D7.1: Cascade actions analytics

Revision: v.1.0

Work package	WP 7
Task	Task 1,2,3,4
Due date	31/12/2025
Submission date	19/12/2025
Deliverable lead	Martel
Version	1.0
Authors	M.C. Campodonico (Martel)
Reviewers	Chathura Sarathchandra (Interdigital)
Abstract	This deliverable provides a comprehensive overview of participation across the three FSTP (Financial Support to Third Parties) calls, summarising overall statistics, key findings, lessons learned, and participant feedback. The document highlights the evolution of engagement, geographical and thematic distribution of beneficiaries, and the main outcomes and impacts achieved through the funded projects.
Keywords	Cascade funding

Document Revision History

Version	Date	Description of change	List of contributor(s)
V0.1	24/11/2025	1st version	M. C. Campodonico (*Martel*)
V0.2	08/12/2025	Input from 3rd project' mentors	Aurora Ramos Lopez (Capgemini), Jarno Pinola (VTT), Roberto Viola (Vicom), Antti Pauanne (UOULU)
V0.3	12/12/2025	Internal review	Chathura Sarathchandra (Interdigital)
V1.0	19/12/2025	Final version ready for submission	Jussi Hapoola (UOULU)

Grant Agreement No.: 101096838 Topic: HORIZON-JU-SNS-2022-STREAM-C-01-01
Call: HORIZON-JU-SNS-2022 Type of action: HORIZON-JU-RIA

DISCLAIMER

Co-funded by the European Union

Project funded by Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera Confederaziun svizra Swiss Confederation — Federal Department of Economic Affairs, Education and Research EAER State Secretariat for Education, Research and Innovation SERI

6G-XR (*6G eXperimental Research infrastructure to enable next-generation XR services*) project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101096838. This work has received funding from the Swiss State Secretariat for Education, Research, and Innovation (SERI).

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

COPYRIGHT NOTICE

Project co-funded by the European Commission in the Horizon Europe Programme		
Nature of the deliverable:	**R**	
Dissemination Level		
PU	*Public, fully open, e.g. web (Deliverables flagged as public will be automatically published in CORDIS project's page)*	**X**
SEN	*Sensitive, limited under the conditions of the Grant Agreement*	
Classified R-UE/ EU-R	*EU RESTRICTED under the Commission Decision No2015/ 444*	
Classified C-UE/ EU-C	*EU CONFIDENTIAL under the Commission Decision No2015/ 444*	
Classified S-UE/ EU-S	*EU SECRET under the Commission Decision No2015/ 444*	

* R: Document, report (excluding the periodic and final reports)

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

DATA: Data sets, microdata, etc.

DMP: Data management plan

ETHICS: Deliverables related to ethics issues.

SECURITY: Deliverables related to security issues

OTHER: Software, technical diagram, algorithms, models, etc.

EXECUTIVE SUMMARY

6G-XR provides an advanced experimental infrastructure designed to validate key Beyond 5G (B5G) and emerging 6G technologies that enable immersive applications such as holographic communication, digital twins, and Extended/Virtual Reality (XR/VR). The project delivers an energy-efficient, end-to-end B5G/6G architecture that integrates network slicing, Open RAN cloud implementations, and multi-access edge computing within a seamless cloud continuum. Through these innovations, 6G-XR promotes more efficient radio spectrum usage, contributes to standards development, and demonstrates impactful use cases supporting the evolution of XR services.

A central element of the project is the implementation of a comprehensive cascade funding programme, which makes 6G XR research infrastructures accessible to external innovators. Through three waves of Financial Support to Third Parties (FSTP) open calls, the project has engaged with SMEs, research organisations and academic teams to test, deploy and validate enablers and use cases that are aligned with the evolution towards 6G.

This deliverable provides a consolidated analysis of participation across the three Open Calls, summarising statistics, key insights, lessons learned, and feedback gathered throughout the process.

The document also examines the engagement of third-party participants, including statistical insights, submission trends, geographical distribution, thematic coverage, and evaluation outcomes. It further summarises the technical outputs, open source contributions, and overall impact of the funded experiments.

The three waves of Open Calls reflect the technological and infrastructural maturity of the project:

- **1st 6G-XR Open Call - Platform and Network Enablers** focused on strengthening and extending the 6G XR infrastructures;
- **2nd 6G-XR Open Call - Stream B Enablers** targeted technology validation and integration of enablers with SNS Stream B thematises; and
- **3rd 6G-XR Open Call - Vertical Replicability Enablers** supported vertical Use Cases applications deployed on the advanced 6G XR research facilities.

Together, these activities broadened the project's reach, validated advanced technologies in realistic environments, and reinforced Europe's strategic leadership in 6G enabled XR services.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AI	Artificial Intelligence
AR	Augmented Reality
B5G	Beyond 5G
CU	Central Unit
DL	Deep Learning
DoA	Description of Actions
DRL	Deep Reinforcement Learning
DT	Digital Twin
DU	Distributed Unit
E2E	End 2 End
ECOT	Edge Computing Optimization Tool
EVCS	Electric Vehicle Charging Station
FPS	Frames Per Second
FSTP	Financial Support to Third Parties
GA	Grant Agreement
GPU	Graphics Processing Unit
IoT	Internet of Things
KPI	Key Performance Indicator
MAE	Mean Absolute Error
MCS	Modulation and Coding Scheme
ML	Machine Learning
MQTT	Message Queuing Telemetry Transport
MR	Mixed Reality
NEF	Network Exposure Function
OC	Open Call

PC	Personal Computer
PRB	Physical Resource Block
QoD	Quality on Demand
QoE	Quality of Experience
QoS	Quality of Service
QUIC	Quick UDP Internet Connection
RAN	Radio Access Network
RIC	RAN Intelligent Controller
RU	Radio Unit
SA	Standalone (5G SA)
SfM	Structure from Motion
SLA	Service Level Agreement
SME	Small and Medium Enterprise
TRL	Technology Readiness Level
UE	User Equipment
UL	Uplink
UPF	User Plane Function
VR	Virtual Reality
XR	eXtended Reality

1 INTRODUCTION AND OVERVIEW OF THE OPEN CALLS

1.1 INTRODUCTION

6G-XR ambition is to strengthen European leadership in 6G technologies by enabling next-generation XR services and infrastructures that will provide beyond-state-of-the-art capabilities towards the 6G era.

The project developed an experimental multisite Research Infrastructure (RI) to provide a validation platform for various 6G-use cases by developing enablers for networking and computing, radio access technologies beyond 5G, enablers for XR services with in-build federation, trial management, abstraction tools as well as energy measurement frameworks.

This framework foresees, through the cascade funding mechanism, the participation of third parties to use to use the 6G-XR research infrastructures, develop and validate XR and 6G-enablers and test vertical replicability.

