D7.3 Dissemination, communications, exploitation and communities engagement report – Intermediate version

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List of Acronyms

Abbreviation / acronym	Description
AI	Artificial Intelligence
CAGR	Compound Annual Growth Rate
Dx.y	Deliverable number y belonging to WP x
EC	European Commission
EUCEI	EUCloudEdgeIoT initiative
GUI	Graphical User Interface
ML	Machine Learning
OC	Open Call
UC	Use Case
WP	Work Package

Executive Summary

This document reports on the dissemination, communication, community building, standardisation and exploitation activities performed by ICOS during the first period of the project based on the strategies already outlined. Additionally, those strategies are measured and updated, when needed, to ensure the project has a significant impact in the continuum arena.

Starting with the dissemination and communication activities, considered as a key pillar of the project strategy to reach the target audience with the appropriate messages and channels, the consortium has been very active with regard to scientific publications and participation in events. In this way, tangible and intangible results have been communicated and properly advertised. The usage of social media channels and online means, such as the website, was considered also of paramount importance to keep the interest of any potential stakeholders with any periodic update on the project progress. Thus, this activity runs in parallel to the more scientific dissemination, avoiding the use of too technical jargon to make the content more attractive. Individual dissemination plans have been also updated, including the activities already performed.

Regarding the open source activities and contributions to standards, the project has focused on identifying those assets that can be of interest of different communities and the steps already performed to do so. Additionally, an updated plan for the last part of the project has been also provided to ensure results reach the appropriate groups and, at least, contacts for further contributions are already in place.

Another important pillar of the impact strategy is the liaison with external bodies and stakeholders in order to nurture results and foster the adoption. These activities will contribute to create a significant community of interest around ICOS and set the basis for a further exploitation of results. In this sense, the activities already performed tackle three different groups: i) related projects/initiatives with relation to any of the project topics, in this way the project ensures a cross-fertilization of its major findings, knowledge or technical development, and a major dissemination through the scientific community; ii) an advisory board composed of external experts in any of the areas addressed by the project, to present results to them and gather additional feedback about the quality or the novelty of results among other things; and iii) a community around ICOS, providing additional information about open calls, what will also serve to validate the approach and technical results of the project.

Last but not least, this document contains all the needed information to exploit project results, starting with the categorization of the key exploitable results, their positioning into the market and the options for their exploitation. This information is later reinforced with a micro-economic analysis of results, in general and using the project use cases as the basis for developing a short of handbook that can be used by decision makers to determine the worthiness of a further investment in adopting ICOS results. The information provided in this section is just a preliminary analysis, as it will be updated later with further inputs from the consortium, according to the project evolution, and by open call winners while also taking into account the feedback from the advisory board.

Finally, all activities have been measured with the thresholds established at the beginning of the project and the corresponding contingency plans have been provided to ensure that the project reach the appropriate impact levels.

1 Introduction

1.1 Purpose of the document

The objective of this document is to report on the dissemination, communication, standardisation, collaboration and exploitation activities performed during the first period of the project. It also updates the plans already drafted at the beginning of the project according to the impact measured through the already established KPIs.

1.2 Relation to other project work

All work performed relies on results developed within technical work packages, as well as on the development of the project use cases.

1.3 Structure of the document

This document is structured in 6 major chapters:

- **Chapter 2** lists the dissemination and communication activities already performed, as well as the actions planned for the last project period.
- **Chapter 3** focuses on the potential contributions to open source projects and standardisation bodies that have been, or can be, performed during the project lifespan.
- **Chapter 4** contains all information related to the already established external liaisons and the plans to continue with these collaborations after the end of the project or beyond.
- **Chapter 5** presents the already identified key exploitable results and the potential paths for exploiting them.
- **Chapter 6** includes the conclusions of the work already performed and the summary of next steps drafted in each of the previous sections.

1.4 Glossary adopted in this document

- **Key Exploitable Result.** Individual, or joint, asset developed within the project with potential enough to cover a specific market need.

2 Dissemination and Communication

This chapter describes the dissemination and communication activities planned and already carried out within the first half of the project. The ICOS project continues to strive to gain further visibility by communicating and disseminating the project news and results in the form of participation in events, conferences, and workshops, as well as scientific publications, social media posts and creating relationships with other projects covering related topics.

2.1 Events

In the table below we list the events that ICOS partners organized or co-organized or to which they participated, while externally representing the project. To avoid duplication, the table only lists events that occurred after March 2023 and therefore have not yet been reported in D7.2.

In addition to these events, there has been an internal workshop connected to the consortium meeting at TUBS premises in Braunschweig, Germany in March 2023[1].

Table 1 List of events[2]

Partner	M/Y	Event
ATOS, XLAB	05/23	EUCEI Concertation Event https://eucloudedgeiot.eu/concentration-and-consultation-meeting-on-computing-continuum-uniting-the-european-ict-community-for-a-digital-future/
ZSCALE	06/23	Devconf, Brno https://research.redhat.com/events/devconf-cz-2023-16-18-june/
CRF	06/23	SWForum workshop, Milan https://swforum.eu/events/swforumeu-way-forward-workshop-future-challenges-software-engineering
SIXSQ	02/23	Edge Service Summit, Berlin https://www.edge-service-summit.de
FBOX	07/23	BDVA workshop https://www.bdva.eu/bdva-workshop-forum-smesstartups-matchmaking
ZSCALE	09/23	Euromicro https://www.euromicro.org/registration/registration.php?event=DSD2023
FBOX	09/23	EUCEI https://eucloudedgeiot.eu/event/webinar-capitalising-cei-open-calls/

[1] This workshop is not included in the list of events as it was internal, thus, only consortium members participated in it.
[2] Events without link were private. This means that there is no public URL available.

Partner	M/Y	Event
FBOX	09/23	The Manufacturing and AI Landscape in Europe https://events.teams.microsoft.com/event/fbdf860f-b751-4948-97c3-b8fc94e0d5ee@46fe5ca5-866f-4e42-92e9-ed8786245545
FBOX	09/23	Cascade Funding Opportunities webinar organised by RCC https://www.rcc.int/pages/2/about-us
FBOX	09/23	Cascade Funding Opportunities webinar organised by NOI Techpark https://noi.bz.it/en
FBOX	09/23	EUCEI - Capitalising on Cloud-Edge-IoT https://eucloudedgeiot.eu/event/webinar-capitalising-cei-open-calls/
FBOX	09/23	IOT Tech EXPO Europe https://www.iottechexpo.com/europe/
FBOX	09/23	IRIS - Webinar Cascade Funding https://www.irisnavarra.com/es/edih
SSEA	09/23	National Energy Research and Policy Conference | SEAI https://www.seai.ie/events/research-conference/
SSEA	09/23	EUCEI Advancing towards the Cloud, Edge, and IoT Continuum: Insights and Impacts https://eucloudedgeiot.eu/event/advancing-towards-cei-continuum/
FBOX	10/23	ICOS Open Call first Q&A
BSC	10/23	Infraestructuras Científico-técnicas Singulares (ICTS) https://www.ciencia.gob.es/Organismos-y-Centros/ICTS.html
BSC	10/23	The InPEx pre-workshop https://numpex.irisa.fr/the-inpex-pre-workshop/
FBOX, SSEA, CeADAR	11/23	Giving Energy an Edge: Showcasing the Edge to Cloud Continuum in Energy https://eucloudedgeiot.eu/event/giving-energy-edge-showcase/
FBOX	11/23	AIOTI Innovative SME showcase webinar https://www.youtube.com/watch?v=lYxklD9V3UA
FBOX	11/23	ICOS Open Call second Q&A
PSNC	01/24	POLAGRA PREMIERY International Agricultural Fair https://polagra-premiery.pl/en

Partner	M/Y	Event
FBOX	01/24	Polish NCP https://www.kpk.gov.pl/wydarzenia/szeroki-horyzont-dzien-informacyjny-horyzont-europa-2024
Suite5	01/24	DL4IoT, co-hosted with HiPEAC https://www.hipeac.net/2024/munich/#/

2.2 Publications

To collect all publications of the project's consortium under a single umbrella, a publicly available publication repository has been created that can be found at:

https://zenodo.org/communities/icosproject/

The following publications works have already been accepted for publication:

Table 2 List of accepted Publications

Authors and Title	Conference/Workshop/Journal
M. Bensalem, F. Carpio and A. Jukan, "Towards Optimal Serverless Function Scaling in Edge Computing Network"	ICC 2023 - 2023 IEEE International Conference on Communications (ICC)
O. A. Karachalios, K. Kontovasilis, A. Zafeiropoulosand S. Papavassiliou, "Distributed Machine Learning and Native AI Enablers for End-to-End Resources Management in 6G"	MDPI Electronics Journal 2023
Giannopoulos E. Anastasios, Spantideas Sotirios, Nomikos Nikolaos, Kalafatelis S. Alexandrosand Trakadas Panagiotis, "Learning to Fulfill the User Demands in 5G-enabled Wireless Networks through Power Allocation: a Reinforcement Learning approach"	2023 19th International Conference on the Design of Reliable Communication Networks (DRCN)
Nomikos Nikolaos, Giannopoulos E. Anastasios, Trakadas Panagiotisand Karagiannidis K. George, "Uplink NOMA for UAV-Aided Maritime Internet-of-Things"	2023 19th International Conference on the Design of Reliable Communication Networks (DRCN)
Kalafatelis S. Alexandros, Trochoutsos Chris, Giannopoulos E. Anastasios, Angelopoulos Angelosand Trakadas Panagiotis, "A Stacking Ensemble Learning Model for Waste Prediction in Offset Printing"	ICIEAEU '23: Proceedings of the 2023 10th International Conference on Industrial Engineering and Applications
K. Skianis, A. Giannopoulos, P. Gkonisand P. Trakadas, "Data Aging Matters: Federated Learning-Based Consumption Prediction in Smart Homes via Age-Based Model Weighting"	MDPI Electronics Journal 2023

Authors and Title	Conference/Workshop/Journal
J. Alonso, “SWForum.eu The Way Forward: Workshop on Future Challenges in Software Engineering”	SWForum.eu Way Forward: Workshop on Future Challenges in Software Engineering (#WayForwardWorkshop)
Jan Antić, “Runtime security monitoring by an interplay between rule matching and deep learning-based anomaly detection on logs”	2023 19th International Conference on the Design of Reliable Communication Networks (DRCN)
P. Gkonis, A. Giannopoulos, P. Trakadas, X. Masipand F. D'Andria, “A Survey on IoT-Edge-Cloud Continuum Systems: Status, Challenges, Use Cases, and Open Issues”	MDPI Future Internet Journal 2023
J. Dizdarević, D. Blažević, M. Grunewald and A. Jukan, “An edge/cloud continuum with wearable kinetic energy harvesting IoT devices in remote areas"	ICC 2024 - 2024 IEEE International Conference on Communications (ICC)
F. Lordan, G. Puigdemont, P. Vergés, J. Conejero, J. Ejarque and R.M. Badia. “Hierarchical Management of Extreme-Scale Task-Based Applications”	EuroPar 2023
E. Rojas, C. Guimaraes, A. de la Oliva, C.J. Bernardos and R. Gazda, “Beyond Multi-Access Edge Computing: Essentials to Realize a Mobile, Constrained Edge”	IEEE Communications Magazine. Nov 2023. DOI: https://zenodo.org/records/10593074
D. Hortelano, I. de Miguel, R. Duran, J.C. Aguado, N. Merayo, L. Ruiz, A. Asensio, X. Masip-Bruin, P. Hernández, R. Lorenzo, E. Abril, “A comprehensive survey on reinforcement-learning-based computation offloading techniques in edge computing systems”	Journal of Network and Computer Applications, Elsevier, Vol. 216, July 2023
R. Seyghaly, J. Garcia, X. Masip-Bruin, M.M. Varnamkhasti, “Enhanced Smart Advertising through Federated Learning”	IWCMC 2023 – The 19th International Wireless Communications & Mobile Computing Conference, Marrakesh, June 2023
A. Hussain, F. Aguilo, E. Simo, E. Marin, X. Masip-Bruin, “An NIDS for Known and Zero-Day Anomalies”	2023 19th International Conference on the Design of Reliable Communication Networks (DRCN)
Baldoni, G., Teixeira, R., Guimaraes, C., Antunes, M., Gomes, D. and Corsaro, A., 2023. A Dataflow-Oriented Approach for Machine-Learning-Powered Internet of Things Applications. Electronics, 12(18), p.3940.	Electronic. 18 September 2023. DOI: https://zenodo.org/records/10026073
Baldoni, G., Quevedo, J., Guimaraes, C., de la Oliva, A. and Corsaro, A., 2023. Data-centric Service- Based Architecture for Edge-Native 6G Network. IEEE Communications Magazine.	IEEE Communications Magazine. 20 November 2023. DOI: https://zenodo.org/records/8335532

Authors and Title	Conference/Workshop/Journal
Baldoni, G. (2023) "A Data Flow Programming Framework for 6G-Enabled Internet of Things Applications". 9th IEEE World Forum on Internet of Things (IEEE WFIoT2023) (IEEE WFIoT2023)	9th IEEE World Forum on Internet of Things (IEEE WFioT2023) (IEEE WFIoT2023), Aveiro, Portugal, 12-27 October, 2023. Zenodo. DOI: 10.5281/zenodo.10025848
Corsaro, A. et all. (2023) "Zenoh-Unifying communication, storage, and computation from the cloud to the microcontroller". 26th EUROMICRO Conference on Digital System Design (DSD).	26th EUROMICRO Conference on Digital System Design (DSD). DOI: https://zenodo.org/records/10635550
G. Baldoni, R. Teixeira, C. Guimaraes, M. Antunes and D. Gomes, "A Dataflow-Oriented Approach for Machine-Learning-Powered Internet of Things Applications"	MDPI Electronics Journal 2023
G. Baldoni, J. Quevedo, C. Guimaraes, A. d. l. Oliva and A. Corsaro, "Data-centric Service-Based Architecture for Edge-Native 6G Network"	IEEE Communications Magazine
I. Esfandiyar, L. Lowinski. "Potential of implementing operational metasystems in agriculture using the ICOS project as an example"	24th Scientific Conference ROL-EKO "Organic farming, design, research, operation, safety and ergonomics of agricultural, forestry and food machinery"
I. Esfandiyar, L. Lowinski, "New challenges in the implementation of digital projects in agriculture"	XXIX Scientific Conference "Scientific, technical and organizational in agriculture"
M. Plociennik, S. Mueller, M. Blaszczak, "Development of the EDGE-CLOUD solutions across domain"	Ibergrid 2023

2.3 Communication channels and tools

This subsection elaborates upon the communication and dissemination channels used by the project reporting their current status, changes that have been made as well as plans for the future on consortium level.

2.3.1 Website

While keeping up the previous schedule of one blog post per month, the ICOS project continues to disseminate the project through the ICOS website. The website itself was improved regarding its visual presence, the consortium is however, currently in discussion on a potential complete redesign.

Table 3 Blog posts

month/year	Partner	Topic
03/2023	UPC	Data-driven application offloading in the continuum
04/2023	TUBS	Function-as-a-Service (FaaS) and Containerization in the Cloud-Edge Continuum: A Primer
05/2023	NKUA	Leveraging Federated Learning in the ICOS continuum
06/2023	BSC	Novel data and processing approaches for the development of hyper-distributed applications
07/2023	CeADAR	Unlocking the Potential of Machine Learning at the Edge: Challenges and Future Trends
08/2023	SixSQ	How Horizon Europe is Empowering the IoT-Edge-Cloud continuum with ICOS & Nuvla.io
09/2023	WSE	Transforming Railway Operations with ICOS Edge-Cloud continuum system
10/2023	XLAB	Novel Approaches to securing ICOS continuum
11/2023	FBOX	Celebrating Success: the first ICOS Open Call Marks Significant Interest in Innovation
12/2023	PSNC	A new approach to agriculture through ICOS

2.3.2 Social media

For the remainder of the project, a new strategy for the social media channels has been established, tied into the blog post strategy. Each blog post is now accompanied by a set or four media posts that link and promote it, published weekly and ensuring constant activity on all social media channels. In light of the developments on the platform Twitter/X and a significant portion of people interested in technical and computer science topics moving away, the project decided to establish an additional dissemination channel on the Mastodon platform. This account was created at the beginning of February 2024 and is now treated in the same way as LinkedIn and Twitter/X starting February 3rd 2024.

This new account is reachable from all ActivityPub platforms under the following addresses:

@icos_project@fosstodon.org

https://fosstodon.org/@icos_project

Table 4 Social media posts

Date	Topic
20.02.2023	First three blog posts
24.04.2023	blog posts four and five
27.05.2023	Blog post “Federated Learning in the ICOS continuum”
30.05.2023	Blog post about second F2F meeting
14.07.2023	Blog post “Novel Data processing approaches at the end”
24.08.2023	Blog post “How Horizon Europe is Empowering the IoT-Edge-Cloud continuum with ICOS”
05.09.2023	First Open Call #1
12.09.2023	First Open Call #2
18.09.2023	First Open Call #3
12.10.2023	First Open Call Q&A 1
13.11.2023	Blog post “AI in conjunction with Wazuh for security” #1
18.11.2023	Blog post “AI in conjunction with Wazuh for security” #2
24.11.2023	Blog post “AI in conjunction with Wazuh for security” #3
04.12.2023	First Open Call results
14.12.2023	Blog post “Cascade Funding” #1
18.12.2023	Blog post “Cascade Funding” #2
28.12.2023	Blog post “Cascade Funding” #3
15.01.2024	Blog post “Smart Agriculture” #4
18.01.2024	Blog post “Smart Agriculture” #5
23.01.2024	Blog post “Smart Agriculture” #6
03.01.2024	Blog post “Smart Agriculture” #7

2.3.3 EUCEI Newsletter

As non-regular means of communication, the EUCEI newsletter has been adopted to share significant milestones where possible. In addition to the contributions listed below, ICOS used the EUCEI channels to announce the first Open Call. The coordination of this channel takes place as part of the monthly EUCEI Taskforce 6 meetings mentioned in section 4.1.2.1.

Table 5 Publications in EUCEI newsletter

Month/Year	Topic
10/2023	Whitepaper 1

2.4 KPIs

The table below contains the status of all KPIs defined for the project, as well as the project month that they are expected to be fulfilled.

Table 6 Dissemination and communication KPIs

ID	Means of verification	Threshold	Timing	Status (M18)
KPI 1	Journal papers	10	M15, M22 and M32	6
KPI 2	Conference papers	15	M36	17
KPI 3	Technical / User workshops	5	M15, M18, M22, M28, M32	1
KPI 4	Project website / Product website	1 / 1	M2, M18	1
KPI 5	Technical / Business whitepapers	5	M15, M22, M32, M36	1
KPI 6	Technical / non-technical videos	4	M15, M22, M28, M32	0
KPI 7	Posters	1	M9	1
KPI 8	Leaflets	2	M9, M22	1
KPI 9	Articles in online magazines	10	M6, M15, M22, M32, M36	0
KPI 10	UCs showcase	4	M36	0
KPI 11	Demonstrators	4	M15, M22, M32, M36	1
KPI 12	Newsletters	6	1 every 6 months	2
KPI 13	Social media followers	400 in Twitter, 150 in LinkedIn	M36	50 Twitter/X, 234 LinkedIn

2.4.1 Contingency plans

For the individual KPIs, the following actions are planned:

- **KPI 1:** Intra-project collaborations are planned to achieve this KPI.
- **KPI 2:** KPI is expected to be reached in time, publication strategy therefore remains unchanged.
- **KPI 3:** One additional workshop has been planned (accepted) in conjunction with the EuroSys conference, and a second proposal has been accepted in the EuroPar conference.
- **KPI 4:** Website is established and well maintained; potential redesign is under discussion.
- **KPI 5:** The next white paper with the topic of ICOS use cases is planned to be released before M21 of the project.
- **KPI 6:** The first technical videos will follow after the first public demonstrations of the system's capabilities in M20.
- **KPI 7:** KPI fulfilled.
- **KPI 8:** A second leaflet will be planned for M22.
- **KPI 9:** We are currently investigating which magazines would have significant impact based on their target audiences, submissions will follow after this process is finished.
- **KPI 10:** UCs' showcases are planned for M36 as a singular event where all use case partners show the benefits that ICOS brings to them based on their workflows.
- **KPI 11:** Demonstrators will be released and properly advertised according to the technical schedule. Thus, the first one is planned for M22 based on ICOS Alpha release.
- **KPI 12:** Next newsletter will be released in M22.
- **KPI 13:** Since the two social media channels (LinkedIn, Twitter/X) have been treated in the same way but show significantly different growth rates, we assume that the relevance of Twitter/X in the field has changed significantly since the definition of this KPI. As further action, to reach an audience as broad as possible, the consortium created an account on the Mastodon platform.

2.5 Partner Activities and Updated plan

Below, the already executed and the planned activities per partner are detailed.

2.5.1 ATOS

As an industrial partner, as well as project coordinator, the work of ATOS has been focused on the overall dissemination of ICOS from a general perspective. In this sense, ATOS has published a short article in its internal newsletter, available for the whole company, in order to provide basic information to all product lines that may benefit from the project results.

Additionally, ATOS has represented the project in several meetings, such as the introductory workshop of the EUCEI community or the concertation event held in Brussels.

Finally, ATOS has produced dissemination material, such as posters or videos to be reused by the rest of the consortium or contributing to the online blog or social media channels.

Plans for the second period of the project are related to the continuation of these activities, as well as contributing to any other according to rising needs.

2.5.2 BULL

BULL is a hardware provider part of the Atos Group, thus, its dissemination activities rely in the collaboration for providing material to ATOS publications.

2.5.3 ENG

ENG participated to the dissemination activities in the project providing material for the blog and the social accounts accordingly to the internal plan.

2.5.4 ZSCALE

ZSCALE has published five papers during the first period of ICOS including journals, magazine and scientific publications by month 18. ZSCALE has also presented a talk in the DevConf.cz conference, at Brno, Czech Republic, held on 16-18 June, 2023, it was related to a data management demo showcasing how to extract information from a ESP32 sensor, and publish it on the cloud, using Eclipse Zenoh protocol.

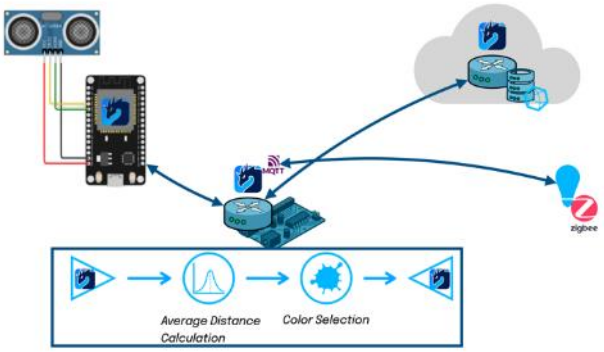

Figure 1: Cloud-to-Thing demo presented at DevConf.cz

This demo showed a Cloud-to-Thing application that collects data from a microcontroller-powered sensor, does some processing at the edge to do some local actuation (turn on a lightbulb) and stores some historical data in the cloud. This demo showed Zenoh and Zenoh-Flow interacting with 3rd party technologies such as MQTT, Zigbee and InfluxDB. The source code of the demo can be find here: https://github.com/gabrik/devconf-cz-demo.

2.5.5 UPC

The UPC team has contributed to disseminating the project, basically through scientific publications in journals and conferences. Moreover, pure academic activities, including supervision of PhD students and Master thesis as well as the transfer of the knowledge collected during the project life into the academic courses for the Computing Science degree (particularly in subjects related to “Future Internet”, “Engineering Projects” and “Smart Cities”). This knowledge is mainly focused on areas related to distributed systems orchestration and cybersecurity provisioning, where challenges linked to ta secure and efficient management of the continuum are analysed. Finally, “social” activities are also covered, from contributions in the blog to activities in social networks. At local level, there is also an initiative to transfer the project progress and outcomes to the local industry, including logistics, manufacturing and health sectors, to make them aware on the benefits an efficient management of resources may have in their local processes, including the edge as a concept usually not yet widely known by small and medium companies.

2.5.6 TUBS

As an academic partner, TUBS contributes to the project dissemination via publications in international peer reviewed journals, conferences, and workshops. By month 18, there have been two of such publications contributed by TUBS in the ICC Conference of 2023 and ICC 2024.

Furthermore, TUBS keeps on designing and supervising Bachelor and Mater theses in the continuum context. Besides this, TUBS contributes through its teaching activities, by M18, one of these activities is a lab for undergraduate students to explore the concepts of IoT, edge and cloud systems as well as

the used protocols in this context. In light of this lab, TUBS offered a workshop for the other consortium partners in March 2023 which received ample participation of almost all partners.

Like they did in the first year of the project, TUBS will continue to manage and publish the blog posts on the ICOS website and update the news and events on the website, as well as the social media channels. To this end, they created a round robin strategy that ensures regular activities on both accounts as well as the website by distributing the effort content contribution among all partners, allowing for weekly social media posts and monthly blog posts. The portfolio of social media accounts has been expanded by beginning of February 2024 through the addition of a Mastodon account through which the same content will be disseminated as through LinkedIn and Twitter/X.

TUBS is also responsible for the organization of training courses/workshops and summer camps. By M18, one such workshop (project-internal) has been established and another one (co-hosted with the EuroSys conference) is scheduled for April 2024.

2.5.7 NKUA

As an academic partner, NKUA is highly interested in project dissemination via the publication of conference and journal articles. In this context, up to now there are three (3) publications in international conferences and three (3) more in high quality journals. Since NKUA is mainly involved in the development and evaluation of machine learning models for energy consumption prediction and anomaly detection (Decentralised Computation Offloading with Energy Efficiency-aware - DECOFFEE model), as their development towards the second iteration of ICOS (IT-2) is progressing, the NKUA team has already identified potential conferences and journals to further disseminate the produced outcomes.

Moreover, NKUA is planning to organize one workshop by M24 with the participation of students from the departments of Ports Management and Shipping and Digital Industry Technologies in order to present the main goals and outcomes of the project.

2.5.8 BSC

As an academic partner, BSC is highly interested in project dissemination participating in conferences and publishing journal articles. By month 18 BSC has published one (1) article in an international conference and has presented other work related to ICOS in two (2) other international conferences. Besides this dissemination activities, BSC also has supported pure academic activities seeking to improve the knowledge related to the Cloud-Edge-IoT Continuum by participating in two (2) Summer Schools, designing and developing one (1) Bachelor Thesis and including part of the research in one (1) PhD thesis. Finally, “social” activities are also covered, from contributions in the blog.

As the developments towards the second iteration of the project progress, the BSC team has already identified other potential conferences and journals where to submit articles to further disseminate the outcomes of the project.

2.5.9 CeADAR

CeADAR Ireland, as a European Digital Innovation Hub, is contributing to the project dissemination via parallel HORIZON projects such as MANOLO, publications, and attendance to workshops. By month 18, the ICOS team from CeADAR has achieved the following:

- CeADAR participated in the Irish Energy Event in November 2023 with SSE and FundingBox to present ICOS and find potential applicants for the first open call.
- CeADAR has written and submitted a survey about AI in production and IoT to a peer-reviewed IEEE impact journal. This paper is pending for review.
- CeADAR has written a blog post for the ICOS website and has contributed to the ICOS whitepaper writing about the Intelligence layer and its components.

- CeADAR has shared project updates, relevant news and publications, and face-to-face meeting news on social media and will continue doing so as part of ICOS.

CeADAR is committed to continuing the dissemination of ICOS in Europe in initiatives such as EUCloudEdgeIoT, where CeADAR attended initial calls in 2023 and has recently joined the TF3 for the architecture and WG8 for artificial intelligence.

Three more journal papers are planned for the remainder of the project. One featuring online machine learning to predict CPU utilisation; one about machine learning in the context of ICOS for energy usage forecasting; and finally, one for intelligent matchmaking. CeADAR is planning dissemination in upcoming workshops, events, and AI training courses in 2024 and 2025.

Finally, CeADAR is working on a strategy to create a community surrounding the development of ICOS services and models. The ICOS AI repository, concerning T4.2 and D4.3 and planned for M36, will add relevant models trained for ICOS to be reused or re-purposed by upcoming use cases and users.

2.5.10 WSE

Presentation of ICOS during Mobile World Congress_EU projects session on 03.2023.

Sharing information about ICOS in WSE´s social media (example of the post with F2F meeting and Use Case deployment)

Preparation of the Blog post in Sept 2023 https://www.icos-project.eu/transforming-railway-operations

2.5.11 XLAB

The SME engagement of XLAB potentiates the development and implementation of research results built in the context of the application of state-of-the-art machine learning methods to the anomaly detection in application and infrastructure logs. To initiate the dissemination of our early results, we have contributed to social media and published a blog post on ICOS website on “Novel Approaches to securing ICOS continuum” (https://www.icos-project.eu/securing-icos-continuum).

XLAB’s research follows the work in ["Jan Antic, João Pita Costa, Ales Cernivec, Matija Cankar, Tomaz Martincic, Aljaz Potocnik, Gorka Benguria Elguezabal, Nelly Leligou, Ismael Torres Boigues: Runtime security monitoring by an interplay between rule matching and deep learning-based anomaly detection on logs. DRCN 2023: 1-5"] and ["Matija Cankar, Nenad Petrovic, João Pita Costa, Ales Cernivec, Jan Antic, Tomaz Martincic, Dejan Stepec: Security in DevSecOps: Applying Tools and Machine Learning to Verification and Monitoring Steps. ICPE (Companion) 2023: 201-205"] to further elaborate on the useful relation between a static rule-matching approach and a dynamic data driven approach based on novel machine-learning methods applied on text of extracted logs. XLAB will target one of the technical/user workshops organised by TUBS, preferably in M24 – August 2024 – with the participation in the possible ICOS workshop collocated to Euro-Par 2024 (https://2024.euro-par.org/). At that workshop, XLAB will present the paper and that should be published in a peer-reviewed journal as a conference proceedings paper. We will also target national and international industrial events to expose these research results following the paper presentation.

From the more technical content of this paper, we plan to derive a lighter and more succinct version aiming for the ICOS audience to be 25published as a blog post planned for September 2024. It will be used to generate social media content to expose XLAB’s innovation built within the ICOS consortium and benchmarked by the use cases in the project. The content of this paper should also be refocused to target XLAB’s audience, including security, automation and code modernisation markets.

2.5.12 FBA

This preliminary phase included the preparation of the open call launch. Key tasks included the following tasks:

- Setting up the Open Call landing page,
- Launching the online community,
- Preparing the Dissemination Toolkit, and preparing for a social media campaign,
- Participation at online webinars as well as other events to communicate about the upcoming Open Call.

The call was published on project ICOS' website[3] and on the Horizon Europe Participants Portal[4]. Full call details were published at the Open Call landing page[5]. A snapshot of the Open Call landing page can be found in the screenshot below.

