on any OS that officially supports Docker or Kubernetes technologies. However, CentOS and Ubuntu are the recommended operating systems.
  - The minimum hardware requirements for the computational nodes are 512MB of RAM, 2GB of free disk space, and support for CPU architectures such as aarch64, x86_64, and amd64.
  - ICOS manages itself using a Container Orchestration approach, requiring Docker Engine (version 18 or higher) or one of the Kubernetes distributions (k3s, k0s, k8s), along with Helm.
  - In IT-1, all computational nodes need to be visible under the same network and have a series of ports opened.
- **Security**: The integration of various systems and devices raises significant security concerns. In addition to the security layer provided by ICOS, additional measures should be implemented to protect data integrity and privacy at the hardware level.
- **Latency**: For edge computing and IoT devices, low latency is essential for real-time data processing and decision-making.

By adhering to these requirements, ICOS can deliver expected functionalities and benefits such as improved efficiency, flexibility, and scalability. While it is a complex task, careful planning and execution can yield significant advantages.

2) Installation and setup of ICOS

In this phase, the general process of installing ICOS onto the infrastructure is executed. This mainly consists of installing the ICOS suites and configuring them with the environment-specific parameters. The setup process is completed whenever ICOS is able to consider the device for interactions like reading data or deploying applications.

For the bare minimum of the ICOS installation, a core Kubernetes cluster is preferable. It should provide enough resources to run the ICOS controller and any application that will be deployed through ICOS. In addition, a separate host with docker-compose installed is required to host the ICOS Lighthouse, as well as an external host that can run the keycloak of the Identity and Access Management (IAM). For the container networking within the Kubernetes cluster, Cilium CNI is recommended to be able to leverage additional functionalities that will be released for ICOS.

The following steps outline the ICOS installation:

1. Installation of IAM (keycloak) onto an externally hosted node.
2. Creation of users in IAM (keycloak) as well as a token for the lighthouse registration (onboarding) service of the core cluster.
3. Installation of the lighthouse onto one external node.
4. Installation of helm onto a device that shall administer the core cluster.
5. Configuration and update of helm repositories.
6. Creation of environment-specific controller_values.yml file for the controller helm chart.
7. Installation of the ICOS controller suite helm chart with the controller_values.yml file to the core cluster.
8. Download of the ICOS client suite to an administration machine.

Note that at this stage ICOS is up, but with "zero" computing capability (no agents connected yet). So next, at least one node with the ICOS agent should be executed (preferably a core Kubernetes cluster, but not mandatory) to join ICOS. In this process, it will connect to the lighthouse, who will provide the link to the controller, connect the controller, and now yes, we have an operative ICOS installation running.

8 Conclusions and Next steps

By November 2023 (M15), ICOS has successfully navigated the preparation phase of the Use Cases process. The project's success in maintaining an end-user focus is attributed to collaborative efforts initiated since the kick-off meeting. Active participation in various forums, including workshops and technical meetings, has shaped ICOS according to the needs outlined in the ICOS Functionalities Prioritization exercise.

The establishment of the Individual Use Case Plan document is a milestone, serving as a vital reference for the development of future validation plans for each Use Case. The ICOS testbeds are approaching completion, with the deployment of necessary equipment in the field expected to conclude by M18. This marks a crucial juncture for initiating the ICOS ecosystem setup process validation.

Looking ahead, the validation strategy for ICOS involves a phased approach to ensure the successful deployment and validation of the ICOS operating system. The subsequent steps will be pivotal in achieving the project's goals, with a clear roadmap for the systematic progression of ICOS development and validation efforts.

The key next steps are listed below:

- Execution of Alpha Release Validation (M15 - M22):
  - Focus on the ICOS ecosystem setup process definition under WP5.
  - 4 Use Cases partners will complete the IoT devices deployment and review ICOS requirements listed in ICOS set up process step 1.
  - Once the ICOS installation toolkit is ready, the ICOS ecosystem will be installed in the internal Use Cases testbeds.
  - D6.5 Report on validation results (M18) will include a description of the set-up process results and will establish validation KPIs per Use Case for further ICOS iterations.
- Beta Release and Feedback Integration (M22 - M32):
  - Feedback received from the initial set-up process will be considered.
  - 5 Open Calls Use Cases will be integrated into the ICOS environment.
  - Work in IT-2 on implementation and integration tasks will continue to include more functionalities and components in ICOS.
- ICOS Complete Release and Continuous Development (M32 - M36):
  - The ICOS Complete Release is the focus in this phase, representing a fully equipped version of ICOS.
  - Continuous development and refinement efforts in IT-2 will ensure that ICOS meets the needs of the Use Cases and achieves its objectives.
  - The ICOS project plans to develop long-term guidelines for new users who wish to adopt and implement ICOS.
  - This toolkit/guideline will facilitate the ICOS installation and use of ICOS for a broad range of users.

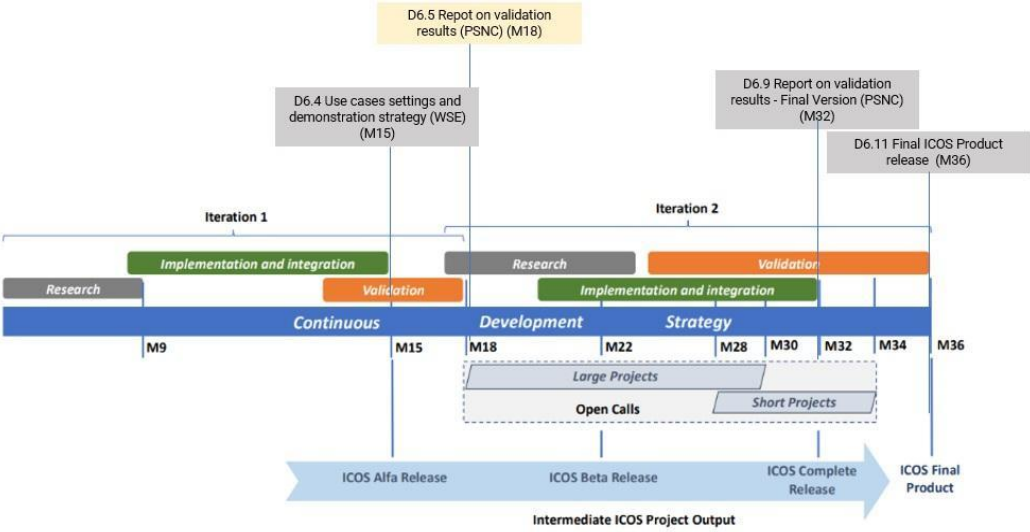


Figure 30: ICOS WP6 next steps

9 References

[1] ICOS. D2.1 - ICOS ecosystem: Technologies, requirements and state of the art. D'Andria, Francesco. 2023.

[2] ICOS. D2.2 ICOS Architecture Design (IT-1). Giammatteo, Gabriele, 2023