The 6G-XR project has identified three different application areas that would benefit from the large-scale deployment of B5G/6G networks:

- **Real-Time Holographic Communications**
- **Collaborative 3D Digital Twin-like Environment**
- **Energy Measurement Framework for Energy Sustainability**

around which five internal Use Cases have been developed: UC1, UC2, UC3 under Real-Time Holographic Communications, UC4 under Collaborative 3D Digital Twin-like Environment and UC5 under Energy Measurement Framework for Energy Sustainability.

Building on the overview of the Open Calls presented in Section 1, the next subsection clarifies this deliverable's specific objectives in relation to the Description of Action (DoA).

It explicitly links Work Package 7 (WP7) and Tasks 7.1–7.4 to the relevant project objectives and Key Performance Indicators (KPIs), directing the reader to the sections where quantitative and qualitative evidence of compliance is reported.

1.2 OBJECTIVES OF D7.1 AND RELATION TO THE DOA

Deliverable D7.1 addresses the requirements of the Grant Agreement and DoA related to WP7. This WP is dedicated to designing, launching, managing and implementing cascading funding or Financial Support to Third Parties (FSTP) within the 6G-XR project. WP7 implements Objective 8: Cascading Actions of the project, contributing directly to Objective 4: Federation Methodologies for External Stakeholders and indirectly supporting the technical and validation objectives of the WPs 2-6 by opening the 6G-XR Research Infrastructure (RI) to external innovators.

1.2.1 Relation to WP7 and Tasks 7.1–7.4

WP7 pursues the following specific objectives, as defined in the DoA:

- O7.1-O7.4: Definition, launch, management, evaluation and contracting of open and competitive cascade calls
- O7.5: Technical mentoring, integration and validation of third-party projects
- O7.6: Monitoring of milestones, KPIs and payments for FSTP actions

As such, D7.1 consolidates the outcomes of Task 7.1: Legal and financial management of cascading calls, Task 7.2: Definition and implementation of open calls and Task 7.3: Selection of cascading partners, by establishing the procedural and methodological basis for Task 7.4 Integration and validation of cascading actions.

1.2.2 Alignment with Project Objectives and KPIs

Through the implementation of three waves of Open Calls (6G-XR_OC1, OC2 and OC3), D7.1 directly supports Objective 8: Cascading Actions and its KPIs:

- KPI 8.1 Implementation of the cascade funding process for three waves of Open Calls
- KPI 8.2 Selection and funding of at least 30 third-party projects
- KPI 8.3 Presentation and dissemination of third-party results through 6G-XR events

In addition, WP7 contributes to Objective 4 (Federation methodologies for external stakeholders) by enabling external access to the 6G-XR platform, testbeds and abstraction/orchestration tools. This supports KPI4.1 (success rate of cascading projects) and facilitates the deployment and validation of federated experiments across multiple sites.

1.2.3 Mapping to D7.1 Structure

The D7.1 structure is as follows:

- **Section 1: Introduction and overview of the open calls**

  This section provides an introduction to the objectives of WP7 and D7.1, explains the rationale behind the cascading funding within 6G-XR and outlines how this aligns with the DoA.

- **Section 2: Open calls statistics**

  This section reports on various quantitative indicators, such as the number of open calls, the number and type of funded third parties, SME participation and the geographical coverage of beneficiaries. It also addresses KPIs related to openness, inclusiveness and participation.

- **Section 3: Outcomes of selected projects**

  This section presents the qualitative and quantitative results of the funded projects. These results include information on achieved TRL progression, technical and innovation impact, contribution to the 6G-XR platform and use cases, and contributions to open-source software, standardisation and reuse.

- **Section 4: Conclusions**

This section summarises the overall impact of the cascading actions, the lessons learned and the contribution of WP7 to achieving the project's objectives and expected outcomes.

1.3 NORTH AND SOUTH NODE

The research infrastructures are divided between the South and North Node.

South Node

Within the South Node, the following Use Cases have been internally developed, leveraging the advanced network capabilities of the infrastructures of "5TONIC testbed" located in Madrid and "i2CAT Testbed" (previously named 5GBarcelona) located in Barcelona.

Figure 1: South Node

Real-Time Holographic Communications

Three of the internal 6G-XR Use Cases (UC) revolve around real time holographic communications, by incorporating novel XR, network and cloud continuum enablers to enhance their performance and interoperability.

UC1: Resolution Adaptation or Quality on Demand: Detect network congestion or Quality of Service (QoS) dropped to trigger network-assisted Rate Adaption recommendation or request Quality on Demand (QoD)

UC2: Routing to the Best Edge: Discover, select and make use of the most appropriate Edge resources to run XR processing or communication functions, based on specific criteria and goals

UC3: Control Plane Optimizations: Integrate holographic communications to the network control plane

North Node

Under the North node other two internal Use Cases have been developed leveraging the advanced capabilities of the VTT 5GTN, UOulu 5GTN testbeds located in Oulu (Finland)

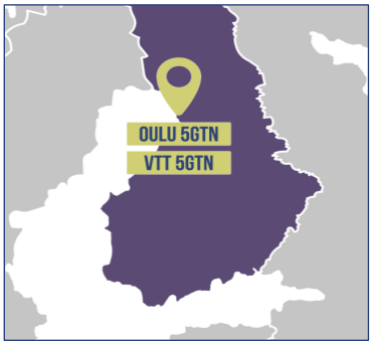

Figure 2: North Node

Collaborative 3D Digital Twin-like Environment (UOulu 5GTN infrastructure)

Remote collaboration enhances societal and team productivity/efficiency. Real collaboration around of a common asset, machine, manufacturing place or environment is enabled

thanks to a collaborative 3D DT environment. Key outcome is extracted due to the capabilities of bridge regional disparities and provide equal opportunities regardless of the geographical location. Traditional example of gaps covered is the disparity between industrial and rural locations.

UC4: Collaborative 3D Digital Twin-like Environment: Enable real-time collaboration and control of physical assets in virtual reality

Energy Measurement Framework for Energy Sustainability (VTT 5GTN, UOulu 5GTN: Infrastructures)

UC5: Energy Measurement Framework for Energy Sustainability: Measure and optimise end-to-end energy consumption in mobile networks

Within the North node, the 6G-XR project aims to deploy an extensive energy measurement framework for the test sites as well as to introduce the required intelligence and functionality into the network components so that the energy consumption data can be utilized to optimize the end-to-end energy consumption and use of local renewable energy for variety of different XR related applications.

1.4 OPEN CALLS: RATIONALE AND STRUCTURE

To achieve its objectives and to open up the infrastructure to broader innovation, 6G-XR implements a series of three cascading Open Calls (OCs) to attract third-party innovators (SMEs, industry, research organisations). The reason for these OCs is threefold:

- To enable external teams to leverage the RI and enablers developed by 6G-XR, thereby extending the impact of the project beyond the core consortium.
- To validate and trial novel XR services, components and architectures in realistic research/testbed environments aligned with the 6G era.
- To foster vertical replicability, i.e., uptake by industry verticals, cross-sector innovation and faster deployment of immersive XR services.