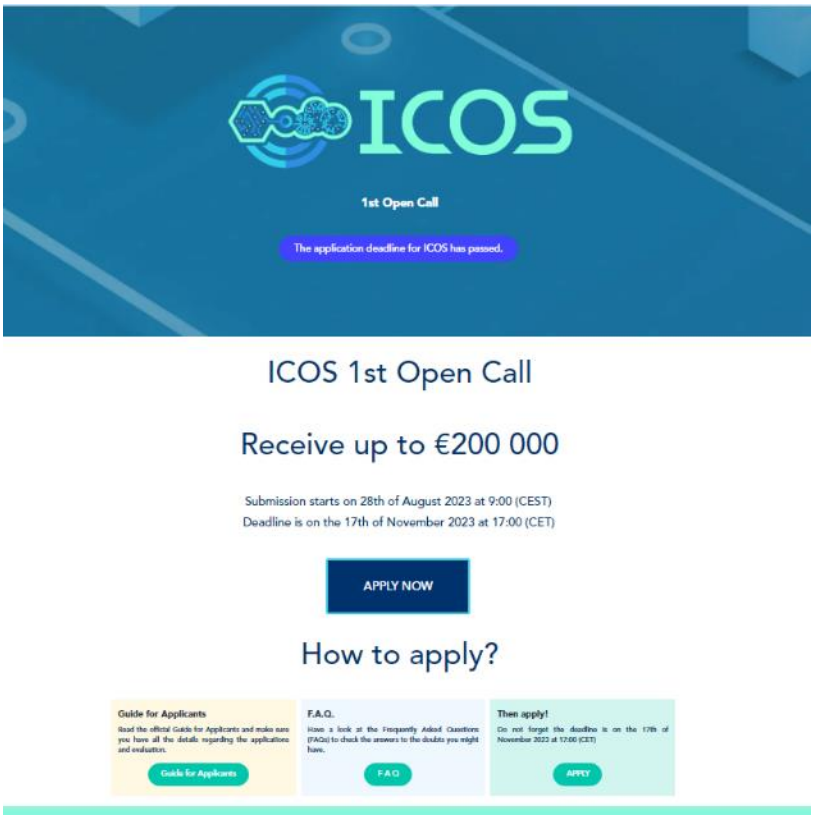

Figure 2: Snapshot of the ICOS Open Call landing page

The following channels were also used to promote the call:

Interactive Q&A sessions

FBA have organized interactive activities such as Infor Day sessions, where users received direct support to clarify their doubts and guide them through various stages of the open call application process to ensure they are fully informed. This provided direct support to the target group by answering questions, providing additional materials, or clarifying any details of the proposal.

[3] https://www.icos-project.eu/first-open-call
[4] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/competitive-calls-cs/3761?keywords=icos&closed=true&programmePart=&pageNumber=3
[5] https://icos.fundingbox.com/

Partners Media & IoT-Edge-Cloud ecosystems

The content strategy included a comprehensive Open Call Dissemination ToolKit[6] to facilitate the work of partners in the dissemination of the open call.

The Open Call was included in:

- The Cloud-Edge-IoT website[7]
- The moneybox section at the FundingBox website[8].

Newsletter

The Open Call was promoted in the FundingBox Funding Opportunities Newsletter, with more than 25.000 subscribers. It was also published in the EUCEI newsletter.

Figure 3: Promotion in the FundingBox Funding Opportunities Newsletter

FundingBox Social Media Channels

The Info Day session was uploaded to FundingBox´s YouTube Channel[9] with 38 views.

Several posts promoting the Info Day, online events, physical events, and the Open Call were published on LinkedIn[10], Spaces, and Twitter.

[6] https://sites.google.com/fundingbox.com/icos-first-open-call-toolkit/hom
[7] https://eucloudedgeiot.eu/open-calls/
[8] https://fundingbox.com/moneybox2/
[9] InfoDay session: https://www.youtube.com/watch?v=H4b8XfL6FNM.
[10] Example of promotional post in FundingBox LinkedIn: InfoDay, ICOS at the AIOTI Innovative SME Showcase, ICOS at the IoT Tech Expo Europe and ICOS 1st Open Call.

Workshops and events

- The Manufacturing and AI Landscape in Europe - 07/09/2023.
- Cascade Funding Opportunities webinar organised by The Regional Cooperation Council (RCC) - Bosnia - on the 18/09/2023.
- Cascade Funding Opportunities webinar organised by NOI Techpark - Italy - on the 20/09/2023.
- EUCEUI - Capitalising on Cloud-Edge-IoT - 20/09/2023.
- AIOTI Innovative SME showcase webinar on 06/11/2023.
- IRIS- Webinar Cascade Funding Presentation Session: Cascade Funding calls 19/09 | 2h | Online - 19/09/23.
- IOT Tech EXPO Europe - where the following flyer was distributed on 26-27/09/2023

Figure 4: Flyer distributed in the IOT Tech EXPO Europe

2.5.13 FBC

FBC has supported FBA in the establishment and launching of the ICOS online community for IoT stakeholders to serve as a resource for Open Call candidates during the application process and to promote professional and innovative cooperation between those with a passion for these technology fields, as well as an online Helpdesk to support applicants during the open call application phase.

The online community is composed of a variety of stakeholders, including developers and innovators who were contacted through the Open Calls, as well as other people and organizations from the public, private, and professional sectors who are interested in utilizing the results of ICOSs to enhance their processes, goods, and services. A wide variety of content has been published to dynamize the community. An example of how it looks on the community landing page can be found in the screenshot below.

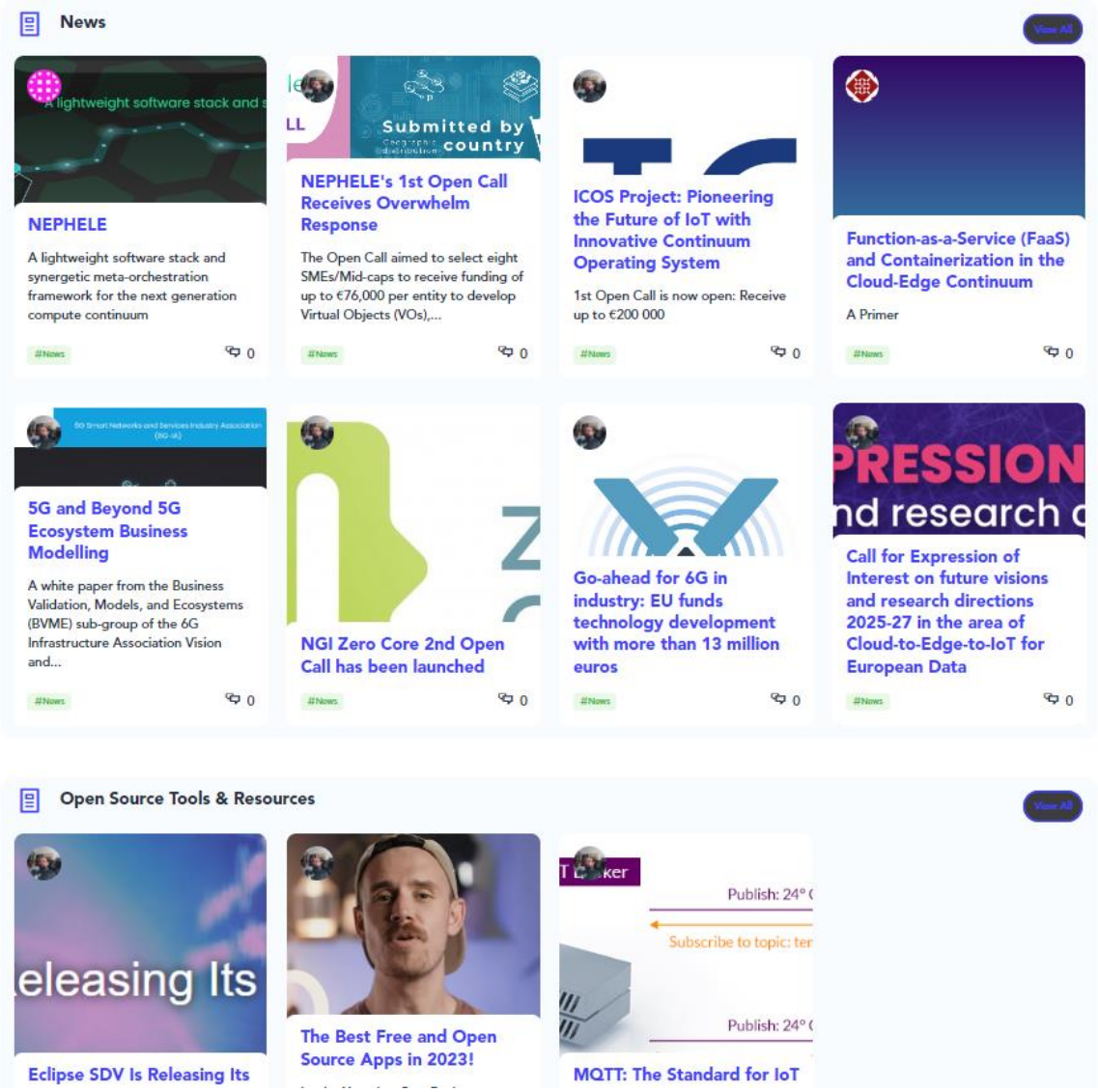

Figure 5: Example of how content is displayed on the community

2.5.14 PSNC

Being an R&D partner, the PSNC team is interested in research activities related to the development of the agriculture related use cases on top of the ICOS ecosystem including the deployment of efficient AI/ML models in the ICOS continuum. This in particular concerns one of the use case scenarios that focus on the agriculture field robots and related challenges.

During the project's second year of running, PSNC participated in multiple events, both online and face-to-face, where ICOS project was presented to the public. Most notable of these events are as follows:

- European Cloud-Edge-IoT initiatives funded by Horizon Europe, May 25 2023 (NCBR/on-line event),
- presentation during ITM Industry Europe, Poznań, May 30 – June 02 2023,

- National Field Days, Sielinko, June 03-05 2023 (presence in the booth, presentation, engagement of the community),
- The Perspektywy Women in Tech 2023 conference, Warsaw, June 14-15 2023 (presentation of wide spectrum of projects that PSNC contributes to),
- Agriculture session during EGI Conference, Poznań, June 19-23 2023,
- "Development of the EDGE-CLOUD solutions across domain" presentation during IberGrid 2023, Benasque, September 24-30 2023,
- Smart City Expo Poland, Łódź, October 23-24 (presence in the booth, engagement of the community).

Apart from event participation, PSNC has written a blog post for ICOS website.

In the third year, PSNC plans to keep the momentum of participating in the events, where ICOS project could reach its target audience. For the time of writing, the IEEE COINS 2024 in London on July 29-31 and the National Field Days in Sielinko on June 08-09 are considered to be, among others, the major events the PSNC team will participate in in 2024.

2.5.15 L-PIT

L-PIT has been actively involved in the project dissemination efforts, supplying content for the blog and social media accounts in line with the internal strategy. Similar to their contributions in the project's first year, L-PIT will persist in overseeing and publishing blog posts on the ICOS website and its own website, in addition to updating news, events, and managing the social media channels.

L-PIT contributes to the project dissemination via publications in international peer reviewed journals, conferences, and workshops. By month 18, there have been two such publications contributed by L-PIT in the World FIRA Conference of 2024 and ROL-EKO 2023. L-PIT has published two conference papers during the first period of ICOS as described and has plans to publish journal and conference papers regarding the current state of use case and ICOS. We are planning to participate in such scientific conferences as IEEE COINS 2024 or CGI 2024, when it comes to industrial events, we would like to attend FIRA USA 2024 and SLUSH 2024. On all these events, L-PIT will present recent results and initial deployments of the worked-out system. Moreover, we would like to present results of our experiments in top-ranked JCR journals. We plan to prepare research papers that will be sent to IEEE Transactions on Robotics (IF = 7,8) and IEEE Transactions on Industrial Electronics (IF = 7,7) or Scientific Reports (IF = 4,6).

L-PIT, as a research institute, offers academic students the chance to undertake their internship and thesis work focused on the development of an agricultural robot, which serves as a use case for the ICOS project. As of the M18, six students have completed their final projects, and two students have participated in internships within the scope of the ICOS project.

2.5.16 FGC

FGC has participated in the dissemination of the project in multiple events and meetings with technology partners and companies in the railway sector. For example, during the UITP Global Public Transport Summit 2023, which took place in Barcelona between 4 and 7 June 2023, we had the opportunity to share experiences, knowledge and discuss several projects, including ICOS, with companies from the railway sector.

In addition, during the week of the 6th of November 2023, the ISBeRG Railways Biannual Meeting was held in FGC premisses, in Barcelona. ISBeRG is an International Suburban Rail Benchmarking Consortium, led by the Imperial College of London, and consisting of 15 suburban rail operators, coming from Copenhagen, Cape Town, Hong Kong, Barcelona, London, Melbourne, Munich, New York, Oslo, San Francisco and Sao Paulo. This program monitors and evaluates the efficiency of the

operators using various Key Performance Indicators. One of the sessions was dedicated to innovation, where a member of FGC enrolled in the ICOS project, presents the current situation of the enterprise in terms of innovation, focusing on the main projects where FGC is participating. In this presentation, he explained the importance of projects such as ICOS to upgrade railway monitoring systems, improving the maintenance of the railway infrastructure and the safety of the service, through the use of IoT sensor Technology.

During the following project period until its completion, FGC will support the project's communication & dissemination activities, as has already been done, by participating in events, workshops and meetings presenting the results and opportunities of ICOS, communicating the projects' results though FGC social media accounts, mainly LinkedIn. ICOS project will be included also in the internal annual reports of FGC, and internal newsletters, documents received by more than 2.000 employees. In addition, FGC will be responsible for preparing the blog post for July 2024, which will deal with subjects related to the importance of railway infrastructure IoT monitoring for service and maintenance improvement.

2.5.17 CRF

During the first stage of the project, CRF has actively participated to the dissemination activities in the project preparing material for the first ICOS white paper, EUCloudEdgeIoT channels and the social accounts accordingly to the internal plan.

During the first stage of the project, CRF has achieved the following:

- Presentation of ICOS at SWForum workshop, Milan https://swforum.eu/events/swforumeu-way-forward-workshop-future-challenges-software-engineering
- Preparation of the blog post and the four Twitter/X related to the automotive use case operated by ICOS, post that will be published in March.
- Activation of a Bachelor Thesis on the Continuum for the automotive sector.

2.5.18 SSEA

SSE Airtricity has actively participated in the dissemination activities of the ICOS project through different channels. Articles have been published in the Internal intranet of SSE Airtricity and SSEA consumer website (Introducing ICOS (sseairtricity.com)) linking with the ICOS project website for people to explore more. SSE Airtricity has also submitted a poster contribution to the National Energy and Policy Conference (National Energy Research and Policy Conference | SEAI) hosted in Dublin in September 2023. Use Case 4 and ICOS have been presented at two events organised by UNLOCK CEI in collaboration with the European commission:

- Advancing towards the Cloud, Edge, and IoT Continuum: Insights and Impacts - EUCloudEdgeIOT – September 2023
- https://eucloudedgeiot.eu/event/giving-energy-edge-showcase - November 2023

In addition, SSE Airtricity will present UC4 in an online workshop Market Pathways for Cloud Edge IoT in the Energy Sector**,** February 2024.

A blog post in the ICOS website is scheduled for March 2024. Social media channels such as LinkedIn and Twitter will also be used to provide broader public updates regarding project progress and milestones.

2.5.19 Suite5

Suite5, as the Ethics Expert in the ICOS project, is ensuring that accepted principles of ethical, legal, privacy monitoring and regulatory compliance and professional conduct are followed within all project activities. In this context, Suite5 has participated in the DL4IoT event of the HiPEAC conference in

Munich on January 2024 presenting the ML/AI activities that have taken place so far in the ICOS project with the abstract "Exploiting DL/ML models for safe, effective, and ethical management of data-intensive Edge/Cloud spectrum applications". In parallel, the news and results of the project until this moment have been communicated through Suite5's social media accounts. In the next period of the project, Suite5 will continue to disseminate ICOS work through its social media channels and will keep on creating liaisons with partners of other EU projects regarding ethics management and AI topics.

2.5.20 SIXSQ

SixSq SA is a Swiss software company and an active member of the European Edge ecosystem. As such, SixSq contributes to the ICOS project dissemination through several channels: activity and reposts on our own social media and website, publication of blog and magazine articles, dissemination among other European projects, and active participation to the EUCEI.eu initiative, especially on the Orchestration topic.

By month 18 of the ICOS project, the SixSq team has achieved the following:

- Writing of a magazine article for the HiPEAC info magazine, issue 69 on the compute continuum, its benefits, and how it is being designed among research projects.
- Contribution to the ICOS blog with an article focusing on orchestration.
- Participation in business events in the field of IoT and edge computing, and promotion of the ICOS project.
- Promotion of the ICOS Open Call through social media, and network.
- Publication of 10 posts on LinkedIn to share project's outcomes and achievements.
- Participation in the EUCEI.eu work on the setting of European standards in the field of edge computing: led the ICOS contribution to WG5 Orchestration, and also contributed to other tracks such as data management, resource management, and monitoring.

For the next year and a half, SixSq plans to keep up with these dissemination and promotion activities. As already stated in the first issue of the Dissemination Plan, we also would like to highlight the value proposition of ICOS in the field of energy. After looking at the different projects that we are involved in which include a focus on energy, it was apparent that they have all identified challenges similar to those which are being targeted by the ICOS solutions. This year, we will start working on a whitepaper to better understand how the compute continuum, and value propositions such as ICOS, can tackle this industry's new challenges. This study will also potentially highlight synergies between ICOS, and other related projects.

2.5.21 NCSRD

NCSRD, as a research institute, focuses on disseminating results via scientific publications either in renowned conferences or journals. So far, NCSRD has published one (1) journal paper related to distributed ML and native AI Enablers for End-to-End Resource Management with direct application on Cloud-Edge-IoT Continuum scenarios. Additionally, NCSRD participates in the Technical Program Committee of the forthcoming 1st International Workshop on MetaOS for the Cloud-Edge-IoT Continuum (MECC 2024) and has participated in the proposal of a workshop, related to next steps in IoT-Edge-Cloud Continuum Evolution in the context of the 30th International European Conference on Parallel and Distributed Computing (Euro-Par). For the following period, NCSRD aims at further disseminating the results that will be obtained via the collaboration with the other ICOS partners, towards the development iterations of the integrated ICOS system and testbed.

3 Open-Source Standardization

This section contains the major contributions to open source projects or standardisation bodies, as well as the established relationships with open source communities in order to maximise the impact of ICOS results and foster their adoption and reusability.

3.1 Open-Source Standardization activities

3.1.1 Zenoh

During the first year of the project, there were meetings between the technical partners working on the Data Management component together with all the use case providers to understand what kind of programming languages they used in their applications (i.e., Java, JS, node, REST), what kind of deployment was used (i.e., local, cloud, robots), what type of long-term storage they envisioned and who can access the data.

The UC1 AgroBot expressed the need of data processing at the edge, as the robot and the platform are at the edge. Data processing can happen in both, then when connectivity is available work can be shared. Both the robot and the platform can lose connectivity and they need to continue to work. UC2 Railway monitoring needed long-term storage, less than 1MB per sample, a sample every 30 minutes, each message has a timestamp, metadata, and a payload. UC2 is based on LoRa, MQTT, REST, SCTP, and FTP, low overhead is essential as LoRa payload can be between 54 and 150 bytes, and communication is multicast-like (one publisher, multiple subscribers). UC4 monitoring required time-series data collection, energy consumption data could be accessed from everywhere but kept stored at the house. Each house acts as a single element, every house has its own AI model and trains it. Such requirements collected from the use cases contributed to the roadmap definition of the Eclipse Zenoh open-source project.

As part of the ICOS impact in standardization activities, the Eclipse Zenoh was recommended by ITU-T FG-AI4AD as communication protocol in autonomous and assisted driving domain.

The **ITU-T Focus Group on AI for autonomous and assisted driving (FG-AI4AD)** [1] was tasked in 2019 with the goal to survey existing protocols and recommend the one that could address the Intelligent Transport System (ITS). The focus group reviewed the most popular protocols available in the state-of-the-art, including HTTP, MQTT, and DDS. Each of these protocols had its own limitations when dealing with data communication. Not all of these are able to work well, or work at all, in the cloud-to-thing continuum.

It is extremely easy to define the data that is relevant, or in other terms, it is easy to express the solution of the problem as a query. Yet, devising how to serve this query is not an easy task – if doable at all – with existing technology. Established communication protocols such as MQTT and DDS were designed more than 20 years ago. Besides providing limited support for distributing data, they don't provide any support for distributed queries. On the other hand, traditional databases are good at answering queries, but the catch is that you need to know where the data is stored. In other terms, the user needs to know where the database that holds that data is located (location-centricity). The challenge posed by the IoT and edge computing use cases is that ideally you need a technology that can answer queries without the issuer of the query knowing where the data is actually located.

In September 2022, the ITU AI4AD focus group published a report [2] where it recommends Eclipse Zenoh for standardization. With Zenoh, solving the autonomous vehicle distributed query use case is as simple as submitting a query that indicates the desired data. A shown in figure X, Eclipse Zenoh's routing (1) determines how to route such a request where there is the data, (2) triggers the execution of the query and (3) consolidates the data back.

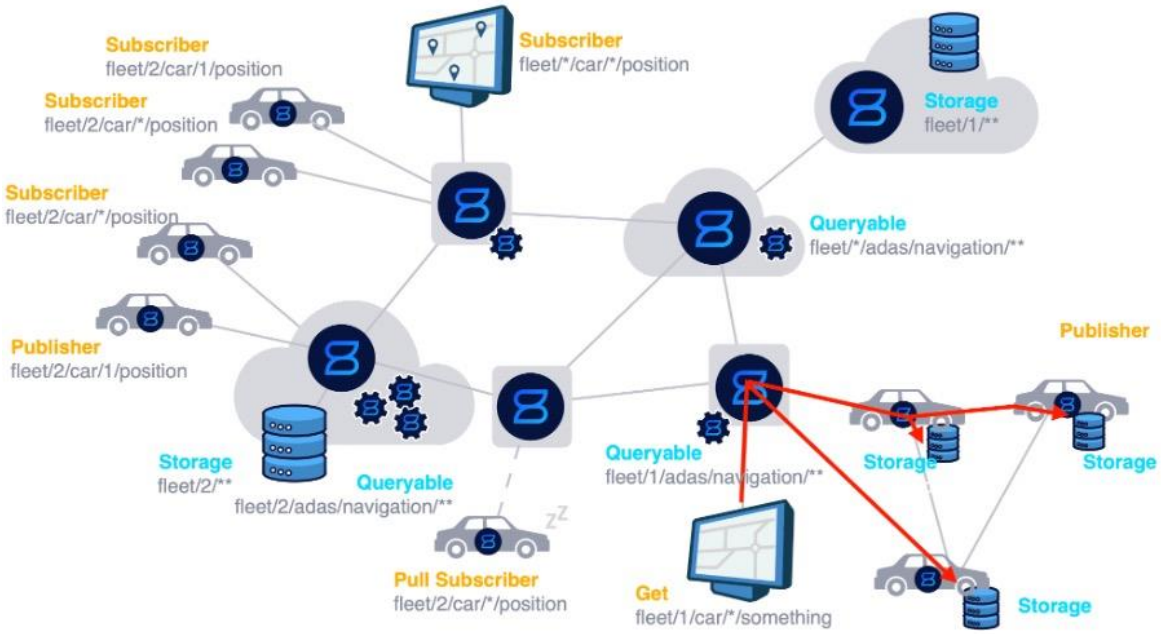

Figure 6: Eclipse Zenoh used for autonomous vehicle real-time query use case

Eclipse Zenoh solves two fundamental problems of edge computing and cloud-to-thing continuum. It provides a protocol that allows sharing data from the microcontroller to the data center and (2) it makes it possible to keep data storage decentralized and retrieve data without having to keep track of where it is stored. If that was not enough, Zenoh also provides built-in support for distributed computations, thus making it a single-stop-shop choice for building edge and cloud-to-thing systems.

3.1.1.1 Eclipse Zenoh Open-Source release

Eclipse Zenoh unifies data in motion, data in-use, data at rest and computations. It carefully blends traditional pub/sub with geo-distributed storages, queries and computations, while retaining a level of time and space efficiency that is well beyond any of the mainstream stacks.

Eclipse Zenoh its being use as part of the Data Management component, which support the data processing, data-in-motion and data-at-rest, as shown in the next Figure.

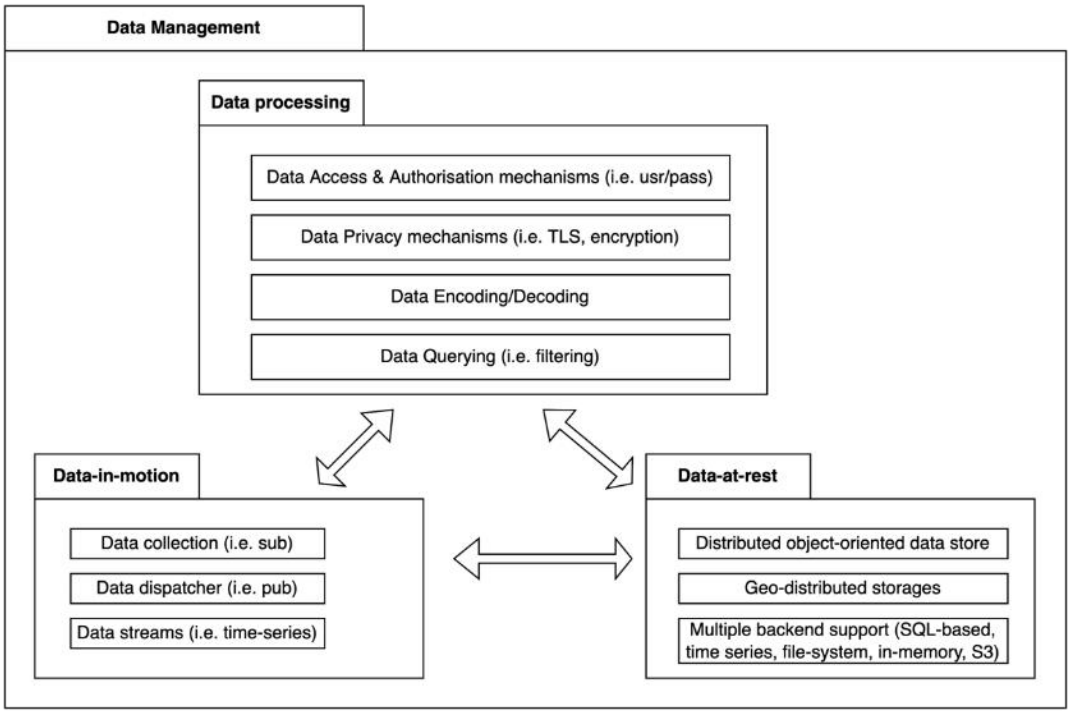

Figure 7: ICOS Data Management component

Since the beginning of ICOS project, 1st September 2022, up to now, end of January 2024, there has been five releases of the Eclipse Zenoh project [3], listed in the following table.

Table 7 Open-source releases of Eclipse Zenoh

Date	Version	New Features
15/01/2024	V0.10.1-rc	▸ New MatchingStatus feature ▸ Add support for errors in replies ▸ Stabilized hop-to-hop compression ▸ Add protocol extensions for user's attachment
27/09/2023	V0.10.0-rc	▸ Improved protocol ▸ Improved multicast support ▸ Low-latency transport ▸ Provide metrics in OpenMetrics format (for Prometheus)
06/06/2023	V0.7.2-rc	▸ New liveliness feature ▸ Multiple routers in peer-to-peer subsystem ▸ Allow whitelisting of supported protocols in config ▸ Introducing Key Expression Trees ▸ Introducing Key Formatters and keformat! macro
21/12/2022	V0.7.0-rc	▸ New TLS mutual authentication ▸ New protocol version v0.7.0 ▸ Improved query payload ▸ Improved connectivity event's status and notifications

Date	Version	New Features
29/09/2022	V0.6.0-beta.1	• New protocol version v0.6.0 ▸ Zenoh-net API was removed, all its features being now accessible in Zenoh API ▸ Configuration via Json5 (or YAML) file ▸ Added support for callback notifications and stream notifications for Queryable, Queries and Subscribers. ▸ New auto query configuration that selects the best consolidation strategy to apply in the current context. ▸ Improved scouting configuration

3.1.2 ClusterLink

As part of ICOS, IBM will extend the ClusterLink project. ClusterLink (Multi-Cluster Application Interconnect) is an open-source project (released under the Apache 2.0 license) designed and implemented by IBM [4].

This work focuses on the connectivity aspects of this new way of operating and consuming digital services. We define the requirements, analyse the challenges and present ClusterLink, our solution for interconnecting current and future multi-cloud applications [5].

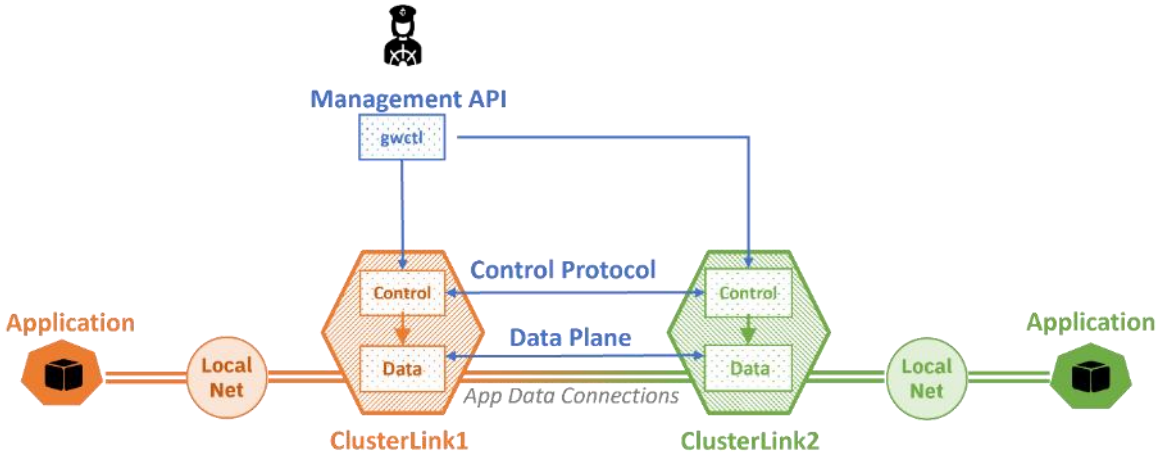

Figure 8: ClusterLink Design Model

The ClusterLink project was developed in accordance with the CNCF Code of Conduct [6].

IBM is exploring the possibility of promoting the project as part of the CNCF community.