1.5 SCOPE OF THE OPEN CALLS

Each call has identified a specific scope:

- the purpose of the **1st 6G-XR Open Call - Platform and Network Enablers** (6G-XR OC1) is to address identified gaps in the 6G-XR infrastructures and targets the development and extension of the four research infrastructures to make them ready for advanced experimentation in upcoming project open calls for experimentation. In particular, the project was looking for networking, computing enablers, XR enablers, RAN enablers and Sustainability enablers in terms of the following implementations.

Details about the Open Call 1 can be found in the project website, as 1st 6G-XR Open Call Info document[1].

- the purpose of the **2nd 6G-XR Open Call - Stream B Enablers** (6G-XR OC2) is to validate, test, and/or incorporate enablers coming out of Horizon Europe SNS JU Stream B thematises. Out of these thematises, in particular, the project was looking for topics and subtopics in the following AREAS (and 6G-XR Infrastructures): reflective intelligent surfaces, deterministic communications, energy measurement, AI/ML for slicing, load balancing, security and trust mechanisms, increased capacity, other Stream B thematises.
  Details about the Open Call 2 can be found in the project website, as 2nd 6G-XR Open Call Info document[2].

- the purpose of the **3rd 6G-XR Open Call - Vertical Replicability Enablers** (6G-XR OC3), by providing access to advanced 6G-XR infrastructure, testbeds, and enablers, is to allows external teams to deploy, replicate, and validate their own XR use cases, from real-time holographic communications to immersive technologies and energy measurement framework for energy sustainability, as part of shaping the 6G era**.**
  Details about the Open Call 3 can be found in the project website, as 3rd 6G-XR Open Call Info document[3].

1.6 TIMEFRAME

The three subsequential Open Calls were executed between 2023 and 2025, composed of different phases as per the table below.

Table 1: Open Calls timeframe

Call phases	6G-XR-OC1	6G-XR-OC2	6G-XR-OC3
Opening of the Call	September 2023	March 2024	December 2024
Feasibility Check	31 October 2023	29 April 2024	10 January 2025
Final submission	27 November 2023	22 May 2024	7 March 2025
Start of the project	January 2024	September 2024	April 2025
End of the project	June 2024	February 2025	October 2025

- **Targeted participants**: SMEs, industry, research scientific organisations and academia.
- **Eligibility**: the key eligibility rules are reported below:
  - legal entity in EU Member State or Horizon Europe Associated country; single entity;

[1] 1st 6G-XR Open Call Info document: https://6g-xr.eu/open-calls/oc1/

[2] 2nd 6G-XR Open Call Info document: https://6g-xr.eu/open-calls/oc2/

[3] 3rd 6G-XR Open Call Info document :https://6g-xr.eu/open-calls/oc3/

- not affiliated with 6G-XR consortium partners
- no affiliation to any of the consortium partners of the 6G-XR project
- the submission of proposals by a single party only, no consortia admitted.

1.7 OPEN CALLS DETAILS

The financial framework of the 6G-XR cascading funding mechanism was designed to ensure balanced support across the three Open Call waves while maximising the number and quality of funded experiments. Each Open Call allocated a fixed maximum contribution of €60.000 per third-party project, with an implementation timeframe of six months. The table below summarises the distribution of the budget across the three waves, including the number of funded projects and the total funding awarded under each Open Call.

Table 2: Open Calls details

Open Call	Project duration	Max funding (€)	No of projects	Total funding (€)
6G-XR-OC1	6 months	60.000	8	480.000 €
6G-XR-OC2	6 months	60.000	10	600.000 €
6G-XR-OC3	6 months	60.000	12	720.000 €

1.8 EVALUATION AND AWARD

The evaluation was carried out by an independent, jury of external experts with no affiliation to the consortium or conflicts of interest. Each eligible proposal was reviewed independently by at least two experts, after which consensus meetings were held to agree on final scores. Based on these results, the expert panel established a joint ranking of all proposals and awarded the grants accordingly.

Evaluations were conducted according to the following predefined criteria as described in the Information Document for each Open Call: **Clarity and Methodology, Ambition, Impact, Replicability, Contribution to Standardisation, Team Capacity, Value for Money, SME Participation, Gender Dimension, Maturity/trajectory of the proposing organization/proposed development**.

The evaluation and award process was designed to ensure transparency, impartiality and consistency, resulting in a fair and robust ranking of all proposals submitted.

Each Open Call followed a structured and transparent evaluation process:

- **Eligibility criteria** ensured participation from independent EU/Associated-country organisations without affiliation to the consortium.
- **Two-phase submission (feasibility and final)** enabled technical refinement through the feasibility feedback from 6G-XR mentors.
- **Independent evaluation** with experts in the relevant domain who had no affiliation with the consortium and no conflicts of interest.

- **Two evaluators reviewed each proposal based on the following criteria**: Clarity and Methodology, Ambition, Impact, Replicability, Contribution to Standardisation, Team Capacity, Value for Money, SME Participation, Gender Dimension, Maturity/ trajectory of the proposing organization/proposed development.

- **Admissible proposals underwent consensus assessment**, resulting in a ranked list from which the highest-scoring experiments were funded.

2 OPEN CALLS STATISTICS

This section provides an overview of the participation and evaluation outcomes and overall engagement across the three 6G-XR Open Calls. It combines quantitative and qualitative insights to illustrate how the cascading funding scheme attracted a diverse set of innovators It assesses the effectiveness and reach of the Open Call Programme by analysing application numbers, geographical distribution, thematic focus and selection trends.

2.1 PARTICIPATION AND SELECTION STATISTICS

It outlines the statistical outcomes of the Open Calls, outlining participation trends, geographical coverage, organisational diversity, and the distribution of selected experiments across the North and South Nodes. It also highlights recurring patterns such as multiple submissions, admissibility rates, and the overall competitiveness observed throughout the evaluation process.

Participation across the three Open Calls demonstrated a strong and consistent interest from the European innovation ecosystem, with SMEs constituting the majority of applicants, complemented by an active contribution from research institutes and academia.

Proposals were submitted from a broad geographical spectrum, including Southern, Western, Northern, and Eastern Europe, confirming the programme's EU-wide reach.

Each Open Call followed a rigorous eligibility and evaluation workflow, distinguishing between admissible and non-admissible proposals (e.g., multiple submissions, non-final versions, or insufficient feasibility) taking into consideration the two phases of the submission (feasibility and final).

After external evaluation, selected experiments were matched to either the North Node (Oulu 5GTN, VTT 5GTN) or the South Node (i2CAT, 5TONIC, 5GBarcelona/i2CAT testbed) according to, from one hand to the technical fit and infrastructure needs and on the other to balance the workload on the four 6G-XR facilities.

Many topics received multiple proposals, and selection often required balancing technical feasibility, innovation relevance, and facility availability.

The resulting portfolio of funded experiments demonstrates a diverse and complementary set of technological explorations aligned with 6G-XR's strategic objectives.

Number of proposals received per Open Call

The figure below presents the number of proposals received for each Open Call, providing an overview of community engagement and responsiveness to the call topics.

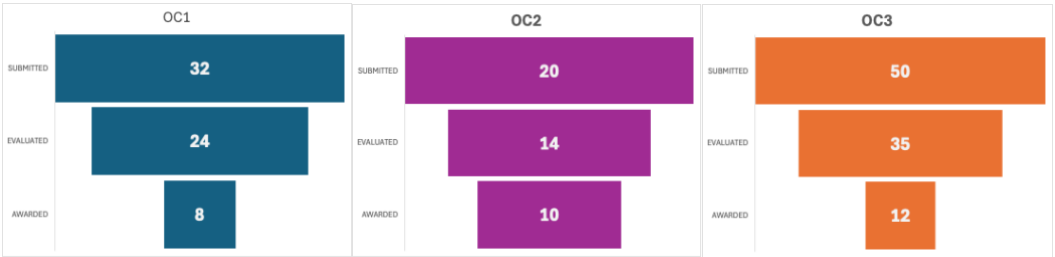

Figure 3: Participation in 6G-XR Open Calls

Success rates

The success rates are calculated on the admissible projects excluding multiple submission, not eligible and not feasible proposals in compliance with the respective info document. With regards to the feasibility, all the submissions have been checked and verified their feasibility within the corresponding 6G-XR Research Infrastructure. And all the project received feedback from the mentor of the selected 6G-XR facility allowing the applicant, in case of not compliance, to adjust the proposal in the final submission. The higher success rate in Open Call 2 reflects the more specialised scope aligned with SNS Stream B themes, while Open Call 1 and Open Call 3 observed broader and more competitive participation.

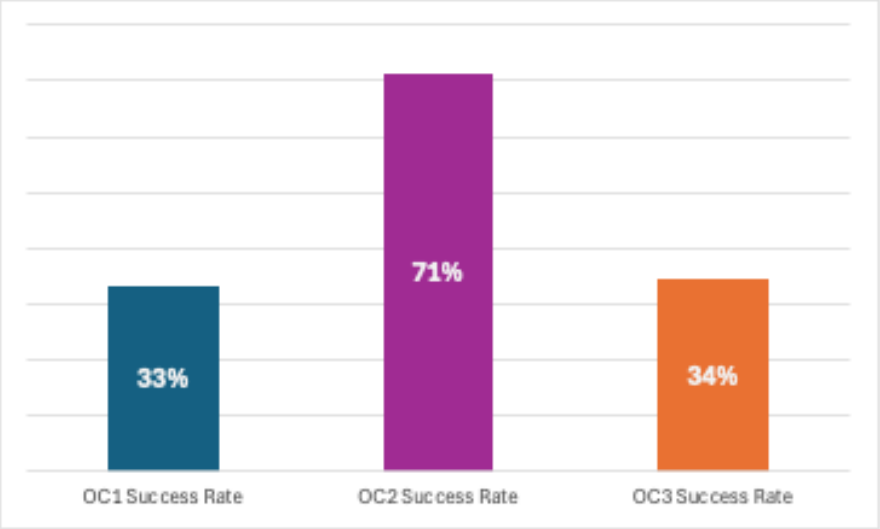

Figure 4: Success Rate in Open Call 1, Open Call 2, Open Call 3

Geographic Distribution

The Open Calls collectively attracted proposals from a wide geographical area, covering Northern, Southern, Eastern, and Western Europe. This demonstrates strong EU-wide interest in 6G-XR infrastructures and the inclusive nature of the cascade funding programme.

The figures below show the countries represented respectively for each Open Call, selected vs non-selected.