3.2 Other Open-Source activities

Besides the plan of contributing some of the ICOS components as open-source (public git repositories), we have also identified a few upstream communities where parts of the ICOS contributions are targeted:

Table 8: Open-Source Contributions

Leading partner	Upstream project	Contributions
ATOS	Open Cluster Management	Open Cluster Management is a project for ICOS focused on multicluster and multicloud scenarios for Kubernetes apps (https://github.com/open-cluster-management-io). ATOS, in the context of ICOS is evolving the OCM project Open APIs.
TUBS	BenchFaaS/ Benchfaster	The BenchFaaS project and now its evolution and continuation "Benchfaster" are part of TUBS' research technology portfolio and can be used not just for publications related to the continuum but also for quick evaluation and benchmarking of new technologies. Learnings and technologies of the ICOS project will continue to influence the development of this framework. (https://github.com/tubskns/benchfaas)
TUBS	OpenFaaS functions	The repository of OpenFaas functions is used by TUBS to publish all serverless functions that they use as part of their publications. Thus, publications written in the context of ICOS will feed back new functions into this repository to be freely available to researchers across the world. (https://github.com/tubskns/openfaas-functions)
TUBS, UPC	NoTE Lab	NoTE Lab: Network of Things Engineering Lab is a lab for undergraduate students that teaches them about the IoT-edge-cloud continuum by leading them through the process of setting up distributed workflows. Technologies used in the ICOS project will be adopted by this lab if they bridge gaps that TUBS identifies. (https://github.com/tubskns/notelab-code)
BSC	COMPSs	COMPSs aims to provide a task-based programming model that eases the development of applications to run in parallel on all kind of distributed infrastructures: clusters, clouds, virtualized environments and the Digital Continuum. The framework, whose development is led by the Workflows and Distributed Computing group of the BSC, is widely used for the development of Scientific Workflows running on HPC systems (details can be found in the portal of the OpenSource initiative WorkflowHub – https://workflowhub.eu/). Learnings from the ICOS project will influence on future developments and new features will be considered for adoption. (https://github.com/bsc-wdc/compss)
BSC	dataClay	dataClay is an active object store and data management platform developed at BSC. During the ICOS project, several improvements and technical features required by the ICOS components are being designed and developed. Those contributions are synchronized back upstream; these features will become part of the main release of the dataClay distribution. (https://github.com/bsc-dom/dataclay)

Leading partner	Upstream project	Contributions
CeADAR	BentoML	BentoML is a framework for ML orchestration and model serving. As part of the ICOS project, new wrappers for libraries such as River and Statsmodels are being developed and will be pushed during 2024. (https://github.com/bentoml/BentoML).
ENG	OpenTelemetry	OpenTelemetry is a CNCF project that includes standards and tools to collect and process telemetry data in distributed systems. In ICOS, an ad-hoc OpenTelemetry distribution is being created tailored to the ICOS Meta OS needs. In the future, possibly new telemetry collectors and processors developed in ICOS can be proposed to be included in the standard OpenTelemetry distribution.

3.3 KPIs

Table 9 Open-Source standardization KPIs

ID	Means of verification	Threshold	Timing	Status (M18)
KPI 1	Number of used standards	4	M36	10
KPI 2	Number of OSS components	4	M36	15

3.3.1 Contingency plans

List all plans related to the ID of the KPIs mentioned before.

- **KPI 1:** ICOS is using well-known (mainly) de-facto standards within its developments, what ensure a high potential of industry uptake. Additionally, it also plans to contribute back to some of them with the project major findings. Thus, there is no risk contemplated at this stage.
- **KPI 2:** The project is not only reusing any open source tools but producing a plethora of open source results (15). The underlying strategy to foster their adoption relies on the previous activities for contributing to other communities.

4 External Liaisons and Community building activities

This section reports on the collaborations already established by the project with related projects/initiatives and the actions undertaken as well as the plans for the last project period. Additionally, it also updates the status of the Advisory Board and the activities related to the Community building, mainly related to Open Calls.

4.1 External Liaisons

In order to enrich project results, several liaisons have been established with other projects and/or initiatives addressing any of the topics proposed by ICOS. The following subsections report on the activities already performed and next steps.

4.1.1 Liaisons with related projects

This section contains the list of projects with who ICOS has established a collaboration and the results of it until this moment.

Table 10 Status of the liaison with aerOS project, activities performed and next steps

Type of project	European project
Acronym	aerOS
Call (link to the website)	DATA-01-05 (https://aeros.project/eu)
Short description	The adoption, innovation and growth of edge-to-cloud and edge computing has highlighted the need for a better infrastructure to support these technologies. The aerOS project aims to address this need by developing a common meta-operating system based on a collaborative IoT-edge-cloud architecture. This system will enable the flexible deployment of applications and innovations using technology such as AI, machine learning and big data analytics, while reaping the many benefits of these technologies.
Common points	Same Meta Operating System group of projects as ICOS.
Performed activities (M18)	Although most of the work has been performed through the EUCEI.eu initiative, ICOS has collaborated with all Meta-OS projects in the initial definition of a taxonomy for the continuum, as well as in the masterpieces needed for developing a reference architecture.
Planned activities (M36)	By the time this document is written, a joint workshop between all Meta-OS has been organized and will be held during the second period.

Table 11 Status of the liaison with FLUIDOS project, activities performed and next steps

Type of project	European project
Acronym	FLUIDOS
Call (link to the website)	DATA-01-05 (https://www.fluidos.eu/)
Short description	The FLUIDOS project aims to create a fluid, dynamic, scalable and trustworthy computing continuum. FLUIDOS aims to build on consolidated operating systems and orchestration solutions such as Kubernetes, on top of which it will provide a new, enriched layer that implements resource sharing through advertising/agreement procedures (in the horizontal dimension) and hierarchical aggregation of nodes inspired by inter-domain routing on the Internet (in the vertical dimension).
Common points	Same Meta Operating Systems group of projects as ICOS[11]. The ICOS's decentralized and distributed data management component, more in particular Eclipse Zenoh, can be used at the edge and fog computing, and in embedded devices as well. In FUIDOS it is used in a robotics context (Robotnik).
Performed activities (M18)	Robotnik (https://robotnik.eu), one of FLUIDOS's partners, is using the decentralized and distributed data management component that it is currently used in ICOS. More in particular, ZSCALE is doing supporting activities with issues related to the **32urop-bridge-ros2dds** (https://github.com/eclipse-zenoh/32urop-plugin-ros2dds) in a Kubernetes (K8s) setup.
Planned activities (M36)	Continue the collaborations and support for the common challenges in ICOS and FLUIDOS.

Table 12 Status of the liaison with NEPHELE project, activities performed and next steps

Type of project	European project
Acronym	NEPHELE
Call (link to the website)	DATA-01-05 (https://nephele-project.eu/)
Short description	The NEPHELE project aims to introduce two core innovations, namely: s) An IoT and edge computing software stack for leveraging virtualization of IoT devices at the edge part of the infrastructure and supporting openness and interoperability aspects in a device-independent way. Through this software stack, management of a wide range of IoT devices and platforms, while edge computing functionalities can be offered on demand to efficiently support IoT applications' operations; b) A synergetic meta-orchestration framework for managing the coordination between cloud and edge computing orchestration platforms, through high-level scheduling supervision and definition, based on the adoption of a "system of systems" approach.

[11] Under Horizon Europe's Cluster 4 Destination 3, call HORIZON-CL4-2021-DATA-01-05 (Future European platforms for the Edge: Meta Operating Systems (RIA)), the Commission selected the following group of projects: ICOS, NEMO, Fluidos, aerOS, NEPHELE and NebulOus, to design and implement the next generation of meta-operating systems to provide value in key industrial and societal applications.

Common points	Same Meta Operating Systems group of projects as ICOS.
Performed activities (M18)	Although most of the work has been performed through the EUCEI.eu initiative, ICOS has collaborated with all Meta-OS projects in the initial definition of a taxonomy for the continuum, as well as in the masterpieces needed for developing a reference architecture.
Planned activities (M36)	By the time this document is written, a joint workshop between all Meta-OS has been organized and will be held during the second period.

Table 13 Status of the liaison with NEMO project, activities performed and next steps

Type of project	European project
Acronym	NEMO
Call (link to the website)	DATA-01-05 (https://meta-os.eu/)
Short description	Developing a flexible, secure and adaptable meta-operating system for the continuum.
Common points	Same Meta Operating Systems group of projects as ICOS.
Performed activities (M18)	Although most of the work has been performed through the EUCEI.eu initiative, ICOS has collaborated with all Meta-OS projects in the initial definition of a taxonomy for the continuum, as well as in the masterpieces needed for developing a reference architecture.
Planned activities (M36)	By the time this document is written, a joint workshop between all Meta-OS has been organized and will be held during the second period.

Table 14 Status of the liaison with NebulOus project, activities performed and next steps

Type of project	European project
Acronym	NebulOus
Call (link to the website)	DATA-01-05 (https://nebulouscloud.eu/)
Short description	NebulOus[12] project aims to enable brokerage ecosystems that seamlessly exploit the compute continuum from fog to edge to cloud in a device independent manner and includes demonstrators in key industrial and societal applications.
Common points	Same Meta Operating Systems group of projects as ICOS.

[12] https://nebulouscloud.eu/

Performed activities (M18)	Although most of the work has been performed through the EUCEI.eu initiative, ICOS has collaborated with all Meta-OS projects in the initial definition of a taxonomy for the continuum, as well as in the masterpieces needed for developing a reference architecture.
Planned activities (M36)	By the time this document is written, a joint workshop between all Meta-OS has been organized and will be held during the second period.

Table 15 Status of the liaison with TARDIS project, activities performed and next steps

Type of project	European project
Acronym	TARDIS
Call (link to the website)	HORIZON-CL4-2022-DATA-01 (https://www.project-tardis.eu/)
Short description	TaRDIS's primary goal is to significantly ease the complexity and reduce the effort of building correct and efficient heterogeneous swarms. TaRDIS focuses on supporting the correct and efficient development of applications for swarms and decentralised distributed systems, by combining a novel programming paradigm with a toolbox for supporting the development and execution of applications.
Common points	Decentralised distributed systems and distributed AI. Interoperability among hardware elements and heterogeneous infrastructures.
Performed activities (M18)	First release of TARDIS programming environment that included the first release of decentralized and distributed machine learning (ML) approaches for the supported use cases. These approaches are based on deep reinforcement learning, that it is also studied in the framework of ICOS for efficient energy monitoring of the involved ICOS nodes and task offloading when necessary.
Planned activities (M36)	Distributed AI and AI-based orchestration. At this final stage of both projects the goal is to develop appropriate orchestration environments for the dynamic execution of the adopted ML approaches in a variety of participating nodes and use cases.

Table 16 Status of the liaison with OASEES project, activities performed and next steps

Type of project	European project
Acronym	OASEES
Call (link to the website)	H2020-NMBP-TO-IND-2018-2020 (https://oasees-project.eu/)
Short description	The project aims to deliver a fully open-source, decentralized and secure swarm programmability framework for edge devices
Common points	Decentralized AI/ML approaches for edge computations Open source frameworks

Performed activities (M18)	Overall architecture and use cases definition Data federation and trust principles, which is directly applicable to ICOS use cases as well (e.g., Energy Management and Decision Support System)
Planned activities (M36)	Cloud to Edge AI/ML enablers. This activity will run in parallel with efficient energy consumption and prediction model in ICOS (DECOFFEE model). The goal is to reduce the energy footprint of the involved devices during service execution and minimize achieved latency to support critical applications. Security framework for the OASEES connectivity continuum. Common requirements are identified in both projects.

Table 17 Status of the liaison with CODECO project, activities performed and next steps

Type of project	European project
Acronym	CODECO
Call (link to the website)	DATA-01-16 (https://he-codeco.eu/)
Short description	By creating a novel cognitive edge-cloud management framework, CODECO aims to contribute to a more flexible support of vertical business service governance across the edge-cloud continuum. To achieve this goal, CODECO aims to propose and intelligent and cross-layer orchestration between the decentralised data flow, computation and network services to address the edge-cloud challenges arising from the increasing decentralisation of Internet and IoT services.
Common points	CODECO's resource management technology leverages the expertise of Cloud Native Computing Foundation technologies (i.e., Kubernetes distributions / Prometheus, etc.) to provide a centralized abstraction layer for managing and monitoring distributed computing resources. ATOS and RedHat, partners in the ICOS and CODECO projects, are developing a common technology strategy for the development of both projects.
Performed activities (M18)	Overall architecture and use cases definition. First version of the CODECO technology: Custom resources as extensions of the Kubernetes API and Prometheus.
Planned activities (M36)	Development of the second and final version of the CODECO technology: Custom resources as extensions of the Kubernetes API and Prometheus.

Table 18 Status of the liaison with MobiSpaces project, activities performed and next steps

Type of project	European project
Acronym	MOBISPACES
Call (link to the website)	DATA-01-01 (https://mobispaces.eu/)
Short description	The MobiSpaces project aims to deliver an end-to-end mobility aware and mobility optimised data governance platform. Using AI-based mobility analytics to optimise the entire data path and increase energy efficiency, the Mobility Data Space will contribute to Europe's green transition. To achieve this, MobiSpaces leverage resource management technologies to provide a centralised interface for managing and monitoring distributed / decentralised computing resources.
Common points	The MobiSpaces resource management technology leverages ICOS' expertise in this area to provide a centralized interface based on Open Cluster Management for managing and monitoring distributed computing resources (using Prometheus).
Performed activities (M18)	First release of MobiSpaces management tools.
Planned activities (M36)	Second release of MobiSpaces management tools with an integrated version of the monitoring (observability stack).

Table 19 Status of the liaison with MANOLO project, activities performed and next steps

Type of project	European project
Acronym	MANOLO
Call (link to the website)	Human-01-01 (https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl4-2023-human-01-01)
Short description	MANOLO seeks to provide a comprehensive and reliable suite of algorithms and tools to enhance the efficiency and seamless optimization of AI systems, reducing the resources and data necessary for training, deploying, and running high-quality and lightweight AI models across both centralized and cloud-edge distributed environments. To achieve this, MANOLO will strive to advance the state of the art in developing a collection of complementary algorithms for training, interpreting, compressing, and optimizing machine learning model by advancing research in areas such as model compression, meta-learning (few-shot learning) and domain adaptation.
Common points	These models operate in the continuum edge to cloud. As in ICOS, the footprint of the models run will be taken care of seeking performance in low end devices.
Performed activities (M18)	This project will kick-off in M17 of ICOS (Jan 2024).

Planned activities (M36)	User Needs, Requirements and Design Principles First Technical requirements & System Architecture Use Case Deployment Plans Training Data/Metadata First prototypes of the MANOLO components Preliminary Business models & Exploitation plans

Table 20 Status of the liaison with ODEON project, activities performed and next steps

Type of project	European project
Acronym	ODEON
Call (link to the website)	HORIZON-CL5-2023-D3-01-15
Short description	ODEON aims to optimize energy data and systems management.
Common points	ODEON's key objective is the design and development of an efficient and distributed data and processing management solution for the continuum, referred to as Cloud-Edge Data and Intelligence Service Platform, what undoubtedly will require a sort of meta-OS to support the envisioned core functionalities. ICOS may play as a baseline solution to technically support this objective.
Performed activities (M18)	The project started in Jan 2024 and is right now identifying specs and requirements that will be considered to optimally allocate processes into the continuum.
Planned activities (M36)	Optimizing resources utilization in the energy sector by adopting some of the ICOS outcomes, particularly focusing on the matchmaking process that must be responsible for optimizing resources utilization.

Table 21 Status of the liaison with PIACERE project, activities performed and next steps

Type of project	European project
Acronym	PIACERE
Call (link to the website)	HORIZON-CL5-2023-D3-01-15
Short description	PIACERE enables the automation of deployment, configuration, and management tasks that are typically performed manually by an operator. The main approach of PIACERE is an integrated DevSecOps framework to develop, verify, release, configure, provision, and monitor infrastructure as code (IaC).
Common points	PIACERE's common objectives with ICOS lie on the advanced capabilities of runtime security with complementarity potential in respect to innovation, particularly in regard to self-learning and self-healing mechanisms and the static-dynamic duality in security monitoring.

Performed activities (M18)	Co-authorship in the paper [Cankar, M., Petrovic, N., Pita Costa, J., Cernivec, A., Antic, J., Martincic, T. and Stepec, D., 2023, April. Security in DevSecOps: Applying Tools and Machine Learning to Verification and Monitoring Steps. In Companion of the 2023 ACM/SPEC International Conference on Performance Engineering (pp. 201-205).] and ["Jan Antic, João Pita Costa, Ales Cernivec, Matija Cankar, Tomaz Martincic, Aljaz Potocnik, Gorka Benguria Elguezabal, Nelly Leligou, Ismael Torres Boigues: Runtime security monitoring by an interplay between rule matching and deep learning-based anomaly detection on logs. DRCN 2023: 1-5"] about the research results built in the context of the application of state-of-the-art machine learning methods to the anomaly detection in application and infrastructure logs.
Planned activities (M36)	The project ended in November 2024.

4.1.2 Liaisons with related initiatives

During the first period of the project, major contributions to other initiatives are related to the involvement within the EUCEI.eu community and its activities. Further details are provided in the following subsection.

4.1.2.1 Detailed activities within EUCEI.eu initiative

Task Force 1: Strategic Liaisons

Description: The main objective of this task force is to allow the liaison of research project with industry-related initiatives in order to Objectives of the task force

Performed activities: Participation in telcos and/or workshops, contributions to documents, etc.

Results: Documents or any other kind of material (already available or planned).

Task Force 2: Open Source Engagement

Description: The main objective of this task force is to support projects in their open source strategy, as well as to develop an European open source stack with main results from them.

Performed activities: Participation in telcos and webinars, as well as contribution to the survey for defining a common open source stack of the clout-to-edge-to-IoT continuum by identifying the open source components used and developed as part of the ICOS project.

Results: Events information is available in the EUCEUI.eu website, while the results of the survey are not published yet.

Task Force 3: Architecture

Description: The main objectives of this Task Force are focused on: i) enabling the architectural discussion among projects in the area of IoT/Edge and Cloud to create a continuum (i.e., cloud, edge, IoT, data spaces); ii) identifying the thematic areas in the continuum arena and the building blocks of a potential functional architecture to manage the continuum, and; iii) understanding the contribution of each individual project to the thematic areas previously defined, so a common and widely accepted architecture may be defined. The activity in this Task Force is split into several Working Groups (WGs), as described next. ICOS has identified key partners in the consortium to follow and contribute to the WGs ICOS is interested in, as also shown next.

WG1 Security & Privacy: ICOS contribution to this WG1 is led by XLAB.

Performed activities: XLAB participated in this workgroup with some other ICOS partners (ATOS/EVIDEN, UPC), representing the ICOS project, and has participated in regular calls starting in October 2023. The WG1 defined the core security and privacy functionalities of the reference EUCEI architecture. XLAB (and ICOS) contribution was in defining IAM (authentication/authorisation) mechanism and approaches to guaranteeing data integrity and availability as well as system availability. For this, XLAB proposed the AIOps approach with anomaly detection which is also one of the core functionalities of the ICOS Security Layer.

Building on defining the core security and privacy functionalities, XLAB and other partners also contributed to integrating these functionalities into the reference architecture.

Results: Contribution to the reference architecture. XLAB is committed to work on further improving an AIOps solution for ICOS and EUCEI reference architecture and will continue being part of the conversations of this workgroup in 2024.

WG2 Trust & Reputation: ICOS is not participating tom this WG as considered out of the main scope of the project.

WG3 Data management: BSC is leading this WG.

Performed activities: Data management is a pivotal aspect in most Meta-OS projects. Representatives of most projects were available during this WG calls and participated in the discussions. These calls allowed us to identify and characterize the different requirements that are attributed to the data management aspect of the Meta-OS. Given the different nature of the different projects involved in this WG, defining an architecture that encompasses all these use cases while maintaining its flexibility was the main goal. The different meta components of the Data Management were identified and characterized.

Results: A generic data management architecture, with proper characterization of its components, suited for all Meta-OS projects. This architecture was deemed adequate (by the experts from the different projects involved in this WG) for the requirements and challenges that the continuum presents.

WG4 Resource management: UPC leads the participation of ICOS in this activity.

Performed activities: Beyond participating to the different telcos, seminars and workshops, the main ICOS contribution is centred on identifying the proper strategies to accommodate an optimal and efficient management of the entire set of resources in the continuum stack. More specifically, ICOS contributions to the targeted architecture focus on : i) introducing the concept of the agent/controller as the strategy to develop the meta-OS into the different stack components; ii) proposing data as a resource itself to be managed by the architecture as a resource, and; iii) suggesting a clustering architecture to manage the whole set of clusters defined by considering resources aggregation to minimize data flows while guaranteeing accuracy, optimality and efficiency in the resources management process.

Results: Results are included in the first white paper about building a reference architecture, already available in the EUCEI.eu website, and the rest that will be published soon. Additionally, all contributions are included in the final reference architecture document to be promoted as a European standard.

WG5 Orchestration: SIXSQ leads the participation of ICOS in this activity.

Performed activities: Participated in a series of weekly telephone conferences. Acting as a proxy for ICOS, the SIXSQ contribution was to describe the various methods and how ICOS handles the orchestration of the cloud and edge resources and the tools employed. The general strategy of using the ICOS Controller and Agents working with the underlying orchestrators was presented.

Comparisons to other projects' methods were made.

Results: As of now, the specific results and advancements stemming from these discussions are being compiled and are to be determined. The goal is to integrate the insights gained from these collaborative sessions into a cohesive and forward-thinking strategy that aligns with the overarching objectives of the EU Cloud-Edge-IoT architecture initiative.

WG6 Network: ICOS does not contribute to this WG.

WG7 Monitoring & Observability: ENG leads the participation in this WG.

ICOS participated to the various monthly telcos of the taskforce. The contribution of ICOS in this workgroup consists in the identification of the components aimed at collecting metrics and logs from the systems, monitoring the resources and defining policies. ICOS contributed to the definition of the architecture for: 1) collection of monitoring information distinguished from physical (telemetry, infrastructure and resource) and application monitoring (collection of the data about the application status); 2) definition and collection of SLOs; 3) definition of different levels of alerts (paying attention between predictive maintenance and immediate actions).

Results: The result of the WG7 activity was provided in the telcos planned of the task. In the future these results should be provided in the white paper.

WG8 Artificial Intelligence: CeADAR has expressed interest in participating in this workgroup representing the ICOS project and has participated in weekly calls starting in October 2023. There has been a number of calls and a survey run regarding the 'Landscape Framework for Research Assets Evaluation' involving this workgroup until now. As a result, the ICOS Intelligence API has been registered in such survey.

CeADAR is committed to developing an AIOps solution for the edge-to-cloud continuum and will continue being part of the conversations of this workgroup in 2024, meeting both:

i) The standards that are still about to be set on the usage, implementation, reuse, reporting, and automation of AI in production systems, and
ii) The AI act, following model transparency and trustworthiness standards.

Task Force 4: Ecosystem Engagement

Description: Engagement of the FSTP managers under the topic (HORIZON-CL4-2021-DATA-01-05) including ICOS (NEMO, NEPHELE, aerOS and NebulOus) in order to share Open Call results, engage IoT community and organise better outreach and quality of the FSTP funding.

Performed activities: Participation in telcos, webinars and workshops. Provided documents and aggregated data on the Open Calls results and community outreach. Task Force leader and organiser is BluSpecs (https://bluspecs.com/) and webpage with all the data on: https://eucloudedgeiot.eu/task-forces/

Results: Task force leaders organised webinars with the members on: EUCEUI - Capitalising on Cloud-Edge-IoT - 20/09/2023 and 10th November 2023, Giving Energy an Edge: Showcasing the Edge to Cloud Continuum in Energy https://eucloudedgeiot.eu/event/giving-energy-edge-showcase/, the Open Call was included in the **IoT-Edge-Cloud** website https://eucloudedgeiot.eu/open-calls/ other reports and documents will be published online: https://eucloudedgeiot.eu/reports/

Task Force 5: Markets and Sectors

Description:

- Provide insights and transfer knowledge about the CEI demand market trends to projects
- Support the alignment between supply and demand to bridge the gaps
- Support the projects for the commercial exploitation of their solutions

Performed activities: Participation in monthly telcos and workshops, contributions to documents. The list of activities is as follows:

- All use cases provide their input to the Miro Board for MetaOS use-case catalogue.
- Participation in Worshop Agenda Feasibility Assessment Tool 17/10/2023 (WSE).
- Participation in the webinar Advancing towards the Cloud, Edge and IoT Continuum: Insights and Impacts 25/09/2023 (SSE).
- Participation in the webinar for Meta-OS agriculture and crisis management use-cases 20/02/2024 (PSNC).

Results: Meta-OS Use Cases Overview: https://zenodo.org/records/10390848

Task Force 6: Communications

Description: This task force has the objective of creating a brand identity for the EUCloudEdgeIoT initiative as well as fostering promotion of the joined projects in a harmonized way, to maximise impact. To achieve this, a monthly newsletter has been created that promotes content provided by the project that is sent to EUCloudEdgeIoT stakeholders, including Meta-OS RIAs and other existing communities (e.g., H-Cloud, NGIoT…).

Performed activities: Participation in monthly telcos, several workshops (listed in section 21) and contribution to the EUCEI newsletter (listed in section 2.3.3).

Results: Newsletter reference the ICOS open call details on the EUCEI website here: https://eucloudedgeiot.eu/open-calls/

4.2 Advisory Board

According to the strategy already defined in D7.2, ICOS Advisory Board is composed by 3 members, or more, and less than 5 representing different roles within the continuum value chain. The main reason for this number relies on having sufficient representation of these roles while avoiding an overload of feedback that may result in messy recommendations.

First requirement for selecting the profiles was that there must be, at least, one representative of each of the pillars of the continuum: cloud, edge and IoT, with a clear balance between industry and academia experts and, preferably, at least one member from outside Europe to gather a more global vision.

The final list of advisory board members is as follows:

- Silvia Castellvi, from IDSA.
- Svetoslav Duhovnikov, from Airbus.
- Prof. Jianping Wang, from City University of Hong Kong.

Initially, a representative from IBM USA was also included but, as IBM will become a member of the consortium, his presence was no longer requested to avoid any potential conflict of interest.

Additionally, Bogdan Tarnauca, from Siemens, has been contacted and accepted to be a non-fixed member of the ICOS Advisory Board but to provide feedback on demand about specific IoT-related issues.

All these representatives were requested to sign a NDA, as not all ICOS results will be public and they must also provide advice about proprietary tools. This process is ongoing due to the legal implications.

First online meeting will be held during March in order to gather feedback about the ICOS Alpha release. This was considered in this way as ICOS challenges are properly validated in both scientific and industrial arenas, as highlighted by the interest of the different project stakeholders. But additional feedback is needed about the project approach, and its potential uptake by final users. Thus, further information as well as the reporting from periodic meetings will be provided in the final document of this series.

4.3 Community building activities

In order to facilitate the recognition of ICOS project and further the development of IoT, Cloud, and Edge Computing technologies, FBA have established and launched an online community for IoT stakeholders. This online platform is intended to serve as a resource for Open Call candidates during the application process and to promote professional and innovative cooperation between those with a passion for these technology fields, as well as an online Helpdesk to support applicants during the open call application phase. A snapshot of the ICOS Helpdesk is shown in Figure 7.

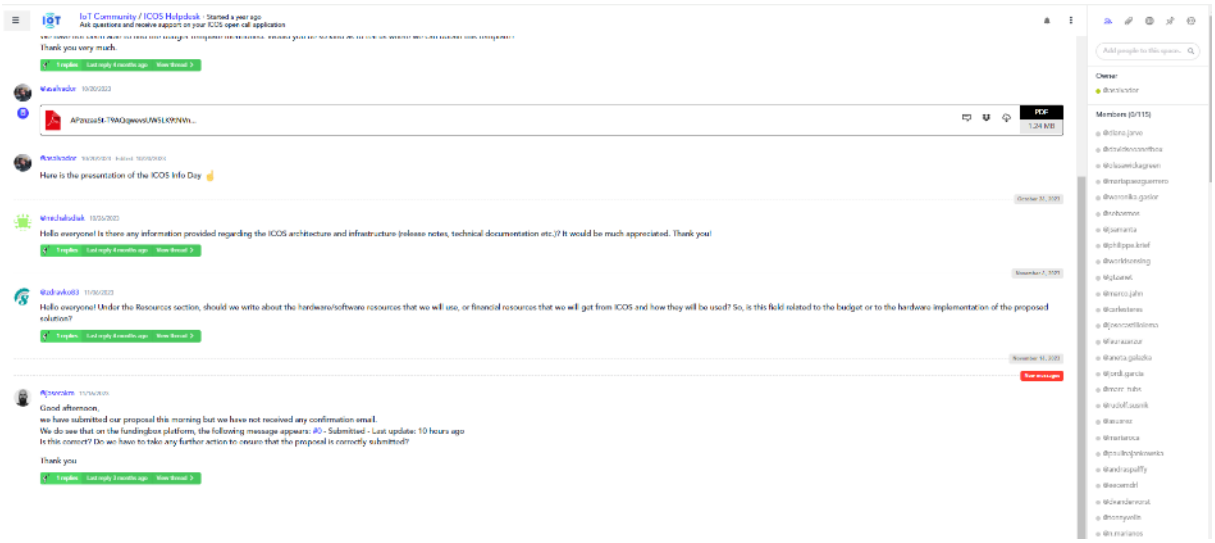

Figure 9: Snapshot of the ICOS Helpdesk in the Community at Spaces

The online community is composed of up of a variety of stakeholders, including developers and innovators who were contacted through the Open Calls, as well as other people and organizations from the public, private, and professional sectors who are interested in utilizing the results of ICOSs to enhance their processes, goods, and services. For them to easily navigate and post in the community, we created a dedicated guidelines that were showcased in a dedicated channel in the community (see screenshot below.)