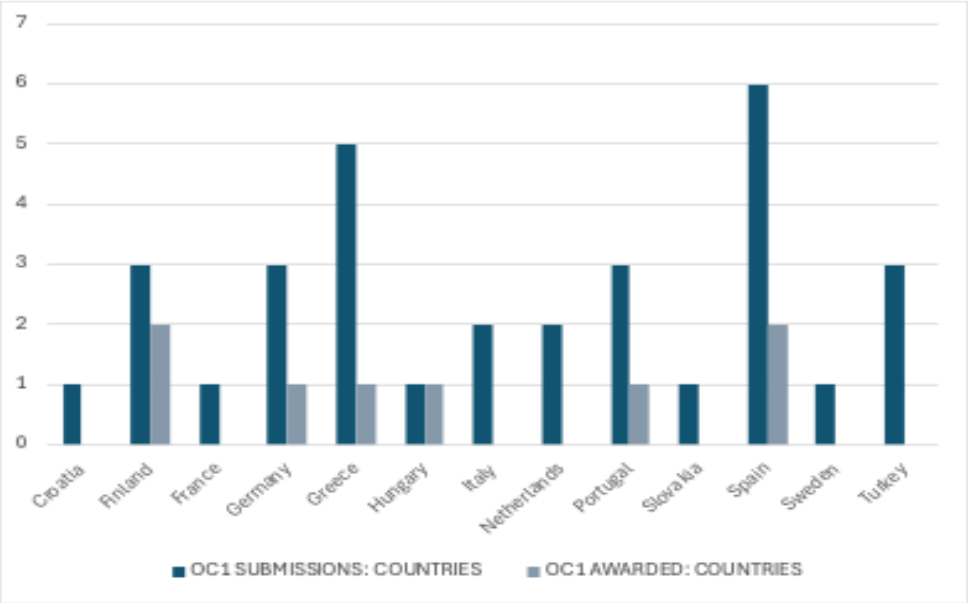

Figure 5: Countries participating in Open Call 1 selected vs non-selected

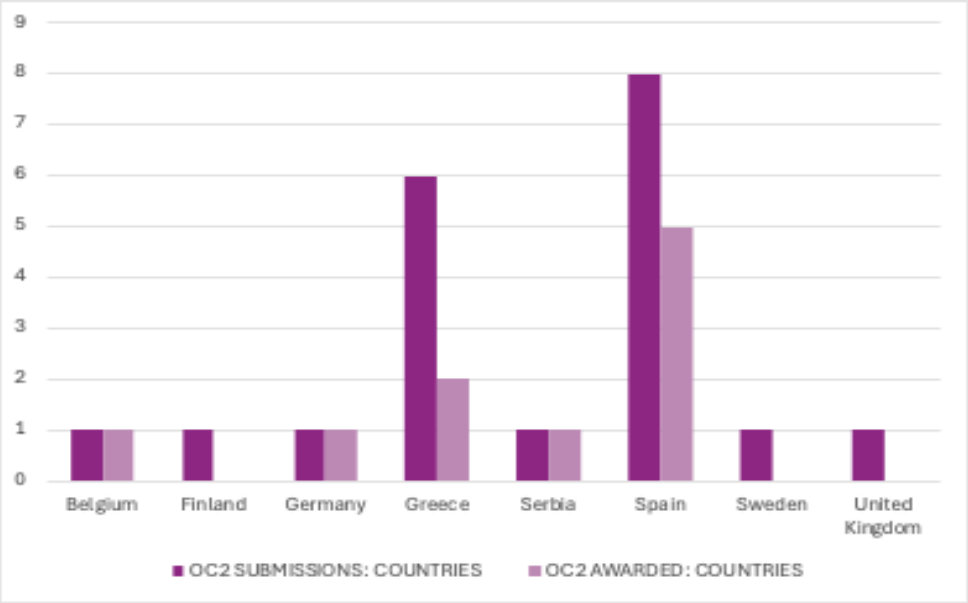

Figure 6: Countries participating in Open Call 2 selected vs non-selected

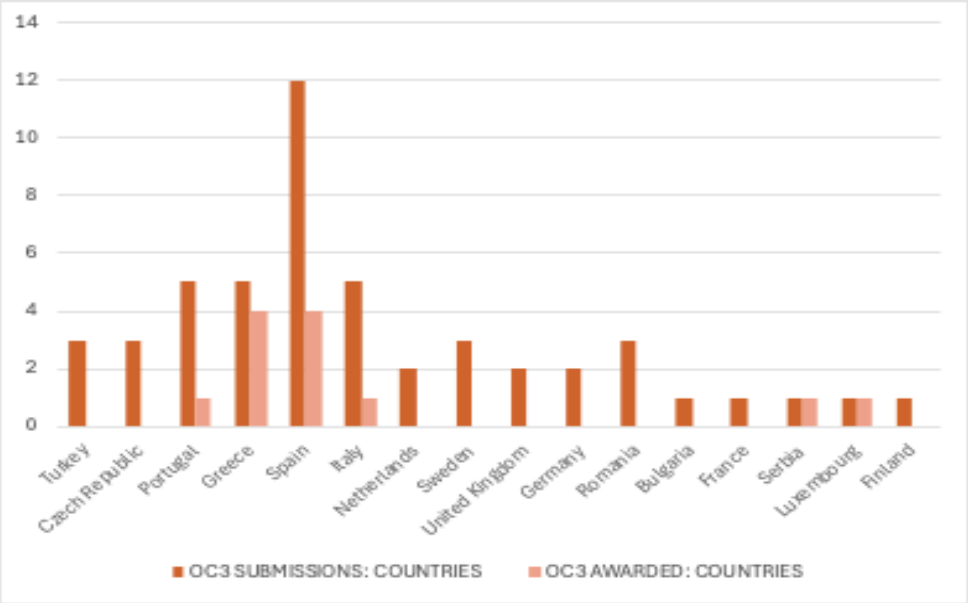

Figure 7: Countries participating in Open Call 3 selected vs non-selected

Organisation Types

The eligible applicants for all the three waves of Open calls are SMEs, academia, research/ scientific organisations. In the graphic below is shown the comparison between the submitted and awarded by type per Open Call.

SMEs were the most represented category, both in submissions and among awarded projects, reflecting their agility and central role in 6G innovation.

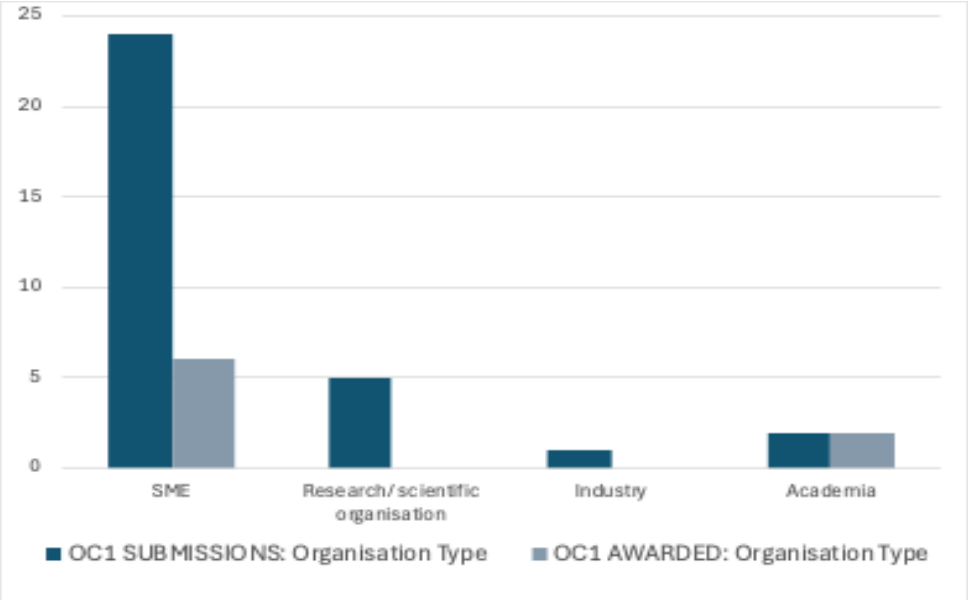

Figure 8: Organisation Types participating in Open Call 1 selected vs non-selected