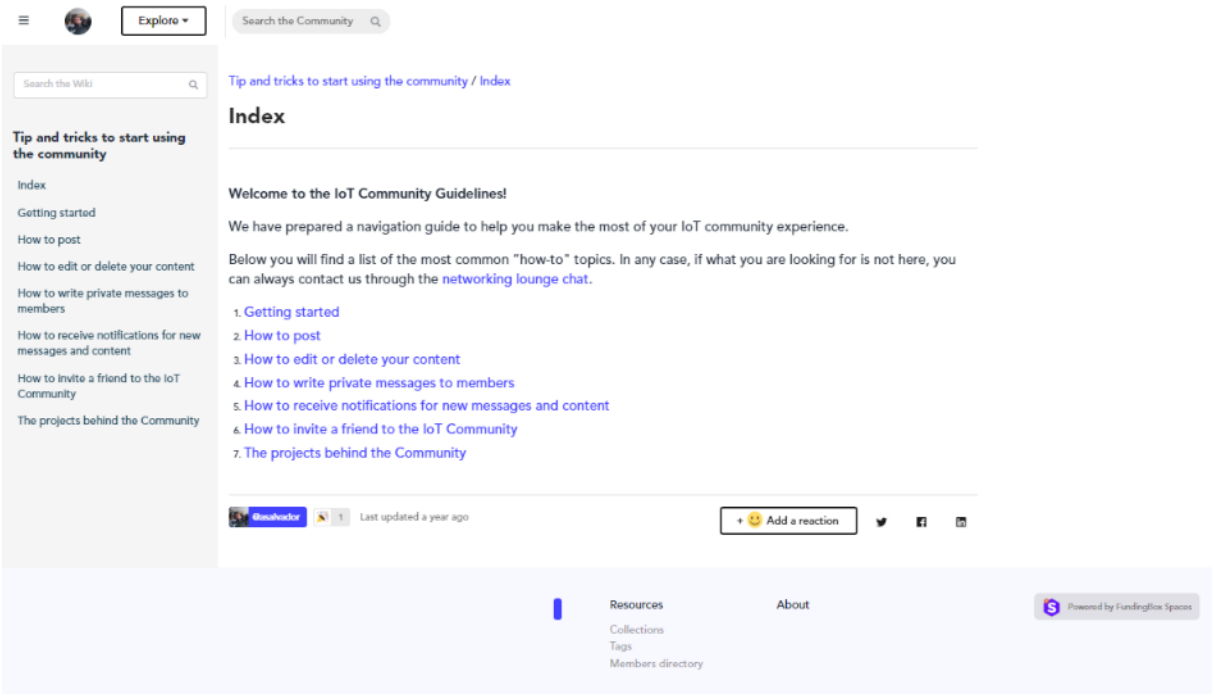

Figure 10: Screenshot of Community Guidelines

FundingBox, in collaboration with the Consortium, has been curating a diverse and engaging content portfolio:

- News and articles interesting about the IoT industry.
- ICOS Open Calls and other funding opportunities information.
- Multimedia content such as images, videos and infographics.
- Events organised, but also other relevant events at the European level attended by the partners of the project.

See an example of the post about various events in the following Figure.

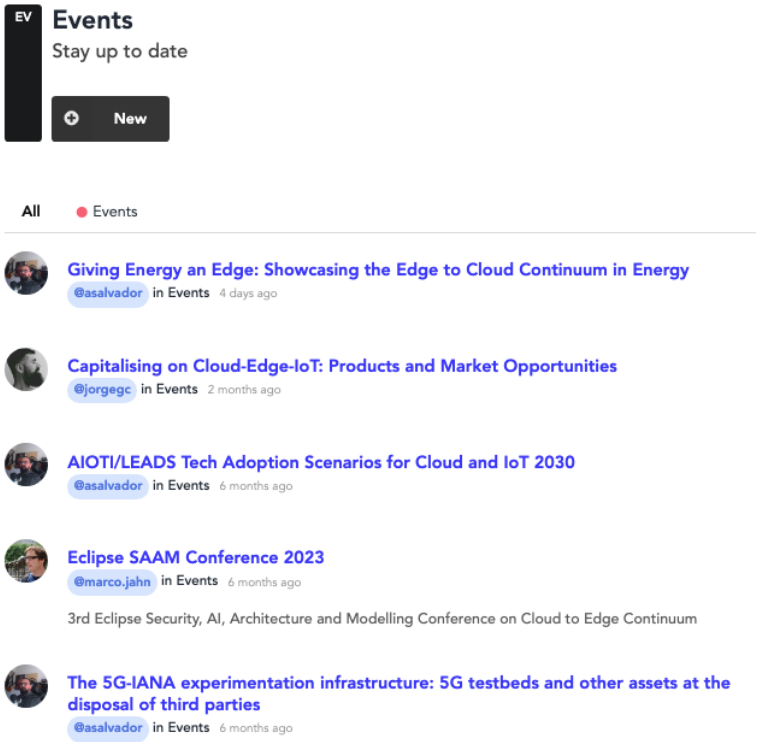

Figure 11: Posts about various events in the community

The community has been growing since the launch, reaching 118 members and more than 65 companies, 95 messages and 42 replies / comments. A screenshot of the analytics can be found in the figure below.

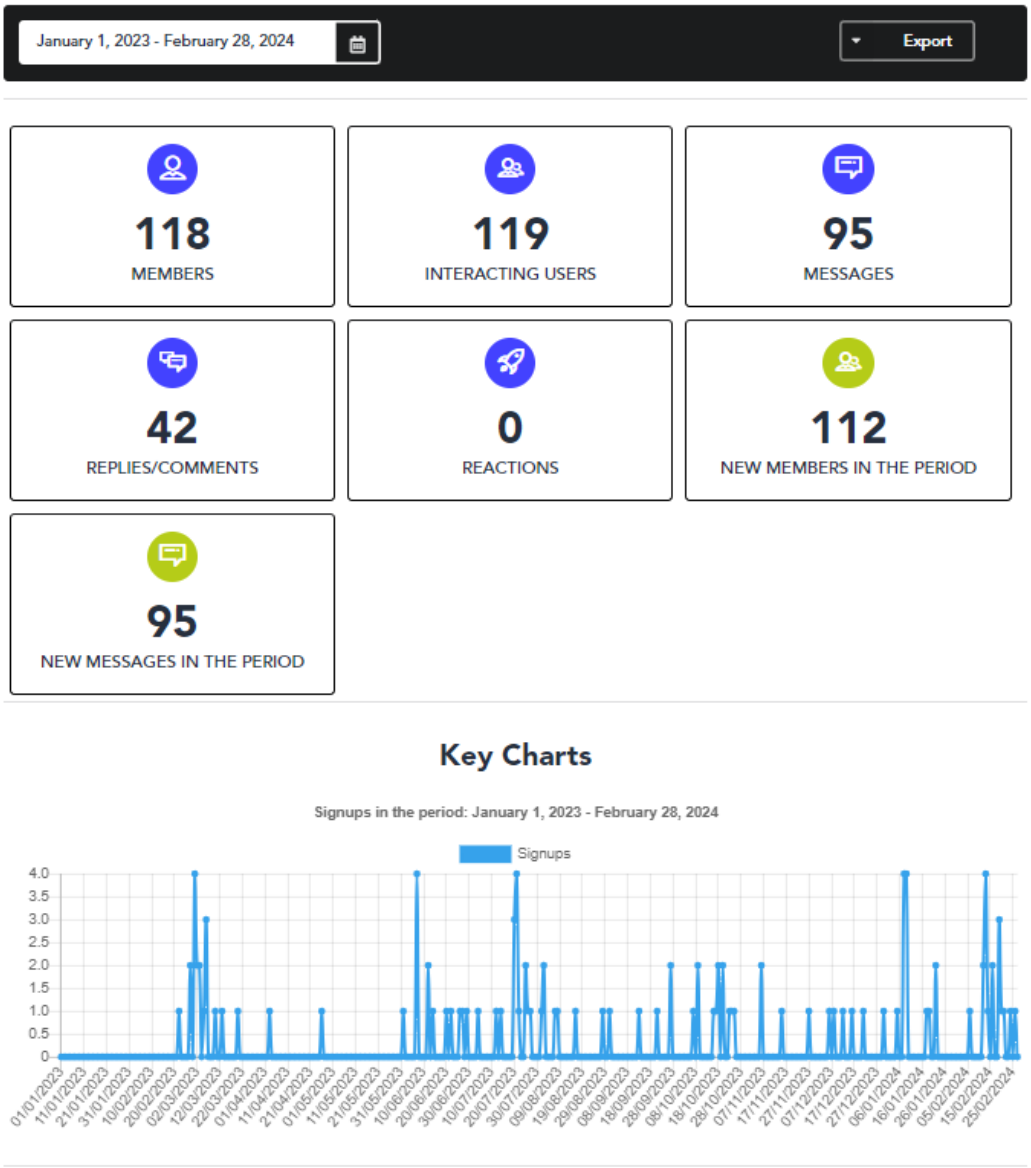

Figure 12: Community analytics screenshot

Since 2024, we decided to move our community to Discord. The decision to migrate our communities from our proprietary platform (https://spaces.fundingbox.com/) to Discord is motivated by a strategic alignment with our long-term aims of cultivating dynamic, cost-effective, and scalable online communities. Discord's strong features, large user base, and integration possibilities make it a great platform for building thriving tech communities.

Maintaining our own proprietary platform is no longer economically efficient. Incurs considerable infrastructure, development, and maintenance costs. With the best value for money principle in mind, by switching to Discord own server we can focus the savings to improve our community engagement activities. We are unable to compete with large international corporations whose core business is providing and developing community platforms. We will be able to move our resources from developing our own tool to administering, maintaining and developing the community on Discord servers.

Discord has over 150 million active users, making it one of the most popular communication platforms in the world. This large user base provides a ready-made audience for our tech communities, enhancing the chances of attracting new members and encouraging active engagement. Furthermore, the expected development trajectory of Discord promises a bright future for our communities, assuring their continuous relevance and expansion, while being GDPR compliant. The platform growth expectation reaches more than 600 million users estimated by 2025.

The unique aspect of the Discord solution is the ability for users to access information and data not just through a web browser, but also on various devices such as computers, tablets, and smartphones. Each server owner has the autonomy to determine the access rules for the knowledge and information stored on these resources. The platform owner does not interfere with the micro-community on Discord.

This approach brings knowledge sharing, thought and idea exchange, closer to the concept of decentralized registers, similar to blockchain technology. Discord's solution safeguards the community against any interference from the platform owner in terms of displayed content and manipulation of messages.

Discord's unique features, such as its customizable channel structure, integrated voice and text chat, and configurable roles, allow for the construction of really live and engaged communities. We will use these features to enhance project collaboration, build meaningful connections among our tech enthusiasts, and offer engaging activities making it an ideal platform to cultivate thriving tech communities that drive innovation and collaboration.

Users of the current communities will be invited to join the new Discord community and messages will be pinned to all the current spaces communities indicating that the new content for them will be offered exclusively on Discord. This will also help select community users who are truly active and can be members of an engaging community that thrives over time, offering much higher interaction rates. The new online community can be seen in a snapshot below, pending to open to the public until we implement the Digital Services Act in our community.

Figure 13: ICOS online community in Discord

4.4 KPIs

Table 22 External liaisons and Community building KPIs

ID	Means of verification	Threshold	Timing	Status (M18)
KPI 1	Supportive partners	20	M36	0
KPI 2	Community members	400	M36	118
KPI 3	Open Calls	2	M18, M28	1
KPI 4[13]	Number of messages (content) posted in the certain period (posts/announcements, files, articles)	-	M36	92
KPI 5[5]	Number of comments to the content in a certain period	-	M36	38
KPI 6	Number of liaisons	3	M36	12 projects and 1 initiative
KPI 7	Number of joint activities	4	M36	1 with other MetaOS projects

4.4.1 Contingency plans

List all plans related to the ID of the KPIs mentioned before.

- **KPI 1:** Elaborate Supportive Partners communication toolkit and engage with related projects.
- **KPI 2:** Add more related projects to the community.
- **KPI 3:** Launch the second open call.
- **KPI 4:** Add more related projects to the community to give more content.
- **KPI 5:** Add more related projects to the community.
- **KPI 6:** Even if the project has established a huge amount of liaisons with other projects and initiatives, further work must be performed to reach potential end users. Thus, work during the second period will focus on more user-related activities, such as participation in events or workshops, with the support of the dissemination activities.
- **KPI 7:** 1 workshop was organized with other MetaOS projects, but further results coming from the work within EUCEI.eu initiative will be released soon, what will significantly increase this KPI.

[13] These KPIs were not initially considered in the proposal, but were identified as 'nice-to-have' in D7.1 to follow up the progress of the community building activities.

5 Innovation and Exploitation

This section provides an overview of the exploitation possibilities for the project. It starts with the individual components, to which applies the individual exploitation strategy, complemented with the key exploitable results, that are part of the project joint exploitation.

In order to provide the most suitable path for the project in the next iteration of this deliverable, several techniques are applied, including a micro-economic analysis to be ready before the end of the project.

5.1 Exploitable assets

All software components developed within the project have the potential to be exploited at individual level. The initial list of already identified exploitable assets is listed below, including their ownership and license, as this information also drives the final exploitation path.

Table 23 Exploitable result #1 – description and license

Name	ICOS Intelligence API Community Edition (AI coordination module)
Owner(s)	CeADAR
Short description	The AI coordination module facilitates optimization, predictive analytics, and applying machine learning models across the edge-cloud continuum. Model output target the implementation of policies for utilizing, sharing, and updating models. This acts as an interface and provides coordination between the meta-kernel and user layers providing and requesting services.
License	GNU GPL v3

Table 24 Exploitable result #2 – description and license

Name	Predictive telemetry metrics model training – Bento (packet) for the AI Analytics module
Owner(s)	CeADAR
Short description	The AI coordination API offers an endpoint for estimating the CPU consumption of the ICOS agents. This model can be repurposed to specific tasks and other telemetry metrics as a training functionality is provided as a separated endpoint.
License	GNU GPL v3

Table 25 Exploitable result #3 – description and license

Name	Online machine learning models - Bento (packet) for the AI Analytics module
Owner(s)	CeADAR
Short description	This is a separate packet to be deployed and complement the list of AI models reachable in the ICOS intelligence layer. These models bring online machine learning capabilities to the Intelligence layer to learn on the fly and adapt to dynamic and non-stationary data streams received in the continuum.
License	Proprietary

Table 26 Exploitable result #4 – description and license

Name	ICOS Intelligence API Developer Edition (AI coordination module)
Owner(s)	CeADAR
Short description	This version builds extra functionalities on top the Community Edition (CE). It makes use of data pipelines and plugins/bento can easily be developed leveraging these. This is supported by a clear repository structure and extra documentation. This version has extra integration with AI libraries, and includes specific Intelligence packets as the online machine learning models.
License	Proprietary

Table 27 Exploitable result #5 – description and license

Name	ICOS AI Marketplace
Owner(s)	CeADAR
Short description	ICOS will create a marketplace of models and solutions developed using the intelligence layer. The aim of this is to create a community of projects using and building intelligent applications for ICOS.
License	GNU GPL v3

Table 28 Exploitable result #6 – description and license

Name	ICOS AI Analytics - Intelligence continuum models
Owner(s)	CeADAR
Short description	ICOS will integrate a set of techniques for optimizing and pruning ML models to be adapted to the characteristics of edge devices without losing accuracy.
License	GNU GPL v3

Table 29 Exploitable result #7 – description and license

Name	Security Layer Coordination module
Owner(s)	XLAB
Short description	AIOps-based tool for the coordination of modelling, capturing and optimizing log streams, with integrated alerting capabilities (D4.1/D4.2). This enables in ICOS a Security Layer including security and trustworthy as key fundamental pillars.
License	OSS licensed with Apache 2.0

Table 30 Exploitable result #8 – description and license

Name	Security Scan
Owner(s)	XLAB
Short description	Wazuh-based open source runtime security monitoring system capable of detecting security-related events and incidents in the deployed application's environment. It is (to the extent possible) deployable automatically and notifies users about security alerts.
License	OSS licensed with GNU GPL v2 (same license as ELK)

Table 31 Exploitable result #9 – description and license

Name	LOMOS
Owner(s)	XLAB
Short description	The LOg MOnitorin System (LOMOS) is an application of self-supervised machine-learning to the anomaly detection in application and infrastructure logs.
License	Proprietary

Table 32 Exploitable result #10 – description and license

Name	Nuvla.io
Owner(s)	SixSq
Short description	Nuvla.io is a remote management and orchestration platform for edge devices and applications. From the platform, you can remotely manage a large fleet of edge devices on which you can deploy or update apps, get detailed control information, and set up notifications, amongst other features. Nuvla.io works with the NuvlaEdge software, which enables a direct communication channel between edge devices, and the platform.
License	The access to the Nuvla.io platform is free. A PAYG license is bound to the NuvlaEdge software (see next table).

Table 33 Exploitable result #11 – description and license

Name	NuvlaEdge
Owner(s)	SixSq
Short description	NuvlaEdge is containerized software that turns any Linux platform into an edge device (using either Docker or Kubernetes). Once installed on the device, NuvlaEdge enables remote connection to it from the Nuvla.io platform. The user can perform actions directly from the platform on the device: fleet management and monitoring, app deployment and update, amongst other features.
License	PAYG (monthly license per NuvlaEdge software installed on a device).

Table 34 Exploitable result #12 – description and license

Name	Online machine learning models – Bento (packet) for the AI analytics module
Owner(s)	NKUA
Short description	The first package is dedicated to online machine learning models for anomaly detection. The goal of the supervised anomaly detector in this case is to predict the correct class (anomaly or not) based on a provided time series. Five different models have been created and evaluated.
License	Proprietary

Table 35 Exploitable result #13 – description and license

Name	Decentralised Computation Offloading with Energy Efficiency-aware (DECOFFEE)
Owner(s)	NKUA
Short description	This decentralized computation offloading scheme targets to dispatch the tasks efficiently in terms of latency and energy efficiency and also allows both vertical and horizontal offloading decisions. The suitability of DECOFFEE to the ICOS principles lies in two aspects: i) it is a decentralized scheme enabling each ICOS agent to effectively handle its computation task in a distributed manner, and ii) it allows both vertical and horizontal decisions within and across the ICOS continuum, which is in line with the ICOS objectives to go beyond the constantly vertical management and the monolithic decentralized orchestration.
License	Proprietary

Table 36 Exploitable result #14 – description and license

Name	Telemetruum
Owner(s)	ENG
Short description	The asset aims at being a flexible and complete solution for collecting, storing and processing telemetry and logging data in the Cloud-Edge-IoT Continuum. Telemetruum allows an adaptive and automated deployment of collection, storage and processing units along the continuum taking into consideration connectivity and computational power constraints while preserving a unified and complete view on the status and the performance of the entire continuum. The asset offers telemetry data collectors for multiple infrastructure and platforms and an advanced policy-based alerting system.
License	Apache 2.0

Table 37 Exploitable result #15 – description and license

Name	PyCOMPSs
Owner(s)	BSC
Short description	PyCOMPSs/COMPSs is a task-based programming model which aims to ease the development of applications for any distributed infrastructures, such as large High-Performance clusters (HPC), clouds and container managed clusters and across the whole IoT-Edge-Cloud Continuum. COMPSs provides a programming environment for the development of the applications in a sequential and infrastructure-unaware manner; its runtime system detects and exploits the inherent parallelism of applications at execution time and distributes its execution.
License	Apache 2.0

Table 38 Exploitable result #16 – description and license

Name	dataClay
Owner(s)	BSC
Short description	dataClay is a distributed data store that enables applications to store and access objects in the same format they have in memory, and executes object methods within the data store. These two main features accelerate both the development of applications and their execution.
License	BSD3-clause

Table 39 Exploitable result #17 – description and license

Name	Node Feature Discovery (NFD) - Prometheus exporter - Device plugin
Owner(s)	NCSRD
Short description	Node Feature Discovery (NFD) integrated with a custom Prometheus exporter and a Kubernetes plugin for external devices is a comprehensive solution designed to enhance Kubernetes cluster management and monitoring. NFD automates the detection of hardware features and capabilities of nodes in a Kubernetes cluster, enabling more intelligent scheduling decisions based on these attributes.
License	Apache 2.0

Table 40 Exploitable result #18 – description and license

Name	Tetragon Wazuh Agent
Owner(s)	NCSRD
Short description	Tetragon, a powerful eBPF-based security observability and runtime enforcement tool, creates a comprehensive security solution for real-time threat detection and response. This component leverages Wazuh's capabilities for log analysis, compliance checks, and alerting with Tetragon's strengths in deep observability and policy enforcement at the kernel level. Such integration offers enhanced visibility into system and network activities, enabling more precise and immediate identification of malicious behaviour, policy violations, and potential vulnerabilities, ensuring a robust security posture for distributed systems.
License	Apache 2.0

Table 41 Exploitable result #19 – description and license

Name	ICOS Shell
Owner(s)	TUBS, UPC
Short description	The ICOS Shell components consist of the Admin GUI and the Dev CLI, as well as the implementation of the required interfaces for the communication between the ICOS Intelligence, Security and Meta-kernel layers. They are the user interface for the ICOS MetaOS.
License	Apache License 2.0

Table 42 Exploitable result #20 – description and license

Name	Smart & Efficient matchmaking
Owner(s)	UPC
Short description	Solution to smartly and efficiently allocate services (tasks/jobs) into available resources at both the early stage of the service deployment and also at runtime considering potential changes on availability, required quality, etc.
License	Proprietary

Table 43 Exploitable result #21 – description and license

Name	Job Manager
Owner(s)	ATOS
Short description	The asset enables ICOS to create schedulable jobs based on the Application Definition passed by the operator. These jobs once scheduled can be taken over and executed by other ICOS's components.
License	Apache 2.0

Table 44 Exploitable result #22 – description and license

Name	Deployment Manager
Owner(s)	ATOS
Short description	The asset enables ICOS to schedulable and execute jobs defined within the Job Manager. These jobs are interpreted by the specific underlying orchestrator by using a suitable driver for it.
License	Apache 2.0

Table 45 Exploitable result #23 – description and license

Name	Aggregator
Owner(s)	ATOS
Short description	Provides a simple way to query information about a multi-cluster system. It launches a server that, when connected, returns available data about clusters and their states.
License	Apache 2.0

5.2 Key Exploitable Results

To be able to communicate the innovations of the ICOS project, we bundle the R&D outcomes and the technological components that are built, into Key Exploitable Results. These will drive the exploitation activities including the competitors' analysis, will be reported through the Horizon Result Platform in M20, and are as follows (aligned with deliverable D4.1):

KER 1: DATA Layer

Pitch: A single data platform to facilitate the management of data distributed across the continuum, able to seamlessly run on heterogeneous and possibly small devices.

Context: Intelligence Layer and the Distributed & Parallel Execution module within the Meta-Kernel Layer: as they require efficient execution of complex data processing tasks across distributed data. Security (SEC) Layer: the minimization of data transfers using the near-data processing capabilities

provided by the Data Management component not only improves performance but also favours privacy, as data does not need to leave its original location to be processed.

Benefits:

1. Data distribution across the continuum, taking advantage of the entire available infrastructure,
2. Smart data placement and dynamic adaptation to changes in the infrastructure during operation: devices joining or leaving, reorganisations, etc.,
3. Seamless access to data in ICOS, regardless of the location (device or cloud) or nature of resource (in-motion or at-rest), by providing an integrated data platform spanning the whole continuum,
4. Minimisation of data transfers to improve performance and trust, by exploiting near-data processing in various types of devices.

KER 2: SEC Layer

Pitch: Security Layer including security and trustworthiness as key fundamental pillars.

Context: It guarantees the security of ICOS users, resources, and applications at all times, provides a unified interface for interacting with Security Layer modules and communicating with other ICOS components in the Meta-kernel Layer and Intelligence Layer. Security Layer modules (Security Vulnerability Mitigation, Compliance Enforcement, Security Scan and Audit) communicate with each other or with other ICOS components

Benefits:

1. assess security of infrastructure and system/application code (e.g. running vulnerability scanning of docker images)
2. provide a mechanism for the detection of compliance problems regarding controls of specific standards and/or specific policies and rules
3. provide a system to trigger infrastructure changes to ensure standard and/or policy compliance.

KER 3: META-KERNEL Layer

Pitch: Adaptation engine, for monitoring, scheduling and orchestrating workloads across the continuum.

Context: Core functionality of a Meta-OS allowing the lifecycle management of service applications across the continuum. It directly interacts with the Data, Security and Intelligence layers as a whole stack, benefitting from the different features offered by them. Different versions are available in order to make it adaptable to the existing context, facilitating its deployment in several scenarios, from IoT up to edge/cloud.

Benefits:

1. Workload orchestration across the continuum able to operate at device/infrastructure level to deploy applications.
2. Performance monitoring that allows taking informed decisions to ensure the highest QoS/QoE levels.

KER 4: INTEL LAYER

Pitch: Set of techniques for optimizing and pruning ML models to be adapted to the characteristics of edge devices without losing accuracy.

Context: Enhances the security and functionality of the Security and Meta-kernel layers; helps to ensure that analytical and machine learning models are used safely, effectively, and ethically across data-intensive Edge/Cloud spectrum applications. It provides libraries and frameworks for processing and transformation at scale; aggregates libraries and algorithms for training and forecasting using

state-of-the-art methods; includes an AI Models Repository partially supported by the creation of model registries; Trustworthy AI is planned for the ICOS Beta release.

Benefits:

1. The API runs Machine Learning (ML) services from multiple frameworks as a service and runs on a server (an ICOS Controller by default) that orchestrates AI workloads.
2. ML models can be pre-built and added to the API as specified in a developer guide: outputs are model predictions or information about a new model trained in this scenario.
3. Extend ML libraries to make them available to a technical user in order to save storage resources in devices with access to the API.

KER 5: AI MARKETPLACE

Pitch: Creation of an ICOS AI online model catalogue or repository connected to intelligence model registries.

Context: ICOS will create a marketplace of models and solutions developed using the intelligence layer. The aim of this is to create a community of projects using and building intelligent applications for ICOS.

Benefits:

1. Improved outreach to ICOS
2. Demonstration of previous adoption and how to adopt the technology
3. Portfolio of ideas on how to benefit from ICOS services

KER 6: FULL STACK

Pitch: Complete set of features and functionalities easing the IoT-edge-cloud continuum management, including all the four layers (KERs 1-4) and the AI Marketplace (KER 5).

Context: The overall technology in ICOS is a meta operating system for a continuum, a data- driven system built upon the principles of openness, adaptability, data sharing and a future edge market scenario for services and data.

Benefits:

1. devices volatility and heterogeneity, continuum infrastructure virtualization and diverse network connectivity
2. optimized and scalable service execution and performance, as well as resources consumptions, including power consumption, with guaranteed trust, security and privacy
3. reduction of integration costs and effective mitigation of cloud provider lock-in effects

As described above, the first four KERs represent the layers that reflect ICOS architecture, while the last two correspond to the full-stack solution including all the layers, and an AI Services Marketplace to serve the European industrial excellence.

In the following period, the work will continue with the definition of the KERs based on the problem they address and the value that they generate, validated by the early adopters, the project use cases, and the input from the Open Call participants. We are also preparing the application to the coaching programs PDESC and Business Plan Development (BPD) from the Horizon Results Booster, with whom we have good experience and that will surely help us define the KERs in the project. This content will be available in the succeeding deliverable D7.4.

5.3 Market analysis

Continuum computing refers to a huge market, ranging from IoT to edge and cloud, what converges in a continuously growing environment aiming to cover very different vertical needs.

This section provides an overview of the market evolution of some of the major topics addressed by the project.

Cloud computing

Cloud market can be considered as a well-established one due to the common use of its related technologies in daily activities. Thus, even if it is not expected a significant growth, it will be done progressively during the coming years.

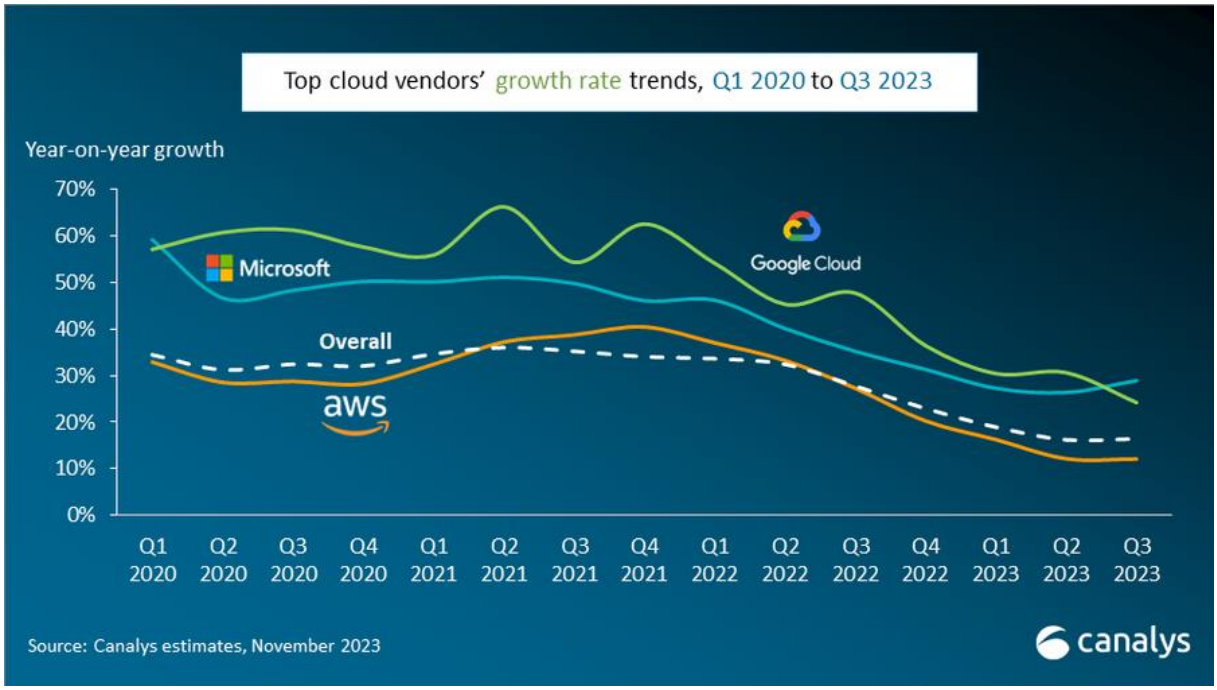

Figure 14: Global Cloud Market [7]

This situation is reflected into the last canalys report [7]. However, figures shown that the three main global cloud providers, aka AWS, Microsoft Azure and Google Cloud grew a 20% what accounts a 65% of total spending in cloud services. While the global market grew a 16% during 2023 compared with the latest 2022 reports, what represented USD 73.5 billion only in Q3 2023. This situation is expected to continue with the same trends, when global market is expected to reach USD 2.4 trillion by 2030 at a lower CAGR than in the previous decade, during which this market grew a 534.9% from 2010 to 2020 [8].

In parallel, the European market reached USD 60 billion in 2022 and it is expected to grow at a CAGR of 25% until 2032, reaching USD 650 billion at the end of the period [9].

Edge computing

On the other hand, edge computing market is not so established as the cloud one, but many verticals are starting to slowly adopt more edge solutions to benefit from its low latencies.

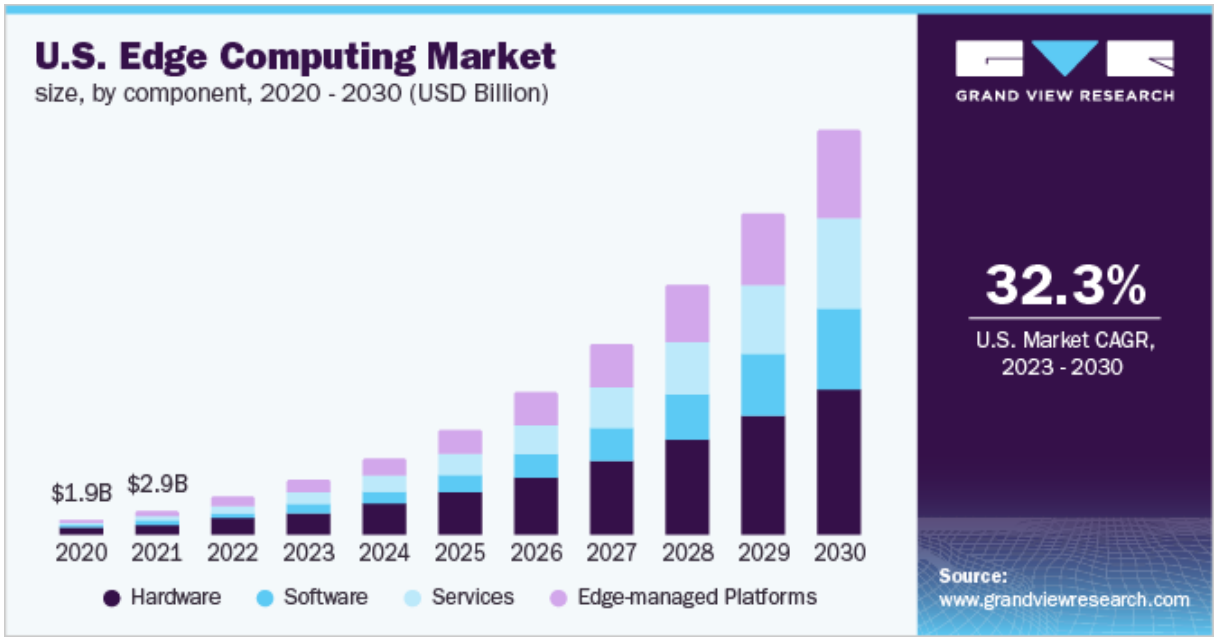

Figure 15:US Edge Computing Market 2020-2030 [10]

This situation is pushing the market growth, going from USD 16.45 billion in 2023 to USD 155.90 billion by 2030, growing at a CAGR of 37.9% [10]. Within this context, North America will experiment the highest growth representing the 50% of the market. At the same time, the global edge market seems to be underrated as it is expected that the penetration of IoT and 5G will push a higher growth in the coming years [11].

The growth in Europe is expected to be lower, at a CAGR of 15.8%. While going into details, French market is expected to grow at a CAGR of 16.7%, while the German one will achieve USD 7.1 billion within the same period [12].

Internet of Things

The increased need of connected devices to perform operations is pushing the global market growth, going from USD 544.38 billion in 2022 to USD 3,352.97 billion by 2030, growing at a CAGR of 26.1% [13].

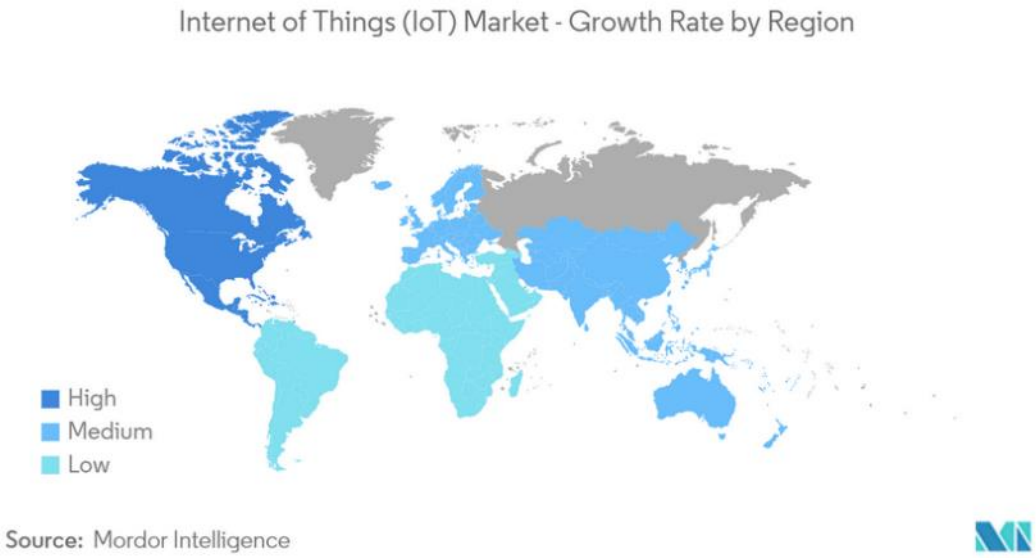

Figure 16: Global Internet of Things Market, by Region [14]

In general lines, the support offered by IoT technology to digital transformation is fuelling the industrial revolution of intelligent connectivity. This allows organizations to implement complex processes to improve efficiency, allowing their own growth [14].

Even if North America is coping the market due to its regional size, it is indeed Europe who is dominating its growth going from USD 216.29 billion in 2023 to USD 1,319.75 billion by 2030, growing at a CAGR of 29.5% [15].

Network

The growth of the previous markets is supporting the network market growth, as more reliable connections are needed to support the increased usage of IoT devices and edge solutions. Global network as a service market is growing from USD 13.63 billion in 2022 to USD 155.17 billion by 2030, growing at a CAGR of 35.3% [16].

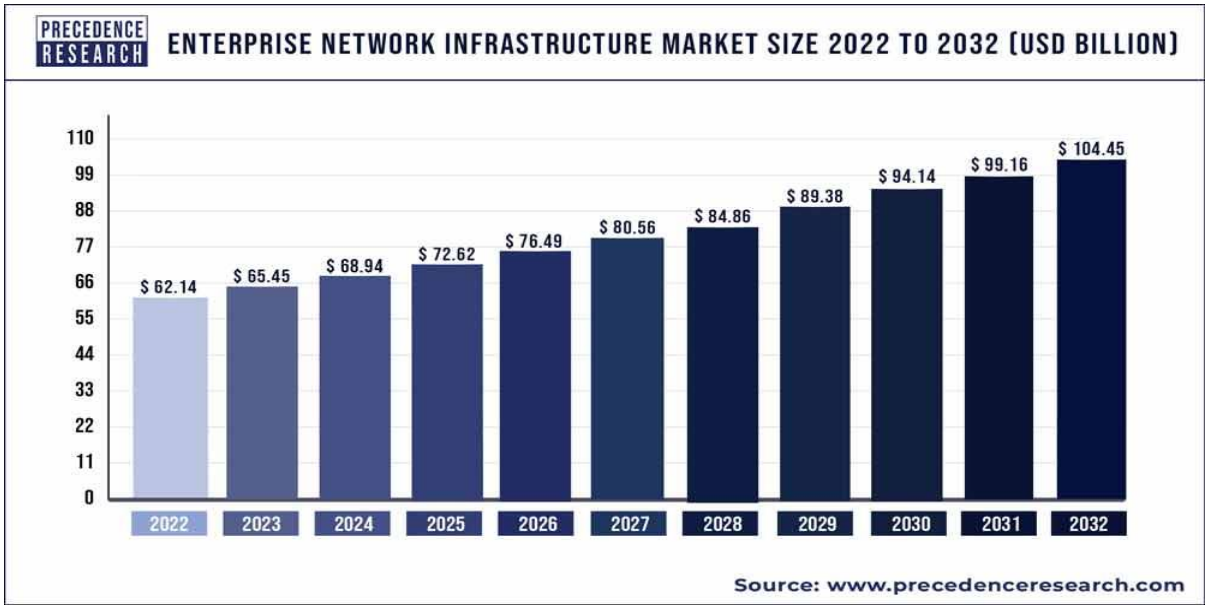

Figure 17: Enterprise Network Infrastructure Market Size, 2022-2032 [17]

Having a look to the private network market, including hardware and software, the growth is slower, but the valuation is higher. This means, this global market is growing from USD 62.14 billion in 2022 to USD 104.45 billion by 2032, growing at a CAGR of 5.33% [17].

This situation is similar within the European market, where managed network services is growing from USD 19.13 billion in 2023 to USD 41.21 billion by 2030 at a CAGR of 11.6% [18]. While the private network marked is growing from USD 369.73 million in 2021 to USD 9.01 billion by 2032 at a CAGR of 43.4% [19].

Cybersecurity

Cybersecurity is an increased need to protect communications in every operation. This situation is pushing the market growth from USD 22.66 billion in 2023 to USD 500.70 billion by 2030, growing at a CAGR of 12.3% [20].

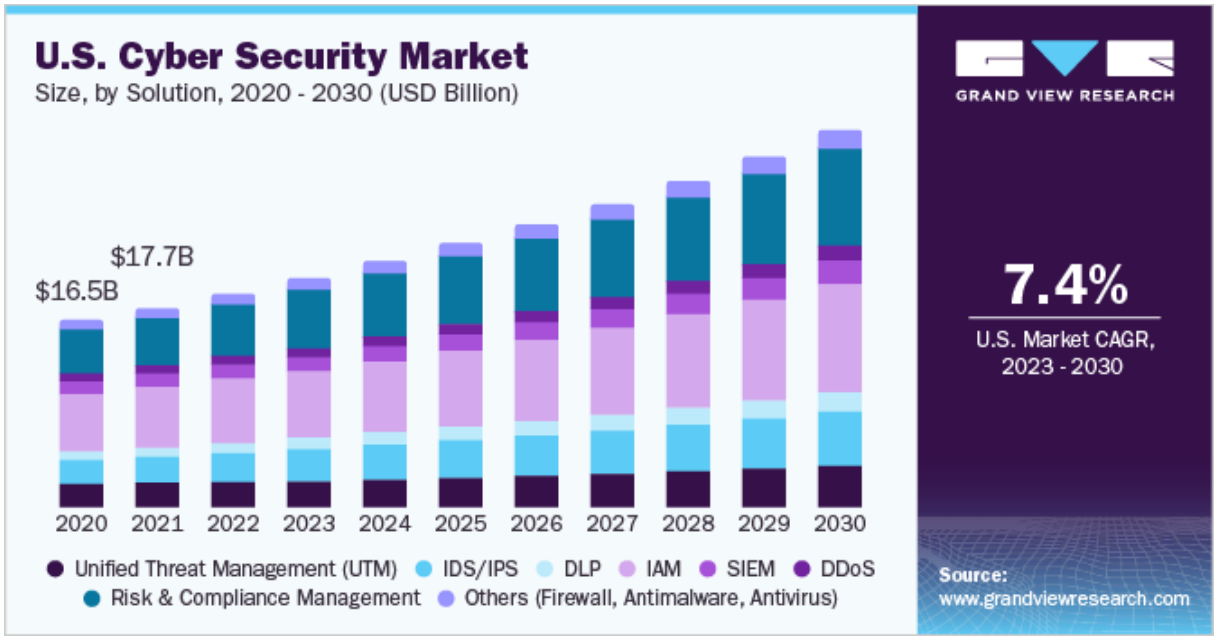

Figure 18: US Cyber Security Market, 2020-2030 [20]

A survey conducted within cybersecurity consumers showed that the total addressable market is valuated between USD 1.5 trillion to USD 2 trillion [21]. This means that the opportunity is even higher for those organisations willing to penetrate into the market.

Due to the growth of digital connectivity in Europe, the cybersecurity market is growing at a CAGR of 10.81%, going from estimated USD 56.96 billion in 2024 to USD 95.17 billion by 2029 [22].

Machine Learning & Artificial Intelligence

More adaptive and tailored services are needed to cover the increased digital demand of different organizations. Improved solutions, based on machine learning and/or artificial intelligence are now covering this need. Thus, this is making the machine learning market grow from USD 38.11 billion in 2022 to USD 771.38 billion by 2032, growing at a CAGR of 35.09% [23]; while the artificial intelligence market is growing at a CAGR of 19%, from USD 454.12 billion in 2022 to USD 2.57 trillion by 2032 [24].

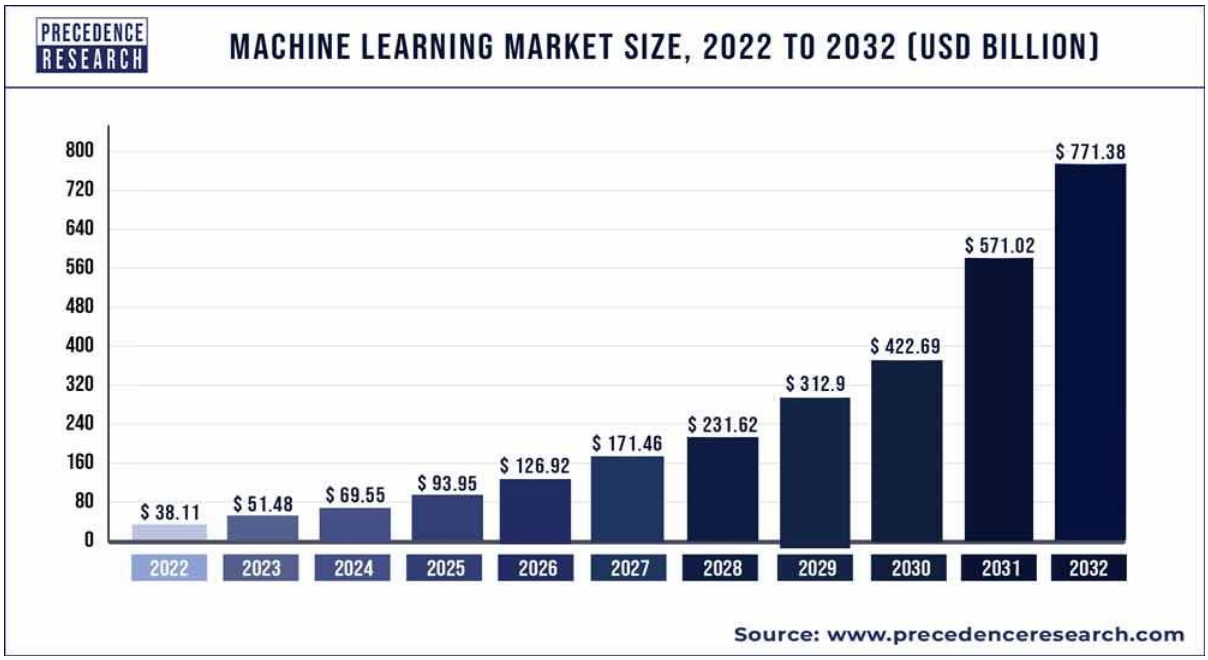

Figure 19: Machine Learning Market Size, 2022-2032 [23]

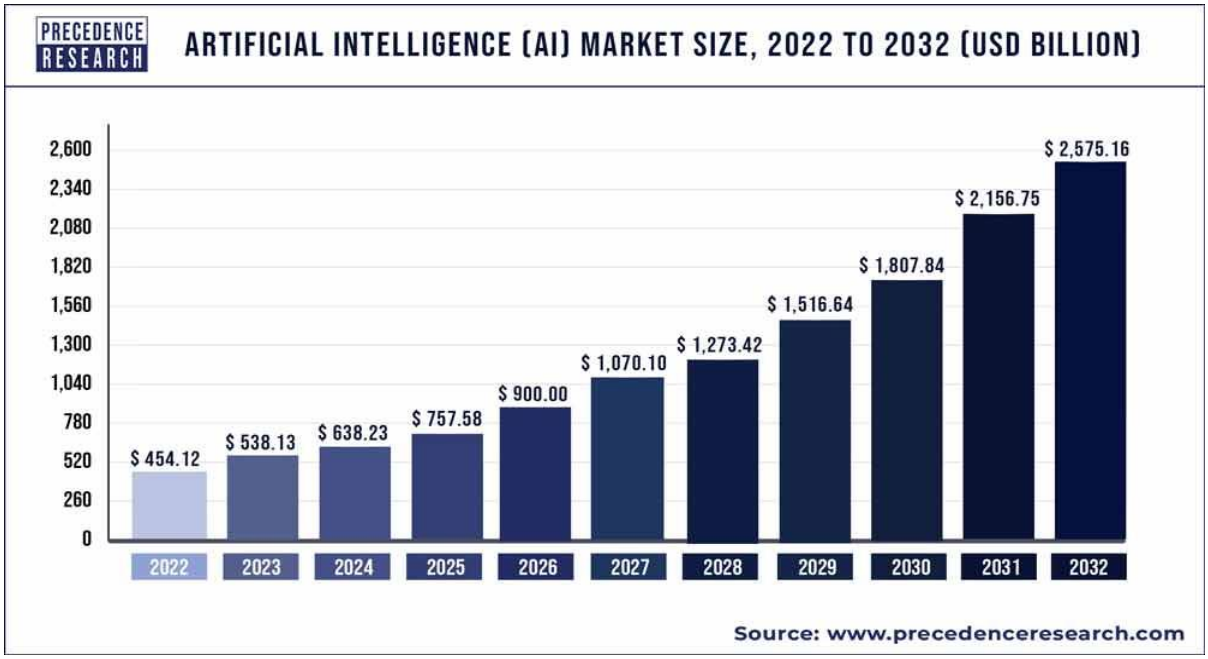

Figure 20: Artificial Intelligence Market Size, 2022-2032 [24]

In this context, the European machine learning market is growing at a very similar CAGR than the global one, 35%, going from USD 19.20 billion in 2022 to USD 225.91 billion by 2030 [25]. While the artificial intelligence market growth is even higher, 25.7% instead of 19%, going from USD 33.65 billion in 2022 to USD 325.29 billion by 2032 [26].

The combination of all this market trends into a single offering is creating a unique market for continuum computing, where different actors from all over the value chain will benefit from latest trends.

5.3.1 Competitors analysis

In this section we will be discussing the initial assessment to a market positioning of ICOS as a result of the competitors' analysis in the light of the defined KERs and their benefits, described in the section 5.3. It builds on the input provided by the consortium partners on the innovation they bring into the project, described in section 5.2, but has focus on the market together with the technology landscape to identify stable actors in the 6 KERs we consider in ICOS.

The methodology adopted is based on the feature comparison with the defined KERs in the project that correspond to layers, in respect to their domain of action. Additionally, we take into consideration: (1) if the competitor solutions belong to a computing continuum platform or portfolio of solutions (e.g., as in the case of AWS) corresponding to the KER 6; (2) if the competitor offers a marketplace for AI services, corresponding to KER 5; and (3) if the competitive solution implies vendor lock, in which case the competitor evaluation is penalized. These are marked below at each competitor with a subscript (P) for computing continuum platform; (M) for AI services marketplace; and (V) for vendor lock-in.

In the following, we describe the target markets associated to each ICOS Layer and the competitors acting on those four domains. We also provide an initial quantitative analysis of the competitors in each target market segment, and their positioning in regards to the technological coverage of ICOS features, and their market presence considering main adopters and business strategies (from what can be accessed online in their website or on Crunchbase). In the short descriptions provided per competitor, we focus on their main competitive features and how they compete with ICOS innovation reflected through its KERs.

Target Market 1: Data Management – The growing application of AI across many industries, in sectors like automotive, healthcare, retail, finance, and product manufacturing, demands a robust and efficient approach to data management. The global AI Data Management Market size and share is currently valued at USD 26.32 billion in 2023 [27].

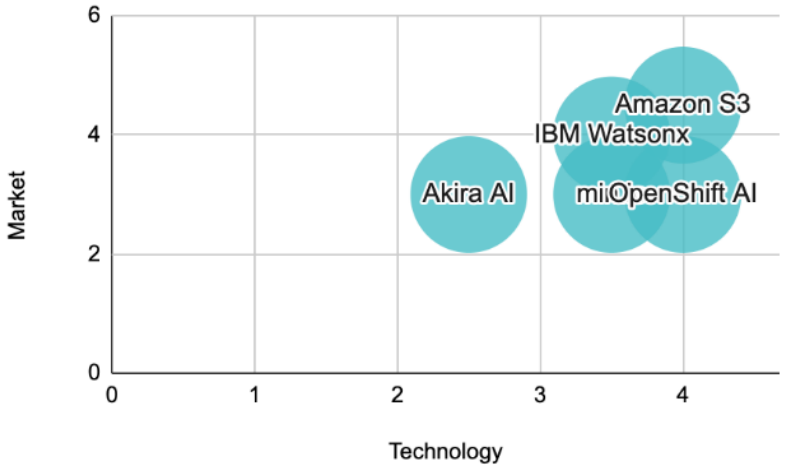

Figure 21: Data management competitors' positioning

- min.io [min.io]: Exascale, S3-compatible object store designed for high-performance AI/ML, data lake, and database workloads; software-defined and deployable on any cloud or on-premises infrastructure, supporting major Kubernetes distributions across public, private, and edge clouds.

- Amazon S3 [AWS](P)(M)(V): Offers a scalable, secure object storage for diverse use cases, featuring configurable access, optimization tools, and in-place querying for robust analytics, including S3 One Zone-IA support for swift retrieval of infrequently-accessed data, meeting dynamic business and compliance needs.
- Red Hat OpenShift AI [Red Hat/IBM](P): Provides data scientists and developers with end-to-end tools for AI/ML lifecycle management, offering a supported sandbox for rapid development, training, and testing of ML models in the public cloud. Its integrated capabilities ensure consistent MLOps across datacenters, public cloud, and edge computing environments.
- Akira AI Data Platform [Akira AI](M): Ensures a secure data pipeline with integrity and management, offering real-time, event-driven, hybrid cloud capabilities across diverse data sources, seamlessly integrating with business and technical flows to enhance operator productivity.
- IBM Watsonx [IBM] (P)(M)(V): Integrates a model studio for foundational models, generative AI, and machine learning; a purpose-built data store on an open data lakehouse architecture; and a toolkit for accelerating responsible, transparent, and explainable AI workflows, ensuring the scalable and impactful use of AI with trusted data in specific business contexts.

Target Market 2: Information Security – The information security market has increased considerably over the past years. It is a critical and rapidly evolving field that has focus on protecting networks, computer systems and data from various forms of cyber threats, including data breaches, cyberattacks, and unauthorized access. The global cyber security market size was reached at USD 211.48 billion in 2022 and it is projected to surpass around USD 691.64 billion by 2032, expanding at a CAGR of 12.58% during the forecast period 2023 to 2032 [28].

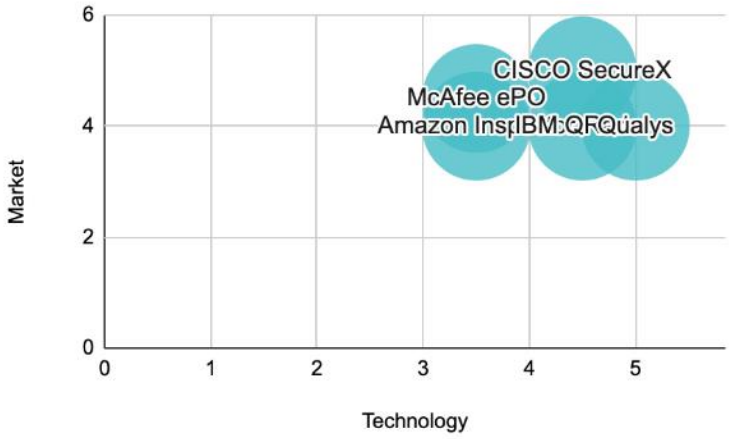

Figure 22: Information security competitors' positioning

- Amazon Inspector [AWS] (P)(M)(V): Offers a security service auditing device configuration, monitoring connected devices for anomalies, and mitigating risks, with a specific focus on IoT devices, seamlessly integrated within Azure Cloud security services in a closed environment.
- CISCO SecureX [CISCO] (P)(V): Provides high-tech products and services, with a comprehensive security portfolio, including IDPSs. Positioned as an endpoint security choice for MSSPs, CISCO SecureX is a cloud-native platform enabling security task orchestration, threat investigation, response, and network device inventory, albeit with relevance contingent on subscriptions to other CISCO services.
- IBM QRadar SIEM [IBM] (P)(M)(V): Empowers security teams with advanced AI, robust threat intelligence, and cutting-edge content for proactive threat response; it extends its capabilities to

address unmanaged IoT devices, focusing on threat management services in isolated IoT environments.

- McAfee ePolicy Orchestrator [McAfee] (P)(V): Offers a diverse product portfolio spanning network, server, cloud, web, SIEM, network analytics, data loss prevention, and endpoint security, complemented by McAfee ePO for comprehensive vulnerability management and incident response, along with the cloud-native MVISION XDR platform providing proactive actionable intelligence across the entire IT infrastructure.
- Qualys [Qualys]: A cloud-based solution detecting vulnerabilities across networked assets, including servers, network devices, peripherals, and workstations, with over 20 years of development, 10,000+ users, and a sigma 6 confidence level for false positives, featuring seamless cloud integration.

Target Market 3: Continuum Management - The Multi-Cloud Management Market is poised for substantial growth in the foreseeable future, driven primarily by the increasing demand for services such as metering and billing, provisioning, compliance management, infrastructure and resource management, identity and policy management, and lifecycle management. The global multi-cloud networking market is expected to increase from USD 2.7 billion in 2022 to USD 7.6 billion by 2027, at a Compound Annual Growth Rate of 22.5% during the forecast period [29].

Figure 23: Continuum management competitors' positioning

- Cloudify [Cloudify]: Open-source, multi-cloud, and edge service orchestration platform enabling application orchestration, infrastructure automation, EDGE networking, and multi-cloud networking.
- AWS Cloud Formation [AWS] (P)(M)(V): Streamlines cloud provisioning through infrastructure as code, enabling automated testing and deployment of templates with CI/CD automation for accelerated infrastructure management.
- OpenStack Heat [OpenInfra] (P): Employs an engine to launch composite cloud applications using code-like templates, managing the entire lifecycle and facilitating seamless infrastructure updates by modifying templates.
- Melodic Cloud [Melodic]: Offers a multicloud optimization platform enabling automatic deployment across diverse providers without configuration changes, followed by continuous monitoring and adaptive reconfiguration for optimal operational efficiency.

- AzureDevOps [Microsoft] (P)(M)(V): Can build, test, and deploy seamlessly in any language, on any cloud or on-premises, with parallel execution on Linux, macOS, and Windows, supporting deployment to individual hosts or Kubernetes; integrates with GitHub and other Git providers, featuring GitHub Advanced Security.

Target Market 4: AI Model Quantisation and Selection – At this level, machine learning allows computers to perform tasks intelligently by learning from data and examples rather than relying on pre-set rules. The embedded AI market is estimated to grow from USD 9.4 billion in 2023 to USD 18.0 billion by 2028, at a CAGR of 14.0% during the forecast period [30].

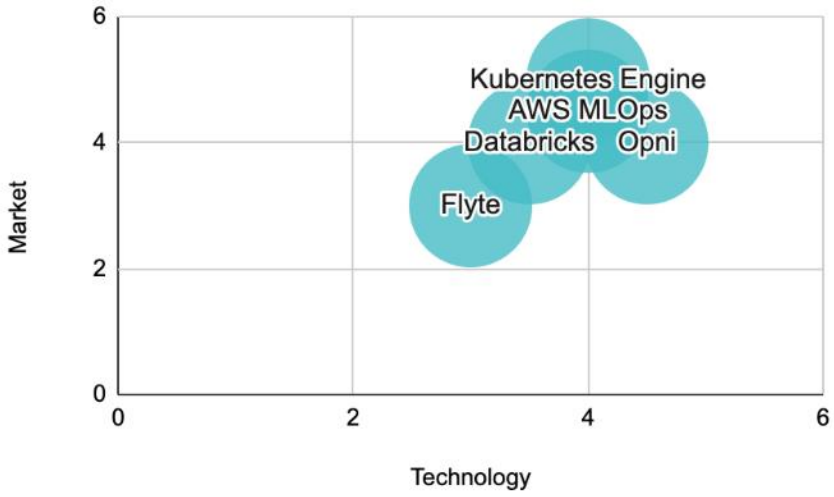

Figure 24: AI model quantisation and selection competitors' positioning

- Databricks Workflows [Databricks]: Provides a fully-managed orchestrator for data, analytics, and AI, ensures high reliability across major cloud providers (GCP, AWS, and Azure) with an increased platform limit to 10,000, automatically available in all customer workspaces (except single-tenant).
- Flyte [Flyte]: Makes dynamic use of heterogenous and resource-intensive infrastructures, providing efficiency, scalability, ease of use, and agility to optimize and automate pipeline management, especially addressing the complexities of AI pipelines compared to traditional ETL pipelines.
- AWS MLOps Workload Orchestrator [AWS] (P)(M)(V): Can establish a resilient pipeline leveraging managed automation tools and ML services for streamlined development and production of ML models; an extendable framework with a standard interface for orchestrating and monitoring pipelines across AWS ML services and third-party providers.
- Google Kubernetes Engine (GKE) [Google Cloud] (P)(M): Can orchestrate GPU and TPU-supported infrastructure for scalable training and serving workloads, seamlessly integrating with distributed computing and data processing frameworks; supports multiple teams on shared infrastructure for optimal resource utilization, exemplified by Google Kubernetes Engine (GKE) platform orchestration for AI/ML workloads.
- Opni [Opni]: Offers multi-cluster and multi-tenant observability, built on Kubernetes, and simplifies the process of creating and managing backends, agents, and data related to logging, monitoring, and tracing, also allowing users to swiftly detect anomalous activities in their data.

We have also identified the target market segments in the context of ICOS technology and innovation and, in a second phase, we will evaluate these over a criteria that reflects the market growth and the relevance for ICOS stakeholders. In this analysis, the market segments derive from the functionality of

the ICOS offering. That will allow us to compare with solutions that have a similar functionality next to our potential customers. In that second phase we will also evaluate the market coverage of our main competitors and compare it with the technological coverage driven by the ICOS KERs.

This next step towards the market positioning includes the evaluation of the product features that are important to achieve the market, and define the value curve in the light of the analysed unique value proposition generated by each of the KERs. We will then use that analysis to position the main competitors in a positioning representation confronting their value regarding product features against their market coverage. This is done through weighted sums at each of the main competitors. It will be re-evaluated throughout the project's lifetime in order to measure the progress of that market positioning.

5.4 Innovation management

In order to properly position ICOS compared with other existing solutions, it is important to highlight what its main innovations are. This information is also useful to develop the appropriate value propositions identifying the pains and gains of the solution.

The initial list of innovations developed within the project can be summarized as follows:

Table 46 Exploitable result #1 – main innovations

Name	ICOS Intelligence API Community Edition (AI coordination module)
Owner(s)	CeADAR
Main innovation(s)	Integration with data management, telemetry and security (anomaly detection). Added API compatibility for timeseries and online ML libraries. Added policies to remove models from the model registries when exceeding a pre-defined threshold.