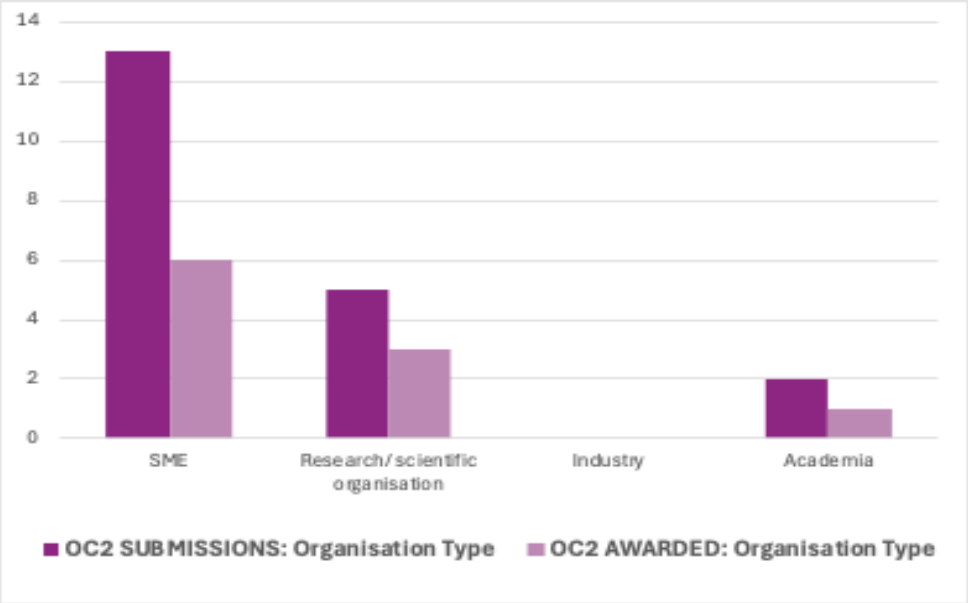

Figure 9: Countries participating in Open Call 2 selected vs non-selected

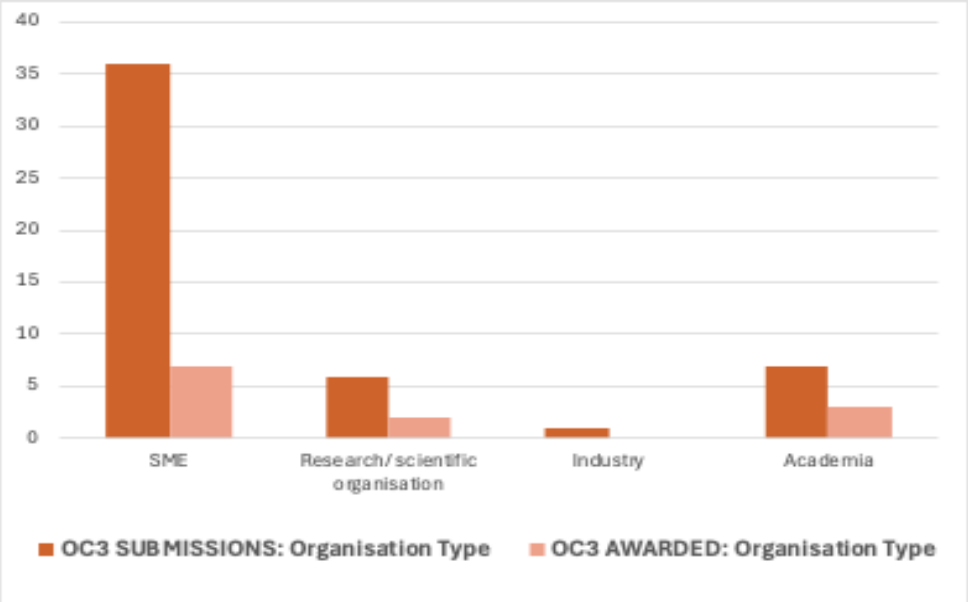

Figure 10: Countries participating in Open Call 3 selected vs non-selected

Budget utilisation

All selected projects got lump sums and followed eligibility criteria (personnel, travel, indirect/overhead 25%) with no advance payments. As shown in the figure below, almost the entire budget planned for third-party projects was awarded, with only a minimal amount remaining.

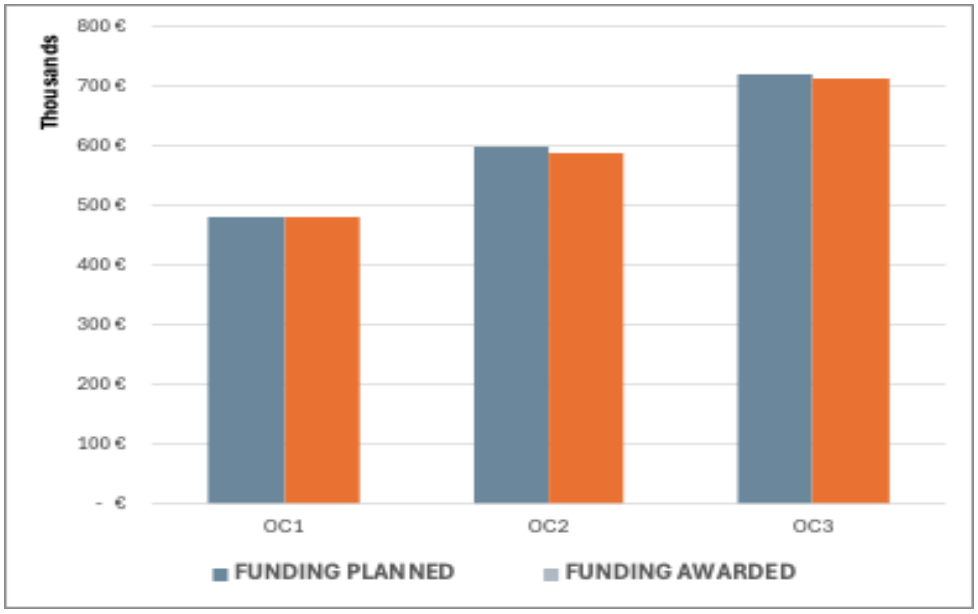

Figure 11: Budget utilisation Planned vs Awarded

2.2 THEMATIC AND TECHNICAL AREAS

The three 6G-XR Open Calls were designed to progressively address complementary thematic and technical areas that support the overall objectives of the project.
Each Open Call targeted specific enablers, areas of experimentation and vertical application areas that could be effectively implemented and validated within the 6G-XR research infrastructures.
The outcomes of each Open Call are shown in the figures below, which provide a comparative overview of the selected areas and sub-areas (named 'TOPXX') and those awarded by the consortium.
The results as reported in the corresponding tables for Open Call 1, Open Call 2 and Open Call 3.

2.2.1 1st 6G-XR Open Call: Platform and Network Enablers

The first Open Call aimed to strengthen and extend the capabilities of the four 6G-XR research infrastructures.
In particular, 6G-XR invited third-party projects to contribute to the development, integration and validation of key platform and network enablers.
This call targeted four main categories of enablers, summarised in the table below.
Table 3 maps each call topic to its corresponding thematic and technical areas, highlighting the specific enablers addressed.

Table 3: Details of the OC1 thematic and technical areas and corresponding enablers

Call Identifier	Areas	Networking and Computing Enablers	XR Enablers	RAN Enablers	Sustainability Enablers
TOP 1	**Automated IP network measurement system**	X			X
TOP 2	**Edge discovery API**	X	X		
TOP 3	**Holographics API**	X	X		
TOP 4	**CAMARA QoD implementation over Open5GS**	X	X	X	
TOP 5	**Fab Lab digital twin environment**		X		
TOP 6	**Advancing Heterogeneous XR Capture Systems**		X	X	
TOP 7	**XR fusion**	X	X		
TOP 8	**Wireless Connectivity for XR Sensors**		X	X	
TOP 9	**Encoding solutions optimized for Point Cloud/Volumetric Video compression**	X	X		X
TOP 10	**Low-latency or scalable streaming protocols and methods for XR**	X	X		X
TOP 11	**QoE assessment models and methods for XR experiences**		X		
TOP 12	**XR Interaction and Collaboration Software Modules and APIs**	X	X		
TOP 13	**Multi-sensory communications and interactions**	X	X		
TOP 14	**End-to-end slicing with RAN resource sharing**	X		X	
TOP 15	**RAN or/and Sustainability enablers**			X	X

The Figure 12 below compares the thematic and technical areas proposed in Open Call 1 with those ultimately awarded, highlighting the distribution of submissions versus selected projects.

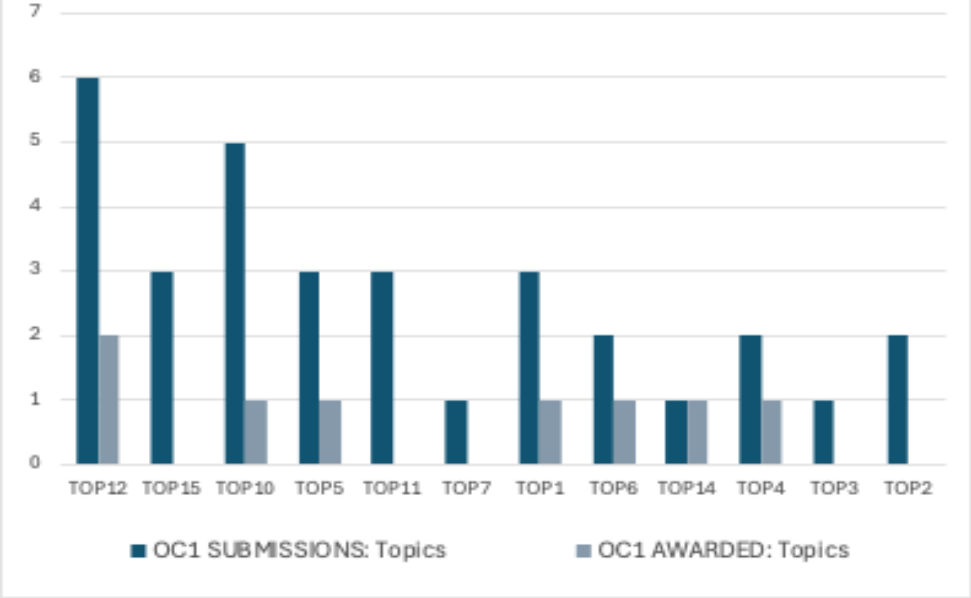

Figure 12: Thematic and Technical Areas in Open Call 1: submissions vs awarded

2.2.2 2nd 6G-XR Open Call: Stream B Enablers

The second 6G-XR Open Call focused on validating, testing and integrating technological enablers aligned with the thematic priorities of Horizon Europe's SNS JU Stream B.
This call aimed to leverage 6G-XR research infrastructures to assess advanced network technologies and system-level innovations relevant to future 6G architectures in an experimental setting.

In particular, the call addressed a broad range of Stream B themes, including: **Deterministic communications and networking, Reflective intelligent surfaces, AI/ML-based slicing, Energy measurement and optimisation, Security and trust mechanisms, Load balancing across the device-edge-cloud continuum, Increased network capacity** and other thematises that are not included in the previous ones.

This variety of topics enabled experimentation across multiple layers of the network stack, supporting both performance-driven and sustainability-oriented objectives.

Table 4 summarises the thematic and technical areas covered by each call topic, indicating the corresponding 6G-XR Node(s) and Facility(ies) made available for experimentation within the project.

Table 4: Details of the OC2 thematic and technical areas and corresponding 6G-XR facilities

Call Identifier	Areas	Sub-area	6G-XR Node	6G-XR Facility
TOP1	**Reflective intelligent surfaces**	150 GHz Reflective Intelligent Surface (RIS)	North	UOulu 5GTN
TOP2.1	**Deterministic communications**	Implementation and verification of wireless deterministic communication links on 3D digital twin use case	North	UOulu 5GTN
TOP2.2		Deterministic networking	South	5GBarcelona
TOP2.3			North	UOulu 5GTN
TOP3.1	**Energy measurement**	Sustainability enablers for energy measurement and optimisation	North	UOulu 5GTN
TOP3.2			North	VTT 5GTN
TOP3.3		Monitoring of energy consumption of VNFs for Multimedia Streaming	South	5GBarcelona
TOP3.4			North	VTT 5GTN
TOP4	**AI/ML for slicing**	AI/ML algorithm for efficient resource optimization in the 5G slicing techniques	North	UOulu 5GTN
TOP5.1	**Load balancing**	Mechanisms for load-balancing and service migration to enable Device/Edge/Cloud continuum	South	5TONIC
TOP5.2		Mobility Load Balancing on ORAN campus network	South	5GBarcelona
TOP6.1	**Security and trust mechanisms**	Multi-stakeholders security and trust mechanisms for Edge North Bound interfaces	South	5TONIC
TOP6.2			South	5GBarcelona
TOP6.3		Confidential computing environments for end-to-end energy efficiency	North	VTT 5GTN
TOP7	**Increased capacity**	6G channels	South	5GBarcelona
TOP8	**Other Stream B thematises**	Other proposals coming from Stream B thematises	North/South	all

The Figure 13 below compares the thematic and technical areas proposed in Open Call 2 with those ultimately awarded, highlighting the distribution of submissions versus selected projects.

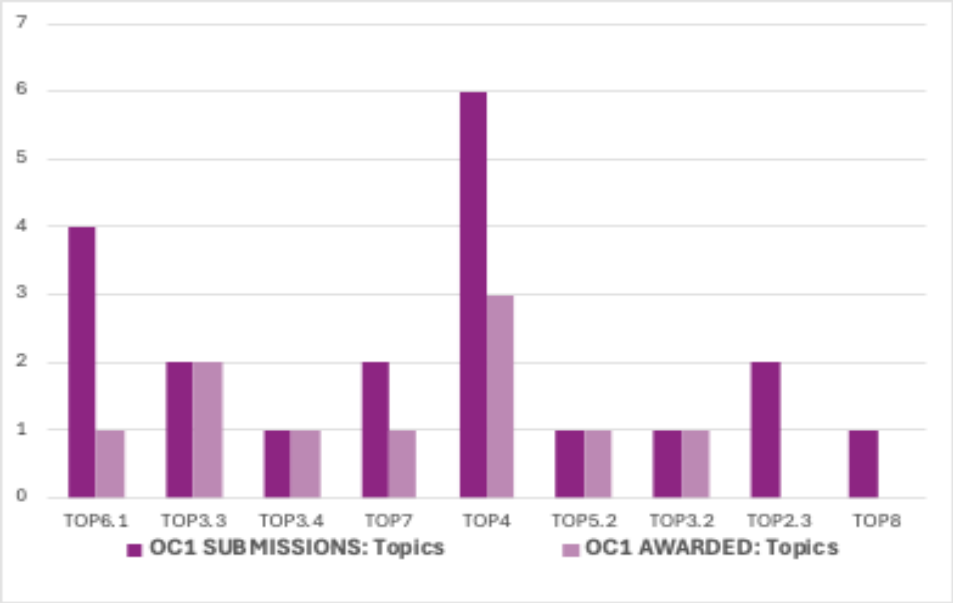

Figure 13: Thematic and Technical Areas in Open Call 2: submissions vs awarded

2.2.3 3rd 6G-XR Open Call: Vertical Replicability Enablers

The third 6G-XR Open Call focused on the deployment, replication and validation of XR-driven use cases in vertical sectors, with a particular emphasis on real-time holographic communications, immersive services and energy sustainability.