Table 47 Exploitable result #2 – main innovations

Name	Predictive telemetry metrics model training – Bento (packet) for the AI Analytics module
Owner(s)	CeADAR
Main innovations	Forecasting functionality for telemetry metrics allowing offloadable model training and MLOps.

Table 48 Exploitable result #3 – main innovations

Name	Online machine learning models - Bento (packet) for the AI Analytics module
Owner(s)	CeADAR
Main innovations	Implementation and integration of online machine learning frameworks over an AI as a service API.

Table 49 Exploitable result #4 – main innovations

Name	ICOS Intelligence API Developer Edition (AI coordination module)
Owner(s)	CeADAR
Main innovations	Data pipelines functionalities, improved code repository, extra documentation, and extra algorithms and API endpoints available.

Table 50 Exploitable result #5 – main innovations

Name	ICOS AI Marketplace
Owner(s)	CeADAR
Main innovation(s)	New models to be reused or transfer learning to new applications.

Table 51 Exploitable result #6 – main innovations

Name	ICOS AI Analytics - Intelligence continuum models
Owner(s)	CeADAR
Main innovation(s)	Optimized models and model optimization techniques as a service.

Table 52 Exploitable result #7 – main innovations

Name	Security Layer Coordination module
Owner(s)	XLAB
Main innovations	OpenAPI-based coordination of security functionalities already implemented with ICOS Security Scan and ready to be implemented with other ICOS services

Table 53 Exploitable result #8 – main innovations

Name	Security Scan
Owner(s)	XLAB
Main innovations	This technology is able to automatically deploy security monitoring agents, integrated into the monitoring mechanisms and notify about security threats according to the policies, defined in the NFRs.

Table 54 Exploitable result #9 – main innovations

Name	LOMOS
Owner(s)	XLAB
Main innovations	New AIOps functionalities addressing ICOS priorities, and extension of the ML algorithm underlying the LOMOS system to adapt to ICOS types of logs, configuration of alerts for detected anomalies.

Table 55 Exploitable result #10 – main innovations

Name	Nuvla.io
Owner(s)	SixSq
Main innovations	▸ Fleet management enhanced features. ▸ Near-data processing. ▸ Public and private apps marketplace: ability to deploy both ready-to-use apps and your own. ▸ Hardware-agnostic. ▸ Great user experience: all features are also available via REST API for third-party integrations.

Table 56 Exploitable result #11 – main innovations

Name	NuvlaEdge
Owner(s)	SixSq
Main innovations	▸ All IP connectivity + VPN secured communication channel. ▸ Flexible. ▸ IoT peripheral discovery. ▸ Edge device and applications telemetry collection.

Table 57 Exploitable result #12 – main innovations

Name	Online machine learning models – Bento (packet) for the AI analytics module
Owner(s)	NKUA
Main innovations	Documentation, callable APIs, anomaly detection with various ML models

Table 58 Exploitable result #13 – main innovations

Name	Decentralised Computation Offloading with Energy Efficiency-aware (DECOFFEE)
Owner(s)	NKUA
Main innovations	Documentation, callable APIs, deep reinforcement learning Five (5) load forecasting models have been created

Table 59 Exploitable result #14 – main innovations

Name	Telemetruum
Owner(s)	ENG
Main innovations	The asset is based on a strong and stable FOSS technological stack composed by OpenTelemetry, Prometheus, OpenSearch. The asset mainly innovates by providing a dynamic, automated and secure deployment of these technologies along the continuum with ad-hoc, flexible configuration. The asset offers a set of pre-defined metrics, queries and dashboards that allow to know the topology and the status of the continuum as well as a novel service to define global and local deployment and performance policies based on telemetry data to be monitored and enforced in the continuum.

Table 60 Exploitable result #15 – main innovations

Name	PyCOMPSs
Owner(s)	BSC
Main innovations	PyCOMPSs/COMPSs is the only programming environment with a unified syntax that considers the three scenarios that require computation at any tier of the continuum. Unlike classical workflow managers and data analytics solutions, either batch analysis or real-time, which usually target in-cluster executions with some fault-tolerance mechanisms, COMPSs' design turns around the heterogeneity and the mobility of the devices to allow a rapid reaction to devices onboarding or departure. Regarding FaaS solutions, it avoids the vendor lock-in from solutions offered by major Cloud Providers; it actually offers a true serverless architecture (no need of a cloud endpoint due to its peer-to-peer design; and unlike similar solutions for FaaS such as serverledge or FuncX, it is able to detect nested parallelism to create parallelism hierarchies fitting the hierarchic nature of the network topologies in the continuum.

Table 61 Exploitable result #16 – main innovations

Name	dataClay
Owner(s)	BSC
Main innovations	Joint encapsulation of data model and data logic. This architecture provides a mechanism that allows execution offloading (running data logic close to the data structures). This mechanism reduces data transfers and can result in a more efficient use of computational resources.

Table 62 Exploitable result #17 – main innovations

Name	Node Feature Discovery (NFD) - Prometheus exporter - Device plugin
Main innovations	By integrating NFD with a custom Prometheus exporter, cluster administrators can collect and expose metrics related to the discovered node features, such as CPU capabilities, available hardware accelerators, or custom labels indicating specific node properties. These metrics can be visualized and monitored using Prometheus, a popular open-source monitoring system. Additionally, incorporating a Kubernetes plugin for external devices allows the cluster to manage and schedule workloads on nodes with specific external hardware devices, such as GPUs, NICs, or FPGAs, further optimizing resource allocation and workload performance. This integration offers a powerful toolset for optimizing and monitoring Kubernetes clusters, particularly in environments with heterogeneous hardware or specific performance requirements

Table 63 Exploitable result #18 – main innovations

Name	Tetragon Wazuh Agent
Owner(s)	NCSRD
Competitor(s)	Open source solutions such as Tracee, BPFtrace and Kubearmor
Main innovations	Tetragon's utilization of eBPF technology for granular, real-time observability and policy enforcement at the kernel level introduces a revolutionary approach to detecting and mitigating security threats directly within the operating system's core. This capability is seamlessly complemented by Wazuh's extensive feature set for intrusion detection, compliance verification, log analysis, and alerting. The synergy between Tetragon's cutting-edge observability and Wazuh's robust security analytics enables organizations to achieve an unprecedented level of security posture, offering detailed insights into system behaviour and rapid detection of threats.

Table 64 Exploitable result #19 – main innovations

Name	ICOS Shell
Owner(s)	TUBS, UPC
Main innovations	Allows for administration of the ICOS MetaOS

Table 65 Exploitable result #20 – main innovations

Name	Smart & Efficient matchmaking
Owner(s)	UPC
Main innovations	AI-assisted allocation strategy Adaptable runtime re-allocation

Table 66 Exploitable result #21 – main innovations

Name	Job Manager
Owner(s)	ATOS
Main innovations	The Job Manager asset allows to create, manage and schedule different kind of jobs. It is a Go microservice RESTful API that accepts connections from others ICOS assets that can pull mentioned jobs. This microservice also contains a database that serves as root of trust.

Table 67 Exploitable result #22 – main innovations

Name	Deployment Manager
Owner(s)	ATOS
Main innovations	The Deployment Manager asset allows to request, manage and execute different jobs that exist in the Job Manager's persistence. It is a microservice in Go with a sidecar, it is an API that only works in pull mode and won't accept requests.

Table 68 Exploitable result #23 – main innovations

Name	Aggregator
Owner(s)	ATOS
Main innovations	The asset is capable of serving multi-cluster infrastructure state in a flexible manner , as data may be delivered in multiple formats (JSON or Protobuf) and in different data models structures, tailored to the project's needs.

During the second project iteration, each of these innovations will be analysed and categorized to support the exploitation strategy.

5.5 Business model(s)

According to partners plans, there are three potential models that can be applied to project results: i) academic or research, for those organisations not willing to commercialise results but to get indirect revenue from the exploitation of results; ii) open source, at list for the source code and the additional revenues that can be got through the offering of added value services on top of it; and iii) B2B, or direct software commercialization to a specific customer.

Further details about how which business model will be applied to which result are provided below:

Table 69 Exploitable result #1 – business model and exploitation path

Name	ICOS Intelligence API Community Edition (AI coordination module)
Owner(s)	CeADAR
Business model	Open source business model monetized by paid support, training and technology/feature customization
Exploitation path	Aligned with the overall exploitation of the ICOS solution.

Table 70 Exploitable result #2 – business model and exploitation path

Name	Predictive telemetry metrics model training – Bento (packet) for the AI Analytics module
Owner(s)	CeADAR
Business model	Open source business model monetized by paid support, training and technology/feature customization.
Exploitation path	Aligned with the overall exploitation of the ICOS solution.

Table 71 Exploitable result #3 – business model and exploitation path

Name	Online machine learning models - Bento (packet) for the AI Analytics module
Owner(s)	CeADAR
Business model	This technology and its related features are offered as premium paid features over the open source baseline functionality.
Exploitation path	Preparation of commercial solution based on the technological developments in ICOS and use cases.

Table 72 Exploitable result #4 – business model and exploitation path

Name	ICOS Intelligence API Developer Edition (AI coordination module)
Owner(s)	CeADAR
Business model	This technology and its related features are offered as premium paid features over the open source baseline functionality.
Exploitation path	Preparation of commercial solution based on the technological developments in ICOS and use cases.

Table 73 Exploitable result #5 – business model and exploitation path

Name	ICOS AI Marketplace
Owner(s)	CeADAR
Business model	Open-source business model monetized by paid support, training and technology/feature customization
Exploitation path	Aligned with the overall exploitation of the ICOS solution.

Table 74 Exploitable result #6 – business model and exploitation path

Name	ICOS AI Analytics - Intelligence continuum models
Owner(s)	CeADAR
Business model	Open-source business model monetized by paid support, training and technology/feature customization
Exploitation path	Aligned with the overall exploitation of the ICOS solution.

Table 75 Exploitable result #7 – business model and exploitation path

Name	Security Layer Coordination module
Owner(s)	XLAB
Business model	Open source business model monetized by paid support, training and technology/feature customization
Exploitation path	Aligned with the overall exploitation of the ICOS solution

Table 76 Exploitable result #8 – business model and exploitation path

Name	Security Scan
Owner(s)	XLAB
Business model	Open source business model monetized by paid support, training and technology/feature customization
Exploitation path	Benefiting from the overall exploitation of the ICOS solution, but with an individual exploitation roadmap that follows the release and benchmark of the OSS solution.

Table 77 Exploitable result #9 – business model and exploitation path

Name	LOMOS
Owner(s)	XLAB
Business model	This technology and its related features are offered as premium paid features over the open source baseline functionality.
Exploitation path	Preparation of commercial solution based on the technological developments in ICOS, and the benchmark from the use cases in this and other projects as success stories.

Table 78 Exploitable result #10 – business model and exploitation path

Name	Nuvla.io
Owner(s)	SixSq
Business model	PaaS (Platform-as-a-Service)
Exploitation path	Nuvla.io is already exploited by SixSq, and is in line with the ICOS overall exploitation roadmap.

Table 79 Exploitable result #11 – business model and exploitation path

Name	NuvlaEdge
Owner(s)	SixSq
Business model	SaaS
Exploitation path	NuvlaEdge is already exploited by SixSq and is in line with the ICOS overall exploitation roadmap.

Table 80 Exploitable result #12 – business model and exploitation path

Name	Online machine learning models – Bento (packet) for the AI analytics module
Owner(s)	NKUA
Business model	Not decided yet
Exploitation path	The goal is to create open source datasets to be publicly available via IEEE data port. Moreover, part of this work will be published in international conferences or high-quality journals.

Table 81 Exploitable result #13 – business model and exploitation path

Name	Decentralised Computation Offloading with Energy Efficiency-aware (DECOFFEE)
Owner(s)	NKUA
Business model	Not decided yet
Exploitation path	The goal is to create open-source datasets to be publicly available via IEEE data port. Moreover, part of this work will be published in international conferences or high-quality journals.

Table 82 Exploitable result #14 – business model and exploitation path

Name	Telemetruum
Owner(s)	ENG
Business model	Open source business model monetized by paid support, training and technology/feature customization
Exploitation path	The solution will be realized and improved in the ICOS project. The prototype and the experience gained in ICOS will be used internally to the company (by the IT department) that will improve and prepare the solution to be used in real projects where ENG manage client's infrastructures.

Table 83 Exploitable result #15 – business model and exploitation path

Name	PyCOMPSs
Owner(s)	BSC
Business model	Not decided yet
Exploitation path	The solution will be improved in the frame of the ICOS project. As an academic partner, BSC expects to disseminate the solution code as open source as well as publishing the innovations in academic conferences and journals. In addition, the improved version of COMPSs resulting from ICOS will be used in other internal projects as well as in other collaborative projects applied to IoT-Edge-Cloud and HPC infrastructures.

Table 84 Exploitable result #16 – business model and exploitation path

Name	dataClay
Owner(s)	BSC
Business model	Not decided yet
Competitor(s)	Apache IoTDB and eXtremeDB
Exploitation path	The solution will be improved in the frame of the ICOS project. As an academic partner, BSC expects to disseminate the solution code as open source as well as publishing the innovations in academic conferences and journals. In addition, the improved version of dataClay resulting from ICOS will be used in other internal projects as well as in other collaborative projects applied to IoT-Edge-Cloud and HPC infrastructures.

Table 85 Exploitable result #17 – business model and exploitation path

Name	Node Feature Discovery (NFD) - Prometheus exporter - Device plugin
Owner(s)	NCSRD
Business model	Open source business model monetized by paid support, training and technology/feature customization
Exploitation path	The solution will mature alongside with ICOS and the goal is to develop a generic solution that optimize resource efficiency across the infrastructure of NCSRD.

Table 86 Exploitable result #18 – business model and exploitation path

Name	Tetragon Wazuh Agent
Owner(s)	NCSRD
Business model	Open source business model monetized by paid support, training and technology/feature customization
Exploitation path	By leveraging Tetragon's advanced eBPF-based observability for real-time monitoring and enforcement at the kernel level, combined with Wazuh's comprehensive intrusion detection the goal is to safeguard the ICOS project's infrastructure against sophisticated cyber threats.

Table 87 Exploitable result #19 – business model and exploitation path

Name	ICOS Shell
Owner(s)	TUBS, UPC
Business model	Not decided yet
Exploitation path	Aligned with the overall exploitation of the ICOS solution.

Table 88 Exploitable result #20 – business model and exploitation path

Name	Smart & Efficient matchmaking
Owner(s)	UPC
Business model	Not decided yet
Exploitation path	Generate different models that can be trained and even clustered into potential groups to characterize different layout conditions. Scientific publications are also expected to come up.

Table 89 Exploitable result #21 – business model and exploitation path

Name	Job Manager
Owner(s)	ATOS
Business model	This technology and its related features are offered as premium paid features over the open-source baseline functionality.
Exploitation path	This asset will be completed in the ICOS project. It will be internally used by ATOS internal teams to solve business complexities regarding Application Deployments in highly distributed infrastructure in real projects.

Table 90 Exploitable result #22 – business model and exploitation path

Name	Deployment Manager
Owner(s)	ATOS
Business model	This technology and its related features are offered as premium paid features over the open-source baseline functionality.
Exploitation path	This asset will be completed in the ICOS project. It will be internally used by ATOS internal teams to solve business complexities regarding Application Deployments in highly distributed infrastructure in real projects.

Table 91 Exploitable result #23 – business model and exploitation path

Name	Aggregator
Owner(s)	ATOS
Business model	This technology and its related features are offered as premium paid features over the open-source baseline functionality.
Exploitation path	This asset will be completed in the ICOS project. It will be internally used by ATOS internal teams to solve business complexities regarding multi-cluster infrastructure status querying in a flexible data structure format.

5.6 First version of the ICOS micro-economic analysis

ICOS will present a micro-economic analysis at the end of the project with the main aim to support decision making processes for adopting its solutions. This will be split into three main steps:

1. Provide information enough to support decision makers about if it worth to invest in the ICOS solution.
2. Identify how the market is behaving and provided additional information for the ICOS consortium to implement its commercialization strategy.
3. Highlight how customers may benefit from using ICOS results.

5.6.1 Techno-economic analysis

First step relates to the techno-economic analysis of the ICOS solution. This is a basic analysis of the current environment to provide all the needed information to properly position ICOS results. The methodology to be followed presents all the needed information in a simplified manner as everything must be seen in single view. However, all the procedure followed will be also documented to support these highlights.

First step of the analysis consists of an analysis of the risks associated to business growth. In the specific case of ICOS, the consortium aims to introduce new products into the market. Thus, the most common used tool is the Ansoff matrix [31].

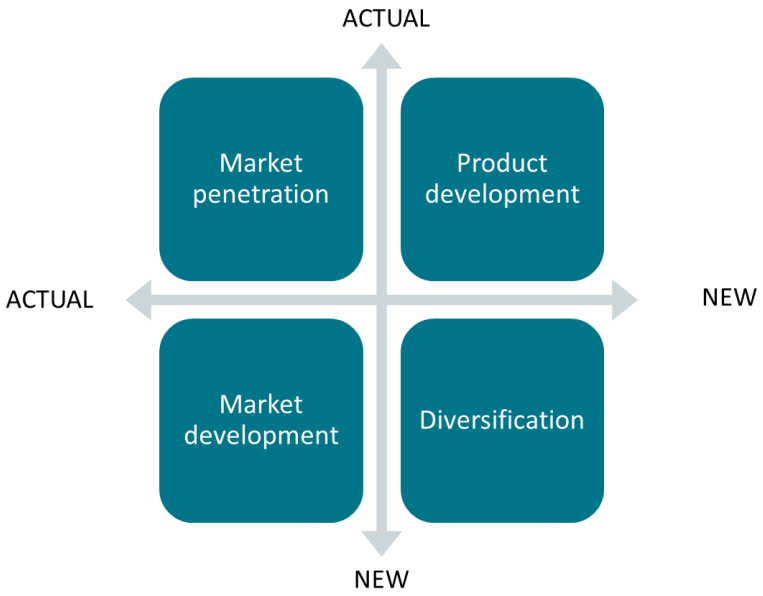

Figure 25: Ansoff Matrix

Within this matrix, four dimensions are analysed:

1. *Market penetration:* analysing if it is possible to increase the sales with an existing product into an existing market.
2. *Market development:* for existing products into new markets.
3. *Product development:* for innovative products, or even new ones, competing into an existing market.
4. *Diversification:* a total uncertain new market for new products, where it is quite complicated to measure the impact.

Results of this analysis will provide additional recommendations for the go-to-market strategy, as they allow to estimate the potential risks of the defined strategy.

The next step is to analyse the real market size where ICOS may compete. In this case, a more thorough market analysis is needed, going from the generalities to the achievable one.

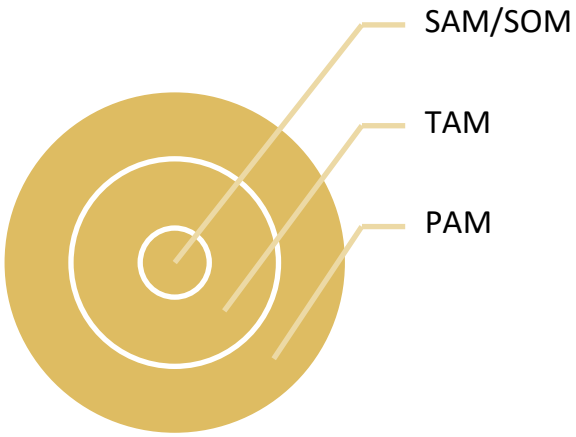

Figure 26: TAM Analysis

The most useful tool to be used is the TAM analysis, as it goes from the global market to the obtainable one:

- *PAM analysis:* collects and analyses information of the global market share.
- *TAM analysis:* focuses on the addressable one, in ICOS case it is referred to the European market share.
- *SAM analysis:* even if the target market is Europe, overall, the consortium is not operating in all countries, specially at KER level. Thus, the available market refers to those countries where the ICOS partners are already established.
- *SOM analysis:* finally, this is the more fine-grained analysis as it relies on the consortium channelling limitations and the contacts already established.

So, for the go-to-market strategy, it provides major highlights about whether if worth to invest, or how much, in the continues development of ICOS results according to the potential return of investment.

Finally, some inbound marketing tools are needed, like Buyer Persona analysis to properly understand potential customers needs and expectations. This means that, beyond identifying the targeted stakeholders, ICOS will collect feedback from them, mainly from project use cases, open call winners and advisory board members. In this way, it is possible to develop tailored strategies for each of them. Additionally, a Customer Lifetime Value analysis will be performed, comparing the worst and best scenarios, to rank the stakeholders based on the potential revenue that ICOS can get from them.

With the results of these analysis, the go-to-market strategy will be presented mapping key exploitable results with targeted stakeholders, business models to be applied and the value proposition to be shared. Additionally, these results will be ordered according to their potential revenue and the expected time-to-market.

5.6.2 Strategic consulting analysis

Once the previous step is finished, it is necessary to analyse the competitors to set the goals the consortium wants to achieve. For example, if a new company was set up 10 years ago to commercialise a similar solution but its valuation is still too low, probably the asset to be commercialized does not have enough value on its own due to a low market penetration even if the market analysis estimates a continuous growth.

Several factors will be taken into account for this analysis:

- Year of foundation of the company and its current valuation, to estimate how long it will take to get benefits from the asset commercialization.
- Merges and acquisitions already happening, to measure how attractive these solutions are to, e.g., bigger companies who want to incorporate them within their portfolio.
- Funding evolution, to measure the progress of a company after a funding round and to measure the attraction of potential investors to this kind of solutions.

This analysis will be performed competitor by competitor at individual and joint asset to provide additional recommendations for the go-to-market strategy, complementing the ones provided during the previous step.

5.6.3 Cost-benefit analysis

This is the third part of a micro-economic analysis, where use cases or any other type of applications are used to measure the investment needed to use a technical solution compared with the potential benefits that can be got.

This first iteration collects the available information from the project use cases that will be further on elaborated and deeply analysed.

5.6.3.1 Use Case 1: Agriculture Operational Robotic Platform (AORP)

General introduction

The Agriculture Operational Robotic Platform (AORP) utilizes ICOS for implementing three key functionalities: Predictive Maintenance of machinery and remote steering, Crop management analytics (weed map), and Validation and Improvements of ML models for robots' operations and steering. The platform autonomously performs tasks such as sowing, tending crops, weed removal, and threat identification, enhancing agricultural efficiency and precision.

Problem to be solved

The use case addresses challenges in predictive maintenance, crop management analytics, and model validation for agricultural robotics. Key issues include accessibility, connectivity, and the need for seamless data management. The existing applications face constraints in optimizing resources based on varying conditions and constraints.

Results after using ICOS

ICOS significantly enhances the use case by providing a robust cloud infrastructure for data storage, analysis, and management. The implementation of ICOS allows for optimized resource utilization, improved connectivity, and streamlined data processing. Predictive maintenance becomes more effective, crop management analytics achieve higher precision, and ML models for robot operations see continuous enhancements. Below, you can see diagrams of the software with and without ICOS integration.

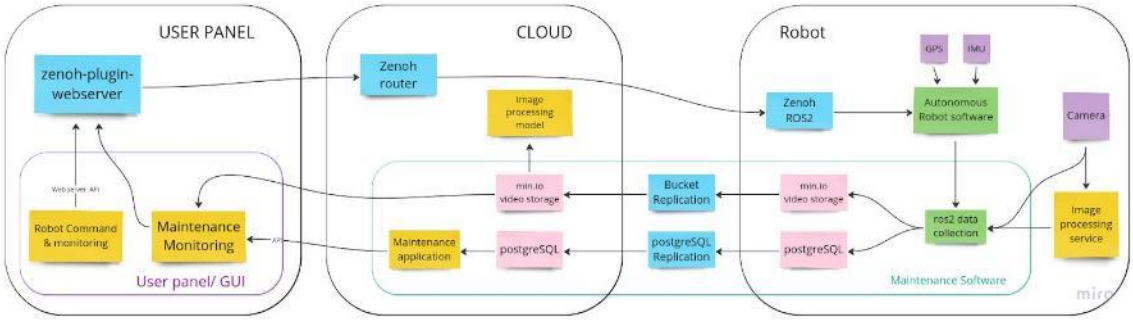

Figure 27: System architecture without ICOS

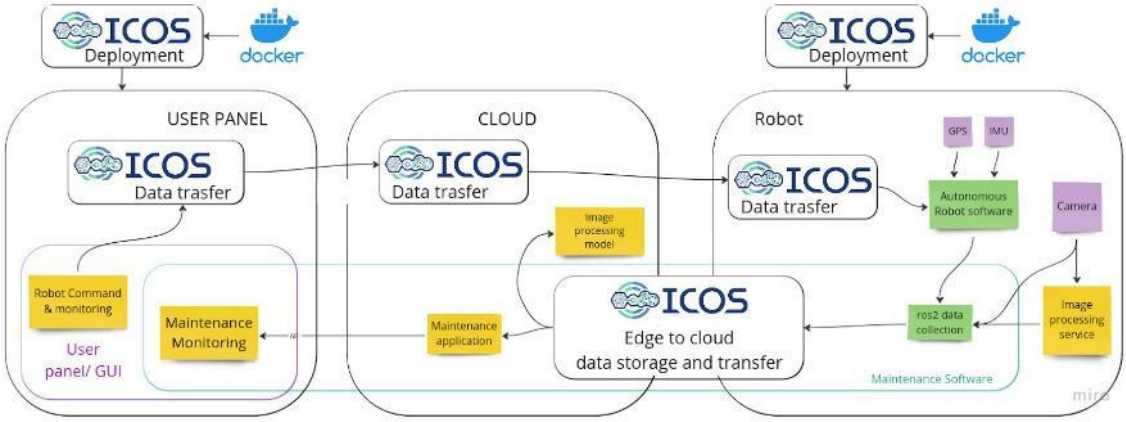

Figure 28: System architecture with ICOS

Technical Description

UC1 has plan to develop a complete software solution for a swarm of agricultural robots to autonomously navigate through a farm, execute planned tasks, collect data and analyse the farm data for future processes such as farm mapping and AI based plant image processing as well as predictive maintenance software for the robots. These software are distributed through multiple edges and clouds, with communication between the software modules.

The below software systems must be developed.

- **Autonomous robot software system**
  - Robot autonomously navigate and execute tasks in the farm
  - Farm data collection
  - Data transfer to cloud
- **Robot monitoring and commanding software system**

  The robot monitoring and commanding software is divided into two separated modules, one facilitates visualization of robotic functionality and control of the robot in low level based on ROS2 which is only functional in local network with robot, and the second module as higher level GUI facilitate the higher level controls such as mission management based on Web or cross platform technologies functional remotely through internet by connecting to robot through cloud services.
- **Robotic panel (low level GUI)**

  An interface that facilitates autonomous functionality of the robot at the farm

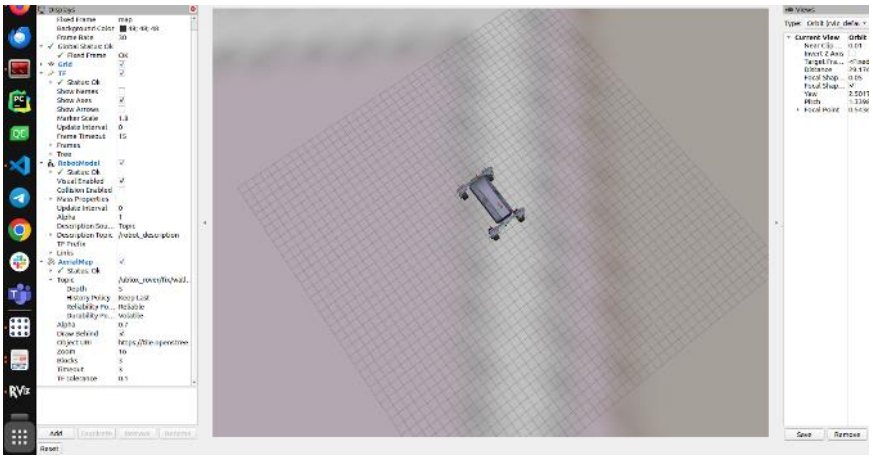

Figure 29: A preview of low level GUI (developed in ICOS)

- **Farm Web app panel (High level GUI)**

  Web app with limited functionalities and monitoring interface accessible to robot and farm data remotely

Figure 30: A preview of initial version of high level GUI (developed in ICOS project)

- **Farm and plant mapping software system (Yield map)**

  A software system that detects plants and weeds, computing the global coordinates of each plant generating a plant intensity map of the farm**.** This software functions over a distributed process from edge node (robot) collecting the plant data, cloud (generating the map) and edge node (UI panel for visualization).

Figure 31: A example of crop and farm map (Yield map)

- **Predictive maintenance software**

  A software system that collects operational data of the farm robot and based on executed missions and status of the robot provides predictive maintenance insight through its UI. This software functions over a distributed process from edge node (robot), cloud (predictive maintenance processes) and edge node (UI panel).

- **AI based Plant analyses system**

  Majority of the tasks planned to be executed by the agricultural mobile robot relies on detection of plants and weeds during operation of the robot, whether for farm mapping, weed termination, plant counting, etc.

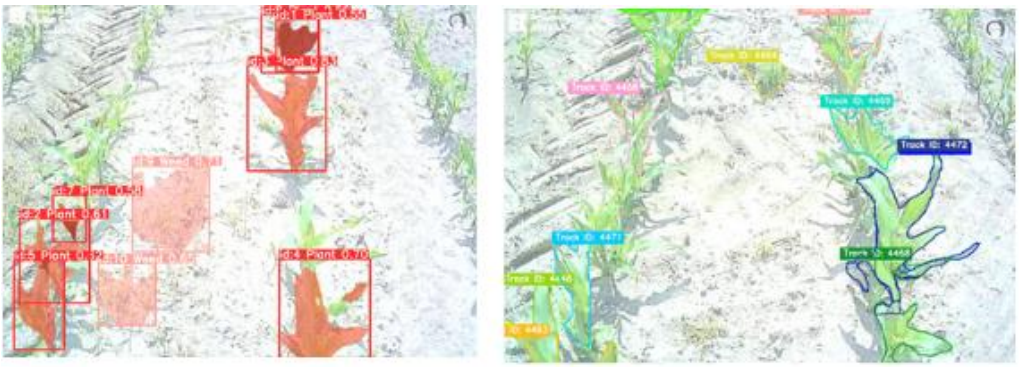

Figure 32: Corn and weed detection, segmentation, counting and tracking (developed in ICOS project)

Use Case Overview

The Agriculture Operational Robotic Platform (AORP) is a sophisticated autonomous system designed for agricultural tasks. The platform incorporates advanced technologies to execute field missions such as sowing, crop tending, weed removal, and threat identification. The AORP leverages the Industrial Cloud Operating System (ICOS) to enhance three primary functionalities: Predictive Maintenance, Crop Management Analytics (Weed Map), and Validation and Improvements of ML Models for robot operations and steering.

Autonomous Robotic Platform:

The mobile platform of the AORP is equipped with four independent steerable wheels, allowing for advanced manoeuvres like skid steering and Ackermann steering. A diesel engine powers hydraulic pumps and alternators, generating electricity to charge batteries. These batteries, connected to a power inverter, supply electricity to external electronic equipment. With a fuel tank capacity sufficient for 88 hours of continuous operation, the AORP is capable of prolonged missions.

Robotic System Architecture:

The robotic platform is driven by a rugged embedded industrial computer (Neousys Nuvo), running Ubuntu as the operating system and ROS2 for functional operation. A ROS2-CAN bridge node facilitates low-level communication with the robot's Electronic Control Unit (ECU) through a USB-CAN adaptor. The platform integrates RGB and RGB-D cameras, lidar, Inertial Measurement Unit (IMU), encoders, and a Global Navigation Satellite System (GNSS) for navigation and data collection.

Data Processing and Navigation:

Cameras and lidar are employed for segmentation, object detection, navigation, and mapping. GNSS, IMU, and encoder data are fused to provide accurate state estimation. Raw sensor data and navigation stack in ROS2 enable the robot to simultaneously localize itself on the map, navigate to the destination, and avoid obstacles. Communication channels were upgraded to LoRa, WIFI, and xG modems, enabling control and data transfer locally and to the cloud.

ICOS Integration:

ICOS serves as the backbone for deployment, data management, storage, and analysis. The Predictive Maintenance functionality utilizes ICOS to store raw data on the cloud, allowing for cloud analysis and sending control signals back to the robotic platform in case of issues. Crop Management Analytics leverage ICOS for transparent management in the continuum, optimizing resource use based on constraints. Validation and Improvements of ML Models utilize ICOS to transfer data from devices to the cloud for training and continuous improvement.

Functionalities:

1. Predictive Maintenance and Remote Steering: ICOS stores raw data on the cloud, enabling predictive maintenance analysis based on vibrations and signal control information. Control signals are sent back to the robotic platform to address issues. A user interface for maintenance management is created, emphasizing secure connections and access policies.
2. Crop Management Analytics (Weed Map): ICOS manages the continuum of data processing, enabling precision weed mapping during field missions. The system optimizes the use of ICOS elements based on connectivity and precision requirements, ensuring efficient resource utilization.
3. Validation and Improvements of ML Models: ICOS facilitates the transfer of data to the cloud for the training and enhancement of ML models. The use of near and far-edge computing is optimized, focusing on movement speed and handling unexpected obstacles to improve the overall capabilities of the robotic platform.

The integration of ICOS into the AORP's operational framework enhances its technical capabilities, addressing challenges in data management, connectivity, and optimization of resources across various agricultural tasks.

Business Description

Use of ICOS in AORP addresses number of challenges that can potentially have significant impact of business efficiency both in maintain existing product and providing cut-to-need hardware solution for each agent deployed. The positive impact of business validation can be observed in following areas:

1. Platform software development cost – providing ready to use modules the time needed for developing dedicated modules is reduced drastically. This refers to i.e. predictive maintenance module, maintenance data flow, firmware update mechanisms, system management environment,
2. Hardware BOM cost – thanks to mixed infrastructure architecture and possibility to use cloud base computing power there is possibility to reduce cost of BOM in agents keeping only computing power related to gathering and executing commands from remote. In order to keep development of the use-case ongoing there has been used powerful CPU+GPU in order to process visual AI identification of the crops. We plan to with use of ICOS reduce needed hardware to be more efficient in cost for each machine.

Use Case Overview

The project of Agriculture Operational Robotic Platform *is vital for new farming directions that has been seen for couple of years now. The idea behind creating* is to be able to deliver in comparably short time firmware for such devices consisting of customized modules. This approach does not fulfil the need of providing easy to maintain and control platform for operations of each functional node of the system, which in case of AORP consists at least of field robotic device, local platform for gathering data. Other parts of the system that need to be consider depending on local needs is remote maintenance access (from position of manufacturer), multiple remote control panel access.

Positioning

ICOS can drastically reduce the cost of development and maintenance of platform that will be used by

Additional Material

The described software is distributed on edge and cloud as listed below in agricultural use case:

1. **Robot (edge 1) - Nuvo boxed industrial computer**
2. Ubuntu desktop

3. ROS2 Humble
4. Dockerized
5. **Robotic panel (edge 2) - Gaming laptop config**
6. Ubuntu desktop
7. ROS2 Humble
8. Dockerized
9. **Farm panel computer (edge 3) - Business laptop config**
10. Running web/ Flutter app
11. OS independent
12. Dockerized
13. **Cloud - VPS (Virtual Private Server)**

The image below illustrates the edge-cloud environment setup in UC1.

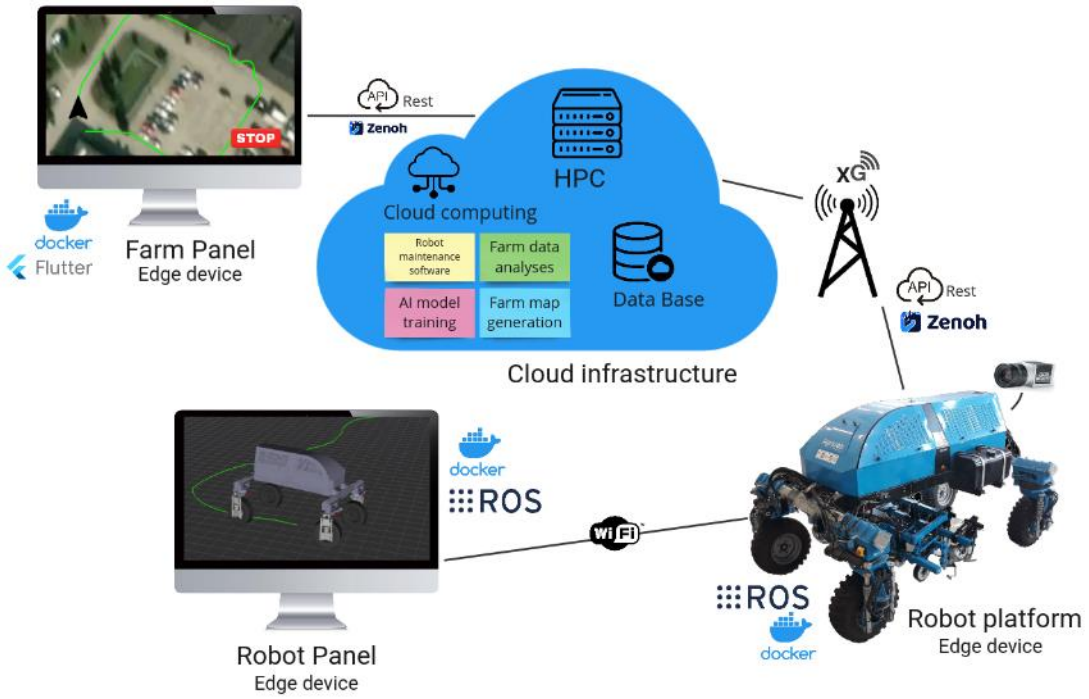

Figure 33: Edge-cloud environment

5.6.3.2 Use Case 2: Railway Structural Alert Monitoring system (RSAM)

General introduction

Ferrocarrils de la Generalitat de Catalunya (FGC), in collaboration with Worldsensing (WSE), is implementing a pioneering Use Case focused on Railway Structural Alert Monitoring. This initiative integrates the cutting-edge technology of the ICOS to enhance safety, operational efficiency, and maintenance practices across FGC's extensive railway network.

Problem to be solved

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. 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.

Results after using ICOS

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

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

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

Technical Description

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
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.
IoT Gateway:
The gateway serves as a communication hub between the IoT devices (nodes) and the central cloud-based system (CMT). 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.
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.

Requirements

Table 92 UC2 Requirements

Priority	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

Priority	Application name	Problem	Requirement for ICOS	Expected Validation date
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)

Business Description

Ferrocarrils de la Generalitat de Catalunya (FGC):

FGC is a key player in Barcelona's transportation sector, managing a robust rail network that caters to over 90 million passengers annually. Emphasizing safety and innovation, FGC leverages technologies like RSAM and ICOS to optimize rail operations, ensuring a reliable and technologically advanced service for its passengers.

Worldsensing:

Worldsensing is a global leader in business-focused smart city solutions and IIoT technologies. Specializing in enhancing urban and industrial operations, Worldsensing provides transformative solutions for traffic management, environmental monitoring, and industrial efficiency. Key products include RSAM for proactive rail maintenance and CMT Cloud for streamlined data processing. Committed to innovation, Worldsensing empowers businesses to thrive in a connected and data-driven future.

Use Case Overview

The integration of ICOS into the RSAM use case represents a strategic move for FGC to enhance operational efficiency, reduce costs, improve safety, and position itself for potential growth and innovation in the competitive transportation sector.

Positioning

As of the current stage, it's important to note that we can only articulate our expectations for the impact that ICOS will bring based on our pre-implementation assessment. The actual impact evaluation will be conducted post-implementation, probably close to the IT2 release. With that clarification in mind, here are our anticipated expectations and future perspectives.

<u>from FGC perspective:</u>

Operational Efficiency and Cost Savings: the integration of ICOS might streamline operations. Real-time analysis and decision-making capabilities are expected to reduce the need for labour-intensive, daily inspections, leading to time and cost savings.

Enhanced Safety and Risk Mitigation:

The critical event detection and decision-making capabilities developed during the project, even in areas with limited connectivity, are expected to enhance safety of the rail network. Early identification and mitigation of potential issues are anticipated to contribute to a safer rail environment and improved operational resilience.

<u>from Worldsensing perspective:</u>

Expansion of Service Offerings:

The experience gained through ICOS may pave the way for the expansion of Worldsensing's service offerings. The integrated system of Worldsensing monitoring solution and ICOS might enable the development of new applications that align with market demands, thus broadening our portfolio and attracting new business opportunities.

Collaboration with Industry Stakeholders:

Worldsensing aims to strengthen collaboration with key industry stakeholders, including railway operators, government bodies, and technology partners. By showcasing the benefits of ICOS in improving operational efficiency, safety, and cost-effectiveness, Worldsensing anticipates fostering partnerships that contribute to shared success and industry advancements.

ICOS Interaction

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.

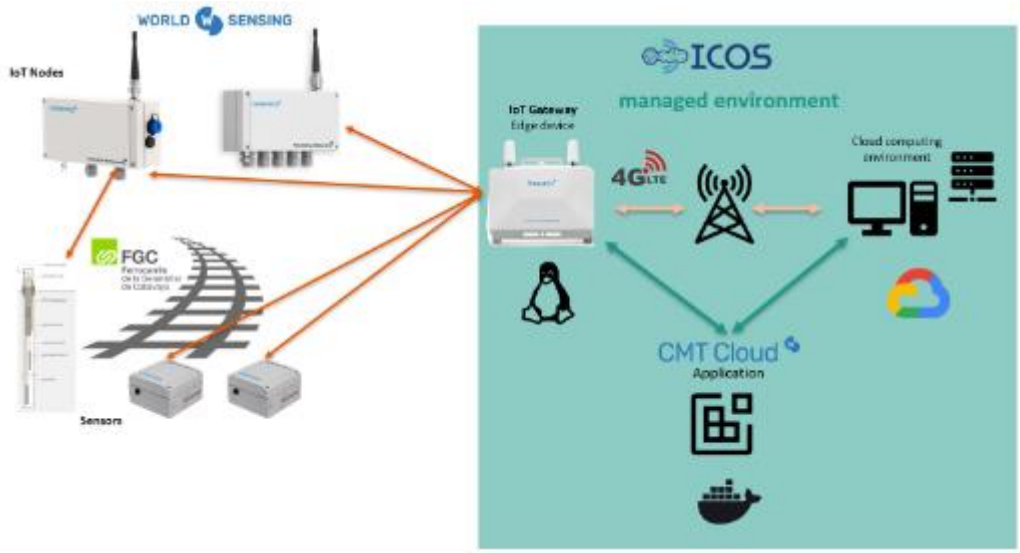

Figure 34: ICOS Use Case 2 testbed

Invested time

The associated costs of implementing ICOS for Worldsensing and Ferrocarrils de la Generalitat de Catalunya (FGC) is not yet known. At this point we can estimate time for components related to the deployment, integration, and ongoing operation of the system.

It's important to note that the actual costs may vary based on the future specific requirements, scale of deployment, and the complexity of the ICOS. Standardizing the ICOS onboarding process is a critical element that can influence not only the initial implementation costs but also the ongoing operational costs and the overall success of the ICOS deployment.

Some potential cost considerations:

1. Software Development and Integration Costs:
   - Customization and development of software components specific to ICOS.
   - Integration of ICOS with existing systems, databases, and IoT devices.
2. Hardware and IoT Device Costs:
   - Procurement of IoT devices such as Tiltmeters, Extensometers, Piezometers, and IoT Gateways.
   - Investment in compatible hardware for edge processing, including servers or gateways.
3. Implementation and Deployment Costs:
   - Costs associated with the installation and deployment of IoT devices along the railway infrastructure.
   - On-site implementation and integration of ICOS components.
4. Training and Education:
   - Training programs for staff to operate and manage ICOS effectively.
   - Educational resources for users to understand the functionalities and best practices of ICOS.
5. Connectivity Costs:
   - Expenses related to establishing and maintaining connectivity, including mobile services for IoT Gateways.
   - Potential costs for network infrastructure enhancements in areas with limited connectivity.
6. Cloud Services and Data Storage:
   - Subscription or usage fees for cloud services, including data storage, processing, and analysis.
   - Costs associated with the utilization of cloud-based applications and microservices within ICOS.
7. Maintenance and Support:
   - Ongoing maintenance costs for software updates, patches, and bug fixes.

5.6.3.3 Use Case 3: In-Car Advanced Infotainment Multimedia Management system (IAIMM)

General introduction

CRF (CRF), in collaboration with ATOS, is implementing an innovative Use Case offering 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. This initiative integrates the cutting-edge technology of the ICOS to 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.

Problem to be solved

The main challenge to be addressed by the use case considering that the proposed multimedia service should be able to operate in mobility context using real time and dynamic information, is 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.

Results after using ICOS

The solution ensured by ICOS should offers

- a reduction of latency ensuring that it will be adequate for the consumption onboard of the multimedia content.
- a secure multiuser communication and interaction infrastructure able to ensure privacy and security of shared data.
- a proper ability to make the right decision allowing that the application could operate regardless of connectivity and poor resources availability.

Technical Description

In the given context, 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.
In the IAIMM use case, the main IoT devices are represented by the vehicles that ingest own position to the service.
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 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.

Requirements

Table 93 UC3 Requirements

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

Business Description

CRF/STELLANTIS (CRF):

CRF is a STELLANTIS company active in innovative initiative is a key player in Barcelona's transportation sector, managing a robust rail network that caters to over 90 million passengers annually. Emphasizing safety and innovation, FGC leverages technologies like RSAM and ICOS to optimize rail operations, ensuring a reliable and technologically advanced service for its passengers.

ATOS:

ATOS is a global leader in business-focused smart city solutions and IIoT technologies. Specializing in enhancing urban and industrial operations, Worldsensing provides transformative solutions for traffic management, environmental monitoring, and industrial efficiency. Key products include RSAM for proactive rail maintenance and CMT Cloud for streamlined data processing. Committed to innovation, Worldsensing empowers businesses to thrive in a connected and data-driven future.

Use Case Overview

The challenges infotainment 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 the ICOS technology to serve such complex application will be exploited not only for allowing the 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.

The integration of ICOS into the IAIMM use case represents an opportunity for STELLANTIS for offering challenging infotainment services on the future connected and autonomous vehicles that represent an added value for our customer enhancing operational efficiency, reducing costs and complexity of the vehicle itself, and contributing to our potential growth and innovation in the competitive automotive sector.

Positioning

As of the current stage, it's important to note that we can only articulate our expectations for the impact that ICOS will bring based on our pre-implementation assessment. The actual impact evaluation will be conducted post-implementation, probably close to the IT2 release. With that clarification in mind, here are our anticipated expectations and future perspectives:

The present infotainment use case is aimed to emphasizes the potential benefits that the ICOS technology can provide to the future automotive services tailored for connected and autonomous vehicles.

It was specially selected considering peculiarities of automotive environment where the need for good on-the-go connectivity on the one hand and limited in-vehicle computing resources on the other, make the implementation of services that require real time interaction with complex multimedia content particularly challenging.

In this perspective the main challenges leverage by ICOS are:

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.

ICOS Interaction

For the In-Car Advanced Infotainment Multimedia Management system, ICOS will manage the application through the Edge and Cloud processing environment.

In particular, 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.

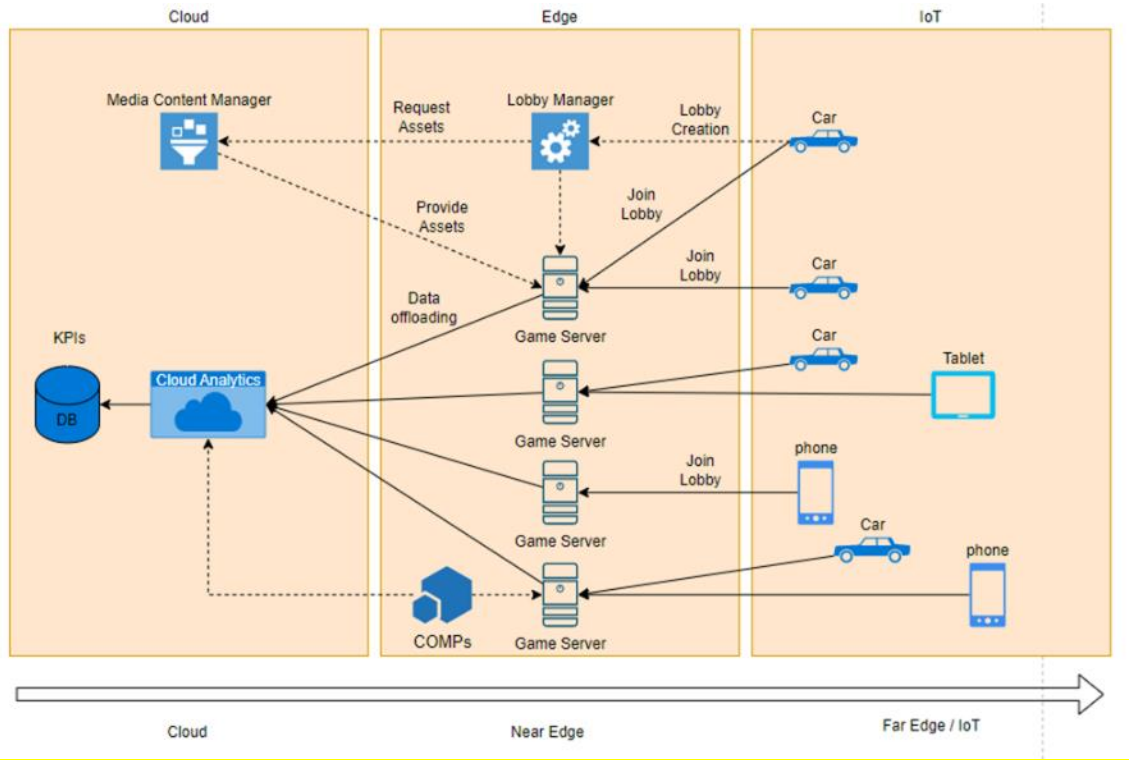

Figure 35: ICOS Use Case 3 testbed

Invested time and costs

The associated time and costs of implementing ICOS for CRF and ATOS is not yet known. At this stage of development, we can estimate time for components related to the deployment, integration, and ongoing operation of the system.

It's important to note that the actual costs may vary based on the future specific requirements, scale of deployment, and the complexity of the ICOS. Standardizing the ICOS onboarding process is a critical element that can influence not only the initial implementation costs but also the ongoing operational costs and the overall success of the ICOS deployment.

1. *Development Costs:* This includes the cost of designing and developing the software and hardware components required for the infotainment service. It would involve expenses related to coding, graphic design, user interface development, and any necessary hardware integration.
2. *Content Creation:* The cost of creating multimedia content and 3D models related to the Points of Interest (POI) near the vehicle's position should be considered. This would involve expenses for content creation, licensing, and any necessary collaborations with content providers.
3. *Testing and Quality Assurance:* Costs related to testing the infotainment service on the L4 shuttles, ensuring its compatibility, functionality, and performance. This includes expenses for testing equipment, personnel, and any necessary software licenses.
4. *Integration and Deployment:* The cost of integrating the infotainment service into the L4 shuttles and deploying it across the fleet. This includes expenses for hardware installation, software integration, and any necessary modifications to the existing infrastructure.
5. *Maintenance and Support:* Ongoing costs related to maintaining the infotainment service, providing technical support, and addressing any potential issues or updates. This includes expenses for personnel, server maintenance, and software updates.

We don't mention here costs regarding for example marketing and promotion of the service that will eventually be considered when the service reaches the right maturity to be launched in the market.

5.6.3.4 Use Case 4: Energy Management and Decision Support System (EMDS)

General introduction

SSE Airtricity in collaboration with ICOS project is implementing an energy management and decision support system based on advance and reliable Machine Learning techniques for energy forecasting. The energy management system will generate personalised and optimised energy suggestions tailored to customer needs. The ICOS operating system will leverage Cloud and Edge capabilities for latency reduction, increased security, and real time solutions to reduce energy waste and costs, flattening the demand curve by removing demand on the grid at peak time and boosting energy usage at night-time.

Problem to be solved

Use Case 4 (UC4) is based around energy usage optimization within a domestic setting. Reaching the net zero goals set up for 2050, together with the need to phaseout fossil fuel consumption, requires the support and active participation from citizens around the globe. Customers with Electric Vehicles, Heat Pumps, PV systems and storage capabilities will play a fundamental role in the transition towards net zero emission energy.

The Algorithm within the ICOS device works by anticipating future demand, knowing what demand is schedulable, forecasting solar Photovoltaic output, knowing EV charging requirements and knowing or anticipating future retail cost signals. It solves the difficult problems of whether it's best to use, store or sell energy when demand, supply and costs are all dynamic. This gives the customer the option of automating the complex cost optimisation decisions, but yet still gives control over which decisions customers would prefer to make themselves.

Results after using ICOS

Latency reduction and Security enhancement: The ICOS system will allow optimal data management, storage and processing capabilities with latency reduction and enhanced security and data privacy using Edge and Cloud computing capabilities.

Cost saving and increase in renewable energy consumption: the ICOS AI 'brain' will shape the future of the Prosumers with the aim of reducing energy waste, mitigating curtailment, maximizing usage of renewable energy, and reducing costs associated to energy consumption.

Improve customer retention and satisfaction: The ICOS system will allow customers to navigate through the complex and dynamic environment of the energy market. ICOS UC4 will allow the implementation of a secure and efficient energy management system with energy solutions tailored to customer needs and sustainability targets for customer trust, customer retention and satisfaction.

Technical Description

The EMDS of UC4 has been built with open-source solutions and it comprises of a IoT sensors and an edge device. These will be installed in 5 Irish households equipped with smart technologies including microgeneration, home energy storage, electric vehicles (EVs) and heat pumps. For the initial phase of the ICOS project one house will be used as test bed to confirm the viability and reliability of the installation.

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

- Inductive Power Monitoring Clamps,
- Smart meters

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 sensor will be used to collect data in the house in real time (30 seconds time interval). Examples of data for UC4 are:

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

Edge device:
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. 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.

Azure Cloud:
A dedicate Azure cloud environment will be used for UC4. This environment is based on microservice architecture with applications such as ML application, storage and processing that will be orchestrated by ICOS Meta OS.

Requirements

Table 94 UC4 requirements

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

Priority	Application name	Problem	Requirement for ICOS	Expected Validation date
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

Business Description

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 supports the green energy transition with the installation of solar PV, home energy retrofit and EV chargers enabling the transition to smart homes.

SSEA UC4 focuses on home energy optimization. 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 knowledge attained during the ICOS trial will enable SSEA to assist domestic and business users by providing more detailed energy reporting helping the customer to navigate through the complex and dynamic environment of the energy market. In addition, ICOS outputs could support development of new customer offerings and viable energy solutions for optimal, cost effective and predictable energy usage.

ICOS Edge capabilities will provide an opportunity to use advanced AI models and ML techniques where learning can be shared from home to home. ICOS will be the proof of concept that will aid SSE to scale in a future where number of houses and customers can be easily augmented and included in complex AI models (starting models are those already established in other houses). ICOS will create a "continuum" where resources are orchestrated in a GREEN, sustainable and efficient way.

Use Case Overview

The integration of ICOS into the EMDS will allow SSEA UC to enhance data security and data privacy, reducing latency. ICOS 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 (reducing grid loss) and increasing the usage of renewable energy sources.

Positioning

ICOS impact is currently being evaluated based on the current understanding of ICOS capabilities and will be fully explored after the implementation and verification of the meta operating system and its future iterations. Our projected expectations are listed below:

Optimization of energy usage, increased energy literacy of participants, cost savings, customer satisfaction and sustainability: as highlighted above, the integration of ICOS and the implementation of UC4 will provide several advantages not only from a business perspective but also from a customer point of view, where customers can make more informative decisions on their energy usage, storage

and generation, in a cost effective and sustainable manner. Real time analysis of energy data will aid customer in shifting their energy usage towards off-peak time, increasing the usage of green energy, mitigating curtailment, reducing grid lost, improving frequency stability and creating dispatchable demands.

Increase security and Data privacy: ICOS edge capabilities and inclusion of ML techniques such as Federate Learning will allow to reduce movements of data, leveraging computer capabilities close to the data sources. In addition, ICOS data management and security layer will allow the use of authentication and authorization procedures for high level of safety and security of Personal Data in accordance with the GDPR principles.

Expansion of Service Offerings and TOU tariffs: The experience gained through ICOS UC4, will aid suppliers like SSEA in implement new customer offering and viable energy solutions for optimal and predictable energy usage.

Collaboration with key Stakeholders:

SSEA aims to strengthen collaboration with key stakeholders in the wider European arena, including technology partners, suppliers, Transmission and Distribution system operators. By showcasing the UC and the benefits of ICOS improving energy efficiency, security, and cost-effectiveness, SSEA intends to contribute to a more sustainable future to pave the path towards net zero emissions.

ICOS Interaction

UC4 include the use of IoT sensors and edge devices installed in 5 Irish households. An ICOS agent will be deployed at the edge device (one agent in each house) while the controller will be deployed in the cloud environment. In the first ICOS iteration, the ICOS Cloud test bed will be used, while the data will be managed at EDGE level. In subsequent releases a dedicated SSE Cloud environment will be integrated in the UC and the data management capabilities of ICOS management layer will be explored and adopted.

MQTT protocols is set up to ensure seamless communication allowing the synchronization and data flow through the continuum (IoT to Edge to Cloud).

As UC4 involves the use of personal data at very granular level, data security, data privacy and data integrity are of fundamental importance. The implementation of security measurements in the ICOS Security Layer along with ICOS Edge processing capabilities will ensure high level of security.

In the first ICOS iteration AI models for energy forecasting will be deployed in the ICOS testbed using the ICOS AI market capabilities, further releases of ICOS will include AI models run at the Edge such as Reinforcement and Federate Machine Learning techniques, with home-to-home model parameters sharing to avail of learnings in other houses.

The onboarding of the ICOS agent and controller will allow the orchestration of services through ICOS Meta OS according to specific requirements for the UC.

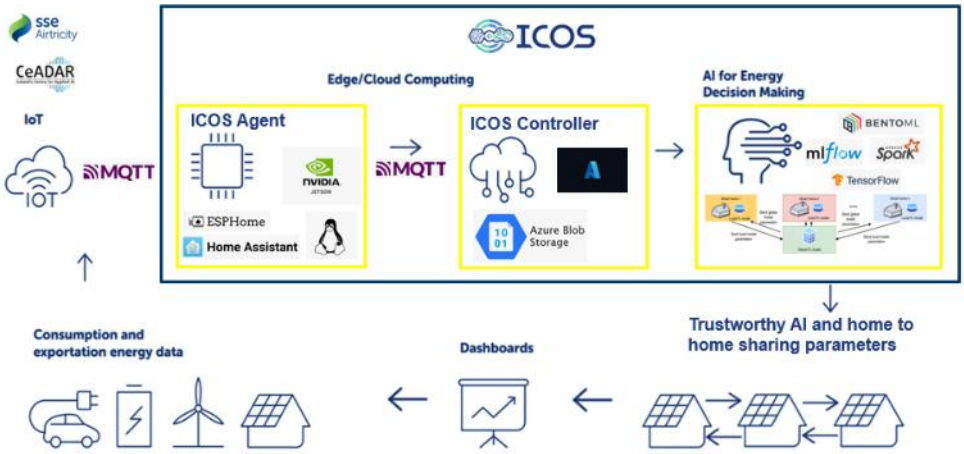

Figure 36: ICOS Use Case 4 architecture

Invested time

The associated costs of implementing ICOS for UC4 will be fully investigated at the end of the project. Current costs associated are linked with the setup and provision of the hardware, deployment of the application and the ICOS components, and the ongoing maintenance of the UC.

Final costs associated with the UC are dependent on the future specific requirements and the complexity of the ICOS operating system and will be evaluated in due course.

Cost breakdowns and considerations:

- Hardware Procurement costs:
  Procurement of the hardware for IoT and Edge devices to be installed in the house including Energy monitoring clamps, Microcontroller Boards and Jetson Nvidia devices.
- Development and Integration costs:
  Costs associated with the design and implementation of the UC. Customization and deployment of dedicated software for the setup of the IoT and Edge devices specific to the UC application. Integration of the ICOS components with the Application infrastructure.
- Training and Education:
  Training and education time for staff to operate and manage the UC and the ICOS infrastructure effectively, including understanding of ICOS functionalities, architecture, and best practises.
- Infrastructure and Connectivity Costs:
  Expenses related the deployment of the UC in the 5 Irish households, to establishing and maintaining the application infrastructure, and to deploy and maintain a dedicate ICOS cloud environment including data storage and cloud subscription services.
- Maintenance and Support:
  Ongoing maintenance costs for software updates, patches, and bug fixes.

5.7 KPIs

This section contains the list of exploitation related KPIs and their corresponding contingency plans.

Table 95 Innovation and Exploitation KPIs

ID	Means of verification	Threshold	Timing	Status (M18)
KPI 1	ICOS micro-economic analysis	1	M36	1 initial draft available
KPI 2	Number of innovations in the market	5	M36	23 (1 per exploitable asset) 5 (1 per key exploitable result) 1 (for the whole stack)
KPI 3	Number of B2B/B2B2C	2	M36	0

5.7.1 Contingency plans

List all plans related to the ID of the KPIs mentioned before.

- **KPI 1:** even if the micro-economic analysis is planned for the end of the project, the methodology to be applied has been developed in advance, and properly documented in this deliverable. In this way, all partners are aware of the type, and amount, of information that will be collected, how and for what, what will easier the procedure at the end.
- **KPI 2:** according to the current reporting, ICOS provides many innovations at individual level and at key exploitable result one. This information will be further elaborated and used in all dissemination material to highlight the assets.
- **KPI 3:** given the maturity of the project results, it is still early to establish commercial connections. However, during the second period different initiatives, more industry oriented, will be contacted to showcase results and try to attract new potential customers/users.

6 Conclusions

ICOS project has been very active in scientific dissemination activities, as already highlighted in the corresponding section with many publications accepted and events participated. However, more emphasis must be performed during the second period to increase the impact of the communication activities. At the same time, it is planned to increase the number of activities to reach other stakeholders from the value chain, developing the appropriate messages for them, to showcase how they can benefit from using any of the project results.

Regarding the open source standardisation, the withdrawal of the responsible partner was expected to limit the scope of the activities. However, remain partners have increased their efforts to still have a significant impact in the arena. The work will continue during the next period.

As for liaisons, during the first period most of the collaboration with ongoing projects was related to the EUCEI.eu initiative, where the consortium was involved in several activities to produce significant results. During the second period more work is expected to be performed directly with related projects to enable cross-fertilization of results for mutual benefit. At the same time, community building activities are progressing as expected with the launch of the first open call. Thus, it will continue in the same way with the launch of the second one.

Finally, significant work has been performed in terms of innovation and exploitation related to individual components, while the first steps for joint exploitation based on key exploitable results are also included in this deliverable. During the second period, the work will be more focused on these key exploitable results and their joint exploitation to ensure the sustainability at the end of the project. As already drafted in the corresponding section, work performed is twofold: i) from the product perspective, to identify competitors and state how users may benefit from project results; and ii) from a company perspective, analysing the growth of companies with similar products, as well as providing means to support decision makers to perform informed actions based on technical and economical results.

The results of all these activities will be provided in the final document of the series, D7.4 expected by the end of the project.

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Annex I: Exploitable results

All partners have provided additional, and non-technical, information about the different software components developed within ICOS and how they foresee their exploitation options after the end of the project. This information will be also updated during the last project period as long as results are more mature.

Table 96 Exploitable result #1

Type of asset	ICOS Intelligence API Community Edition (AI coordination module)
Owner(s)	CeADAR
Short description	The AI coordination module facilitates optimization, predictive analytics, and applying machine learning models across the edge-cloud continuum. Model output target the implementation of policies for utilizing, sharing, and updating models. This acts as an interface and provides coordination between the meta-kernel and user layers providing and requesting services.
License	GNU GPL v3
TRL	4-5
MRL	2-4 (depending on overall ICOS solution)
Business model	Open source business model monetized by paid support, training and technology/feature customization
Competitor(s)	There is no direct competitor for this purpose and the solution is being developed for ICOS. Companies providing AI-as-a-Service are partially competing, but are not tailored solutions as this is.
Main innovation(s)	Integration with data management, telemetry and security (anomaly detection). Added API compatibility for timeseries and online ML libraries. Added policies to remove models from the model registries when exceeding a pre-defined threshold.
Target market	Users of ICOS or other distributed systems that can leverage from an API to offload AI across the network topology.
Exploitation path	Aligned with the overall exploitation of the ICOS solution.

Table 97 Exploitable result #2

Type of asset	Predictive telemetry metrics model training – Bento (packet) for the AI Analytics module
Owner(s)	CeADAR
Short description	The AI coordination API offers an endpoint for estimating the CPU consumption of the ICOS agents. This model can be repurposed to specific tasks and other telemetry metrics as a training functionality is provided as a separated endpoint.
License	GNU GPL v3
TRL	2-4
MRL	2-4 (depending on overall ICOS solution)

Business model	Open source business model monetized by paid support, training and technology/feature customization.
Competitor(s)	Opni – Multi-Cluster Observability with AIOps (https://opni.io)
Main innovations	Forecasting functionality for telemetry metrics allowing offloadable model training and MLOps.
Target market	Sectors that can benefit of predictive maintenance solutions for their ICOS controllers and agents (e.g., manufacturing, logistics and healthcare sectors). Users of ICOS that will be able to estimate future metrics which may contribute to monitoring. Users of ICOS will be benefited as this forecasting will contribute to the creation of policies in the meta-kernel.
Exploitation path	Aligned with the overall exploitation of the ICOS solution.

Table 98 Exploitable result #3

Type of asset	Online machine learning models - Bento (packet) for the AI Analytics module
Owner(s)	CeADAR
Short description	This is a separate packet to be deployed and complement the list of AI models reachable in the ICOS intelligence layer. These models bring online machine learning capabilities to the Intelligence layer to learn on the fly and adapt to dynamic and non-stationary data streams received in the continuum.
License	Proprietary
TRL	2-4
MRL	2-4 (depending on overall ICOS solution)
Business model	This technology and its related features are offered as premium paid features over the open source baseline functionality.
Competitor(s)	Open source libraries such as Creme (https://pypi.org/project/creme/) and scikit-multiflow.(https://github.com/scikit-multiflow/scikit-multiflow)
Main innovations	Implementation and integration of online machine learning frameworks over an AI as a service API.
Target market	Users of ICOS and other distributed frameworks using the ICOS API will be able to improve forecasting results using scalable models that adapt to changes in the data received over time.
Exploitation path	Preparation of commercial solution based on the technological developments in ICOS and use cases.

Table 99 Exploitable result #4

Type of asset	ICOS Intelligence API Developer Edition (AI coordination module)
Owner(s)	CeADAR
Short description	This version builds extra functionalities on top the Community Edition (CE). It makes use of data pipelines and plugins/bento can easily be developed leveraging these. This is supported by a clear repository structure and extra documentation. This version has extra integration with AI libraries, and includes specific Intelligence packets as the online machine learning models.

License	Proprietary
TRL	5-6
MRL	2-5 (depending on overall ICOS solution)
Business model	This technology and its related features are offered as premium paid features over the open source baseline functionality.
Competitor(s)	ICOS Intelligence API Community Edition
Main innovations	Data pipelines functionalities, improved code repository, extra documentation, and extra algorithms and API endpoints available.
Target market	Users of ICOS or other distributed systems that want an enhanced version of the ICOS API.
Exploitation path	Preparation of commercial solution based on the technological developments in ICOS and use cases.

Table 100 Exploitable result #5

Type of asset	ICOS AI Marketplace
Owner(s)	CeADAR
Short description	ICOS will create a marketplace of models and solutions developed using the intelligence layer. The aim of this is to create a community of projects using and building intelligent applications for ICOS.
License	GNU GPL v3
TRL	4-5
MRL	2-4 (depending on overall ICOS solution)
Business model	Open-source business model monetized by paid support, training and technology/feature customization
Competitor(s)	AI communities such as Huggingface or libraries like Tensorflow Hub serve for a similar purpose, but are not direct competitors as models developed in the AI Marketplace as tailored to ICOS and use cases and applications operating over the edge-to-cloud continuum.
Main innovation(s)	New models to be reused or transfer learning to new applications.
Target market	Users of ICOS or other distributed systems that can leverage models already built.
Exploitation path	Aligned with the overall exploitation of the ICOS solution.

Table 101 Exploitable result #6

Type of asset	ICOS AI Analytics - Intelligence continuum models
Owner(s)	CeADAR
Short description	ICOS will integrate a set of techniques for optimizing and pruning ML models to be adapted to the characteristics of edge devices without losing accuracy.
License	GNU GPL v3
TRL	4-5
MRL	2-4 (depending on overall ICOS solution)

Business model	Open-source business model monetized by paid support, training and technology/feature customization
Competitor(s)	The main competitor observed for this is the field of TinyML (https://www.tinyml.org). Other parallel initiatives to ICOS, such as the MANOLO EU funded project will work on this. However, MANOLO is currently in M02 and development does not start until later.
Main innovation(s)	Optimized models and model optimization techniques as a service.
Target market	Users of the ICOS Intelligence API will be able to reduce the computational cost of their deep learning models.
Exploitation path	Aligned with the overall exploitation of the ICOS solution.

Table 102 Exploitable result #7

Type of asset	Individual
Owner(s)	XLAB
Title	Security Layer Coordination module
Short description	AIOps-based tool for the coordination of modelling, capturing and optimizing log streams, with integrated alerting capabilities (D4.1/D4.2). This enables in ICOS a Security Layer including security and trustworthy as key fundamental pillars.
License	OSS licensed with Apache 2.0
TRL	3-4
MRL	2-4 (depending on overall ICOS solution)
Business model	Open source business model monetized by paid support, training and technology/feature customization
Competitor(s)	Datadog (https://www.datadoghq.com/) identifies when a metric is behaving differently than it has in the past, taking into account trends, seasonal day-of-week, and time-of-day patterns
Main innovations	OpenAPI-based coordination of security functionalities already implemented with ICOS Security Scan and ready to be implemented with other ICOS services
Target market	Manufacturing, logistics and healthcare sectors, as well as all other industries that need advanced anomaly detection.
Exploitation path	Aligned with the overall exploitation of the ICOS solution

Table 103 Exploitable result #8

Type of asset	Individual
Title	Security Scan
Owner(s)	XLAB
Short description	Wazuh-based open source runtime security monitoring system capable of detecting security-related events and incidents in the deployed application's environment. It is (to the extent possible) deployable automatically and notifies users about security alerts.

License	OSS licensed with GNU GPL v2 (same license as ELK)
TRL	3-4
MRL	3-4
Business model	Open source business model monetized by paid support, training and technology/feature customization
Competitor(s)	HardenedVault (https://hardenedvault.net/) is a SIEM/XDR solution based on Wazuh with comprehensive security hardening by default; Qualys (https://www.qualys.com/) is a comparative solution to Wazuh automating compliance and protection of IT systems and web applications.
Main innovations	This technology is able to automatically deploy security monitoring agents, integrated into the monitoring mechanisms and notify about security threats according to the policies, defined in the NFRs.
Target market	Manufacturing, logistics and healthcare sectors, as well as all other industries that need advanced anomaly detection.
Exploitation path	Benefiting from the overall exploitation of the ICOS solution, but with an individual exploitation roadmap that follows the release and benchmark of the OSS solution.

Table 104 Exploitable result #9

Type of asset	Individual
Title	LOMOS
Owner(s)	XLAB
Short description	The LOg MOnitorin System (LOMOS) is an application of self-supervised machine-learning to the anomaly detection in application and infrastructure logs.
License	Proprietary
TRL	3-4
MRL	3-4
Business model	This technology and its related features are offered as premium paid features over the open source baseline functionality.
Competitor(s)	Devo AIOps (https://www.devo.com/solutions/aiops/) is a data-driven solution to track and detect anomalous activity across complex service stacks; Zebrium Anomaly Detection (https://www.zebrium.com/blog/using-machine-learning-to-detect-anomalies-in-logs) in a ML-based log anomaly detection tool to automatically detect software problems and their root cause.
Main innovations	New AIOps functionalities addressing ICOS priorities, and extension of the ML algorithm underlying the LOMOS system to adapt to ICOS types of logs, configuration of alerts for detected anomalies.
Target market	Manufacturing, logistics and healthcare sectors, as well as all other industries that need advanced anomaly detection.
Exploitation path	Preparation of commercial solution based on the technological developments in ICOS, and the benchmark from the use cases in this and other projects as success stories.

Table 105 Exploitable result #10

Type of asset	Individual
Name	Nuvla.io
Owner(s)	SixSq
Short description	Nuvla.io is a remote management and orchestration platform for edge devices and applications. From the platform, you can remotely manage a large fleet of edge devices on which you can deploy or update apps, get detailed control information, and set up notifications, amongst other features. Nuvla.io works with the NuvlaEdge software, which enables a direct communication channel between edge devices, and the platform.
License	The access to the Nuvla.io platform is free. A PAYG license is bound to the NuvlaEdge software (see next table).
TRL	9
MRL	9
Business model	PaaS (Platform-as-a-Service)
Competitor(s)	OpenShift, Azure IoTHub, OCM, Rancher, Green Grass, Zededa, Spectro Cloud
Main innovations	▸ Fleet management enhanced features. ▸ Near-data processing. ▸ Public and private apps marketplace: ability to deploy both ready-to-use apps and your own. ▸ Hardware-agnostic. ▸ Great user experience: all features are also available via REST API for third-party integrations.
Target market	Industries such as retail, logistics, telco, energy, etc. which need near-data processing (for instance, asset tracking, energy consumption monitoring).
Exploitation path	Nuvla.io is already exploited by SixSq, and is in line with the ICOS overall exploitation roadmap.

Table 106 Exploitable result #11

Type of asset	Individual
Name	NuvlaEdge
Owner(s)	SixSq
Short description	NuvlaEdge is containerized software that turns any Linux platform into an edge device (using either Docker or Kubernetes). Once installed on the device, NuvlaEdge enables remote connection to it from the Nuvla.io platform. The user can perform actions directly from the platform on the device: fleet management and monitoring, app deployment and update, amongst other features.
License	PAYG (monthly license per NuvlaEdge software installed on a device).
TRL	9
MRL	9

Business model	SaaS
Competitor(s)	OpenShift, Azure IoTHub, OCM, Rancher, Green Grass, Zededa, Spectro Cloud
Main innovations	▸ All IP connectivity + VPN secured communication channel. ▸ Flexible. ▸ IoT peripheral discovery. ▸ Edge device and applications telemetry collection.
Target market	Industries such as retail, logistics, telco, energy, etc. which need near-data processing (for instance, asset tracking, and energy consumption monitoring).
Exploitation path	NuvlaEdge is already exploited by SixSq and is in line with the ICOS overall exploitation roadmap.

Table 107 Exploitable result #12

Type of asset	Online machine learning models – Bento (packet) for the AI analytics module
Owner(s)	NKUA
Short description	The first package is dedicated to online machine learning models for anomaly detection. The goal of the supervised anomaly detector in this case is to predict the correct class (anomaly or not) based on a provided time series. Five different models have been created and evaluated.
License	Proprietary
TRL	2-5
MRL	2-5 (depending on overall ICOS solution)
Business model	
Competitor(s)	ICOS Intelligence API Community Edition
Main innovations	Documentation, callable APIs, anomaly detection with various ML models
Target market	User of ICOS or other distributed systems that want an enhanced version of the ICOS API.
Exploitation path	The goal is to create open source datasets to be publicly available via IEEE data port. Moreover, part of this work will be published in international conferences or high-quality journals.

Table 108 Exploitable result #13

Type of asset	Decentralised Computation Offloading with Energy Efficiency-aware (DECOFFEE)
Owner(s)	NKUA
Short description	This decentralized computation offloading scheme targets to dispatch the tasks efficiently in terms of latency and energy efficiency and also allows both vertical and horizontal offloading decisions. The suitability of DECOFFEE to the ICOS principles lies in two aspects: i) it is a decentralized scheme enabling each ICOS agent to effectively handle its computation task in a distributed manner, and ii) it allows both vertical and horizontal decisions within and across the ICOS continuum, which is in line with the ICOS objectives to go beyond the constantly vertical

	management and the monolithic decentralized orchestration.
License	Proprietary
TRL	2-4
MRL	2-4 (depending on overall ICOS solution)
Business model	
Competitor(s)	ICOS Intelligence API Community Edition
Main innovations	Documentation, callable APIs, deep reinforcement learning Five (5) load forecasting models have been created
Target market	Users of ICOS or other distributed systems that want an enhanced version of the ICOS API.
Exploitation path	The goal is to create open-source datasets to be publicly available via IEEE data port. Moreover, part of this work will be published in international conferences or high-quality journals.

Table 109 Exploitable result #14

Type of asset	Individual
Owner(s)	ENG
Short description	Telemetruum. The asset aims at being a flexible and complete solution for collecting, storing and processing telemetry and logging data in the Cloud-Edge-IoT Continuum. Telemetruum allows an adaptive and automated deployment of collection, storage and processing units along the continuum taking into consideration connectivity and computational power constraints while preserving a unified and complete view on the status and the performance of the entire continuum. The asset offers telemetry data collectors for multiple infrastructure and platforms and an advanced policy-based alerting system.
License	Apache 2.0
TRL	2-4
MRL	2-4
Business model	Open source business model monetized by paid support, training and technology/feature customization
Competitor(s)	Open source multi-infrastructure monitoring management systems like Opni and Observatorium. Commercial suites like DataDog, Splunk, CloudWatch.
Main innovations	The asset is based on a strong and stable FOSS technological stack composed by OpenTelemetry, Prometheus, OpenSearch. The asset mainly innovates by providing a dynamic, automated and secure deployment of these technologies along the continuum with ad-hoc, flexible configuration. The asset offers a set of pre-defined metrics, queries and dashboards that allow to know the topology and the status of the continuum as well as a novel service to define global and local deployment and performance policies based on telemetry data to be monitored and enforced in the continuum.
Target market	Companies that manage large, distributed and heterogeneous IT infrastructures.

Exploitation path	The solution will be realized and improved in the ICOS project. The prototype and the experience gained in ICOS will be used internally to the company (by the IT department) that will improve and prepare the solution to be used in real projects where ENG manage client's infrastructures.

Table 110 Exploitable result #15

Type of asset	Individual
Owner(s)	BSC
Short description	PyCOMPSs/COMPSs is a task-based programming model which aims to ease the development of applications for any distributed infrastructures, such as large High-Performance clusters (HPC), clouds and container managed clusters and across the whole IoT-Edge-Cloud Continuum. COMPSs provides a programming environment for the development of the applications in a sequential and infrastructure-unaware manner; its runtime system detects and exploits the inherent parallelism of applications at execution time and distributes its execution.
License	Apache 2.0
TRL	3-5
MRL	2-4 (depending on overall ICOS solution)
Business model	
Competitor(s)	Apache Spark, Apache Storm, Apache Beam, Apache Airflow Swift, Pegasus, Serverledge, FuncX, AWS Lambda
Main innovations	PyCOMPSs/COMPSs is the only programming environment with a unified syntax that considers the three scenarios that require computation at any tier of the continuum. Unlike classical workflow managers and data analytics solutions, either batch analysis or real-time, which usually target in-cluster executions with some fault-tolerance mechanisms, COMPSs' design turns around the heterogeneity and the mobility of the devices to allow a rapid reaction to devices onboarding or departure. Regarding FaaS solutions, it avoids the vendor lock-in from solutions offered by major Cloud Providers; it actually offers a true serverless architecture (no need of a cloud endpoint due to its peer-to-peer design; and unlike similar solutions for FaaS such as serverledge or FuncX, it is able to detect nested parallelism to create parallelism hierarchies fitting the hierarchic nature of the network topologies in the continuum.
Target market	Potential ICOS users as well as any organization requiring an optimization of their computational processes either by parallelizing and distributing the execution or just offloading part of it.
Exploitation path	The solution will be improved in the frame of the ICOS project. As an academic partner, BSC expects to disseminate the solution code as open source as well as publishing the innovations in academic conferences and journals. In addition, the improved version of COMPSs resulting from ICOS will be used in other internal projects as well as in other collaborative projects applied to IoT-Edge-Cloud and HPC infrastructures.

Table 111 Exploitable result #16

Type of asset	Individual
Owner(s)	BSC
Short description	dataClay is a distributed data store that enables applications to store and access objects in the same format they have in memory, and executes object methods within the data store. These two main features accelerate both the development of applications and their execution.
License	BSD3-clause
TRL	3-5
MRL	2-4 (depending on overall ICOS solution)
Business model	
Competitor(s)	Apache IoTDB and eXtremeDB
Main innovations	Joint encapsulation of data model and data logic. This architecture provides a mechanism that allows execution offloading (running data logic close to the data structures). This mechanism reduces data transfers and can result in a more efficient use of computational resources.
Target market	Application developers who require support for complex data processing in distributed environments, emphasizing latency, bandwidth, and/or resource utilization. Platform providers that want to offer repository of data structures combined with processing data logic within a single environment and a single data model (a data model that combines both data structure and data logic).
Exploitation path	The solution will be improved in the frame of the ICOS project. As an academic partner, BSC expects to disseminate the solution code as open source as well as publishing the innovations in academic conferences and journals. In addition, the improved version of dataClay resulting from ICOS will be used in other internal projects as well as in other collaborative projects applied to IoT-Edge-Cloud and HPC infrastructures.

Table 112 Exploitable result #17

Type of asset	Individual
Name	Node Feature Discovery (NFD) - Prometheus exporter - Device plugin
Owner(s)	NCSRD
Short description	Node Feature Discovery (NFD) integrated with a custom Prometheus exporter and a Kubernetes plugin for external devices is a comprehensive solution designed to enhance Kubernetes cluster management and monitoring. NFD automates the detection of hardware features and capabilities of nodes in a Kubernetes cluster, enabling more intelligent scheduling decisions based on these attributes.
License	Apache 2.0
TRL	2-4
MRL	2-4

Business model	Open source business model monetized by paid support, training and technology/feature customization
Competitor(s)	The is not currently a competitor for this modified version of NFD since it combines individual functionalities in one solution.
Main innovations	By integrating NFD with a custom Prometheus exporter, cluster administrators can collect and expose metrics related to the discovered node features, such as CPU capabilities, available hardware accelerators, or custom labels indicating specific node properties. These metrics can be visualized and monitored using Prometheus, a popular open-source monitoring system. Additionally, incorporating a Kubernetes plugin for external devices allows the cluster to manage and schedule workloads on nodes with specific external hardware devices, such as GPUs, NICs, or FPGAs, further optimizing resource allocation and workload performance. This integration offers a powerful toolset for optimizing and monitoring Kubernetes clusters, particularly in environments with heterogeneous hardware or specific performance requirements
Target market	Cluster administrators, DevOps teams, infrastructure architects, data scientists, and AI/ML engineers, as well as IoT and edge computing operators.
Exploitation path	The solution will mature alongside with ICOS and the goal is to develop a generic solution that optimize resource efficiency across the infrastructure of NCSRD.

Table 113 Exploitable result #18

Type of asset	Individual
Name	Tetragon Wazuh Agent
Owner(s)	NCSRD
Short description	Tetragon, a powerful eBPF-based security observability and runtime enforcement tool, creates a comprehensive security solution for real-time threat detection and response. This component leverages Wazuh's capabilities for log analysis, compliance checks, and alerting with Tetragon's strengths in deep observability and policy enforcement at the kernel level. Such integration offers enhanced visibility into system and network activities, enabling more precise and immediate identification of malicious behaviour, policy violations, and potential vulnerabilities, ensuring a robust security posture for distributed systems.
License	Apache 2.0
TRL	2-4
MRL	2-4
Business model	Open source business model monetized by paid support, training and technology/feature customization
Competitor(s)	Open source solutions such as Tracee, BPFtrace and Kubearmor

Main innovations	Tetragon's utilization of eBPF technology for granular, real-time observability and policy enforcement at the kernel level introduces a revolutionary approach to detecting and mitigating security threats directly within the operating system's core. This capability is seamlessly complemented by Wazuh's extensive feature set for intrusion detection, compliance verification, log analysis, and alerting. The synergy between Tetragon's cutting-edge observability and Wazuh's robust security analytics enables organizations to achieve an unprecedented level of security posture, offering detailed insights into system behaviour and rapid detection of threats.
Target market	Cluster administrators, DevOps teams, companies that provide cloud services
Exploitation path	By leveraging Tetragon's advanced eBPF-based observability for real-time monitoring and enforcement at the kernel level, combined with Wazuh's comprehensive intrusion detection the goal is to safeguard the ICOS project's infrastructure against sophisticated cyber threats.

Table 114 Exploitable result #19

Type of asset	ICOS Shell
Owner(s)	TUBS, UPC
Short description	The ICOS Shell components consist of the Admin GUI and the Dev CLI, as well as the implementation of the required interfaces for the communication between the ICOS Intelligence, Security and Meta-kernel layers. They are the user interface for the ICOS MetaOS.
License	Apache License 2.0
TRL	4-5
MRL	2-4 (depending on overall ICOS solution)
Business model	None
Competitor(s)	Not Applicable
Main innovations	Allows for administration of the ICOS MetaOS
Target market	Aligned with the overall target market of the ICOS solution.
Exploitation path	Aligned with the overall exploitation of the ICOS solution.

Table 115 Exploitable result #20

Type of asset	Smart & Efficient matchmaking
Owner(s)	UPC
Short description	Solution to smartly and efficiently allocate services (tasks/jobs) into available resources at both the early stage of the service deployment and also at runtime considering potential changes on availability, required quality, etc.
License	Proprietary
TRL	2-4
MRL	2-4 (depending on overall ICOS solution)

Business model	
Competitor(s)	
Main innovations	AI-assisted allocation strategy Adaptable runtime re-allocation
Target market	Potential ICOS users as well as any system that requires resources to services mapping.
Exploitation path	Generate different models that can be trained and even clustered into potential groups to characterize different layout conditions. Scientific publications are also expected to come up.

Table 116 Exploitable result #21

Type of asset	Individual
Owner(s)	ATOS
Short description	Job Manager. The asset enables ICOS to create schedulable jobs based on the Application Definition passed by the operator. These jobs once scheduled can be taken over and executed by other ICOS's components.
License	Apache 2.0
TRL	4
MRL	2-3
Business model	This technology and its related features are offered as premium paid features over the open-source baseline functionality.
Competitor(s)	Openshift, Kubernetes Scheduler
Main innovations	The Job Manager asset allows to create, manage and schedule different kind of jobs. It is a Go microservice RESTful API that accepts connections from others ICOS assets that can pull mentioned jobs. This microservice also contains a database that serves as root of trust.
Target market	Companies that need to distribute their applications within a big infrastructure in an automated way without losing the visibility of application components being distributed.
Exploitation path	This asset will be completed in the ICOS project. It will be internally used by ATOS internal teams to solve business complexities regarding Application Deployments in highly distributed infrastructure in real projects.

Table 117 Exploitable result #22

Type of asset	Individual
Owner(s)	ATOS
Short description	Deployment Manager. The asset enables ICOS to schedulable and execute jobs defined within the Job Manager. These jobs are interpreted by the specific underlying orchestrator by using a suitable driver for it.
License	Apache 2.0
TRL	4

MRL	2-3
Business model	This technology and its related features are offered as premium paid features over the open-source baseline functionality.
Competitor(s)	Openshift, Rancher Fleet
Main innovations	The Deployment Manager asset allows to request, manage and execute different jobs that exist in the Job Manager's persistence. It is a microservice in Go with a sidecar, it is an API that only works in pull mode and won't accept requests.
Target market	Companies with big infrastructure that needs to be orchestrated in an autonomous way considering that the applications used by companies is usually multi-component and highly distributed software.
Exploitation path	This asset will be completed in the ICOS project. It will be internally used by ATOS internal teams to solve business complexities regarding Application Deployments in highly distributed infrastructure in real projects.

Table 118 Exploitable result #23

Type of asset	Individual
Owner(s)	ATOS
Short description	Aggregator. Provides a simple way to query information about a multi-cluster system. It launches a server that, when connected, returns available data about clusters and their states.
License	Apache 2.0
TRL	4
MRL	2-3
Business model	This technology and its related features are offered as premium paid features over the open-source baseline functionality.
Competitor(s)	There is not a direct competitor that offers the same features as Aggregator, as its functions are quite tailored to the specific infrastructure that is being modelled.
Main innovations	The asset is capable of serving multi-cluster infrastructure state in a flexible manner as data may be delivered in multiple formats (JSON or Protobuf) and in different data models structures, tailored to the project's needs.
Target market	Companies with large multi-cluster infrastructures that need to constantly query current state of its clusters, nodes and devices.
Exploitation path	This asset will be completed in the ICOS project. It will be internally used by ATOS internal teams to solve business complexities regarding multi-cluster infrastructure status querying in a flexible data structure format.

Annex II: UCs questionnaire

In order to gather feedback about the usability or ICOS results and to validate the market approach, a questionnaire has been shared with the project use cases. This questionnaire is based on ATOS innovation and exploitation methodology for Horizon Europe projects. Given the project timeline, not all questions can be answered, thus, all contributions will be updated at the end of the project including more financial information with the main aim of providing information enough to an external reader to take an informed decision whether to use, or not, ICOS solutions.

Additionally, the same questionnaire will be shared with OC winners in order to gather feedback from external validators. This information will be also shared with the technical work packages to give them useful feedback to improve results.

General introduction

This section aims to provide an overview about each of the use cases to determine if the process followed for adopting ICOS is reusable or not. This section should not be longer than one page.

Short description of the use case

Start with a 2-3 sentence card that will be used as an introduction so whoever reads it knows exactly about what it is useful for and for who.

E.g., 2 applications for health wearables that collect information from elderly people about their glucose levels and predict potential peaks. They will collect the information from 100 devices in London City and send it to Hospital St. Martin where it will be analysed. Results will be shared with the doctor taking care of these patients.

Then you can explain in more details whatever you consider useful to understand your use case.

Problem to be solved

Explain here if you already have any application developed or you built it from scratch, how many applications do you have in your use case, what were the issues that did not allow you to get the maximum benefits from the applications (they can be technical but also market related).

Results after using ICOS

Explain how your use case has been improved according to the problem(s) identified before.

Technical Description

This section is about the technicalities of your use case only.

Use Case Overview

Describe your use case in technical terms, including the architecture (without ICOS), technologies used and/or infrastructure available.

Requirements

List all the specific requirements of your use case, the % of completion by ICOS, and what have been solved and how.

Table 119 UC X requirements

No.	Description	% of completion	What have been solved

Business Description

This section is about the business perspective of your use case only.

Use Case Overview

Explain your use case from a business perspective before ICOS and where you want to be, e.g., enter into new markets, allow business growth, etc.

Positioning

Explain how ICOS have supported the objectives identified in the previous subsection, how your business has evolved and what are your perspectives for the future.

ICOS Interaction

This section is built on top of the answers of the previous one. Here you will explain how you interact with ICOS to solve your problem(s).

ICOS Components

List all the components you are using in your use case, the functionalities integrated and for what.

Table 120 ICOS components used in UC X

No.	Name	Functionalities	Used for what

Invested time

Associated costs are useless for external readers, as their average PM rate may vary from one organization to another. However, time will help them to make an idea about how costly will be for them to adopt any of the ICOS solutions. Introduce the number of hours invested within ICOS to any of the following topics. In case any of the topics cannot be applied to your use case, just add N/A in the corresponding row. Add as many additional rows as needed according to the activities implemented.

Table 121 Time invested in ICOS related activities in UC X

Action	Time	Profiles used	% of time corresponding to each profile
Making new developments to adapt to ICOS requirements			
Integrating ICOS with your application			
Integrating ICOS with your available infrastructure			
Integrating ICOS with any other solution/technology you are already using			
Learning how to use ICOS			
Using ICOS support			

Additional Material

In this section add anything additional you consider useful for explaining your use case. E.g., architecture diagram, workflow showing the interaction with ICOS components, etc.