This call aimed to demonstrate the replicability and scalability of advanced XR applications across different domains and experimental environments, leveraging the full range of 6G-XR research infrastructures, with the scope of the call covering a diverse set of vertical scenarios, including immersive education and training, cultural and industrial applications, collaborative 3D digital twin environments, connected and cooperative automated mobility (CCAM) use cases, and AI-enabled systems.

In parallel, the development and validation of an energy measurement framework was prioritised to support end-to-end energy monitoring, optimisation, and sustainability assessment across XR-enabled network deployments.

Table 5 provides an overview of the thematic areas, technical sub-areas, and the relevant 6G-XR Node(s) and Facility(ies) associated with each call topic, showcasing the range of experimentation enabled by the third Open Call.

Table 5: Details of the OC3 thematic and technical areas and corresponding 6G-XR facilities

Call Identifier	Areas	Sub-area	6G-XR Node	6G-XR facility
TOP1.1	**Real-Time Holographic Communications**	Full-fledged multimedia platforms / services	South	I2CAT
TOP1.2	**Immersive Services**	Training and education	South	I2CAT
TOP1.3		Culture visits and events, by using immersive platforms	South	I2CAT
TOP1.4		Smart Industry / Spaces, by using immersive platforms	South	I2CAT, 5TONIC
TOP1.5		Interactive multiuser multi-sensory experiences	South	I2CAT
TOP1.6		Energy immersive platforms for virtual testing and evaluation	South	5TONIC
TOP1.7	**CCAM**	CCAM in micro-mobility scenarios	South	I2CAT, 5TONIC
TOP2.1	**Collaborative 3D Digital Twin-like Environment**	Simulation and predictionin Industry	North	UOulu 5GTN
TOP2.2		Operational training, remote collaborative operations in education	North	UOulu 5GTN
TOP2.3		Visualization and data sharing	North	UOulu 5GTN
TOP3.1	**Energy Measurement Framework for Energy Sustainability**	Utilization of open data in the optimization of RAN energy usage	North	UOulu 5GTN, VTT 5GTN
TOP3.2		End-to-end energy budgeting	North	UOulu 5GTN, VTT 5GTN
TOP3.3		Visualization of mobile network measurement data	North	UOulu 5GTN, VTT 5GTN
TOP3.4		Calibrations, validations, verification of energy measurement data	North	VTT 5GTN
TOP4.1	**Artificial Intelligence**	AI supervised manufacturing	North/ South	UOulu 5GTN, VTT 5GTN, 5TONIC, I2CAT
TOP4.2		Distributed AI for Energy	South	5TONIC
TOP5.1	**Open Topic**	Open vertical replicability	North/ South	UOulu 5GTN, VTT 5GTN, 5TONIC, I2CAT

The Figure 14 below compares the thematic and technical areas proposed in Open Call 3 with those ultimately awarded, highlighting the distribution of submissions versus selected projects.

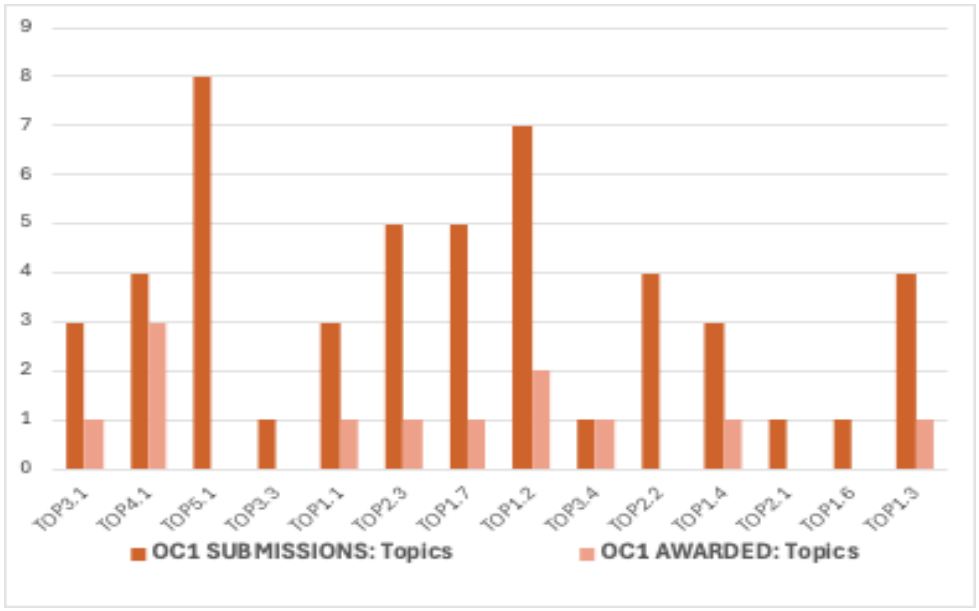

Figure 14: Thematic and Technical Areas in Open Call 3: submissions vs awarded

2.3 RESEARCH INFRASTRUCTURES AND TESTBEDS SELECTION

As outlined in previous sections, the 6G-XR project made four advanced research infrastructures available to third parties across the North and South nodes, in order to support the execution of open call projects.
Applicants were given the flexibility to select the 6G-XR Node and specific facility that best suited their experimentation and technical requirements.
For several call topics, multiple testbed options were available, enabling applicants to select the most suitable environment for their use case.

The figures below present a comparative analysis of the nodes and testbeds selected in the proposals submitted versus those ultimately awarded by the consortium. This comparison is shown both in aggregate across all Open Calls and separately for Open Calls 1, Open Call 2 and Open Call 3, providing insight into applicants' preferences, infrastructure utilisation and alignment between demand and final project selection.

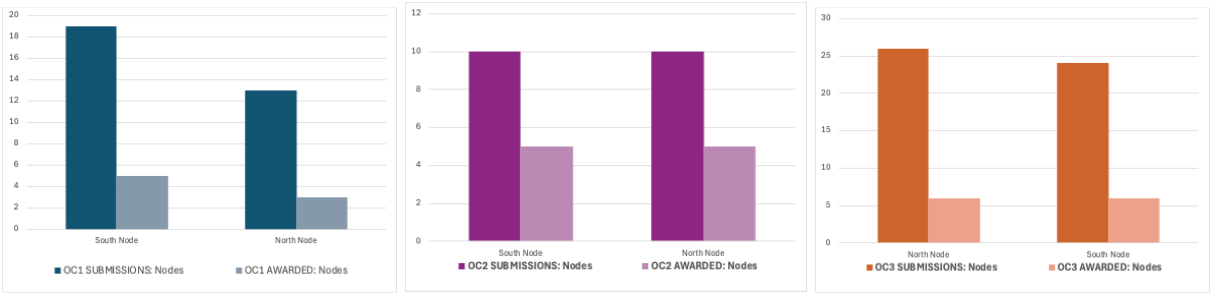

Figure 15: 6G-XR nodes and facilities in Open Call 1, 2 and 3: submissions vs awarded

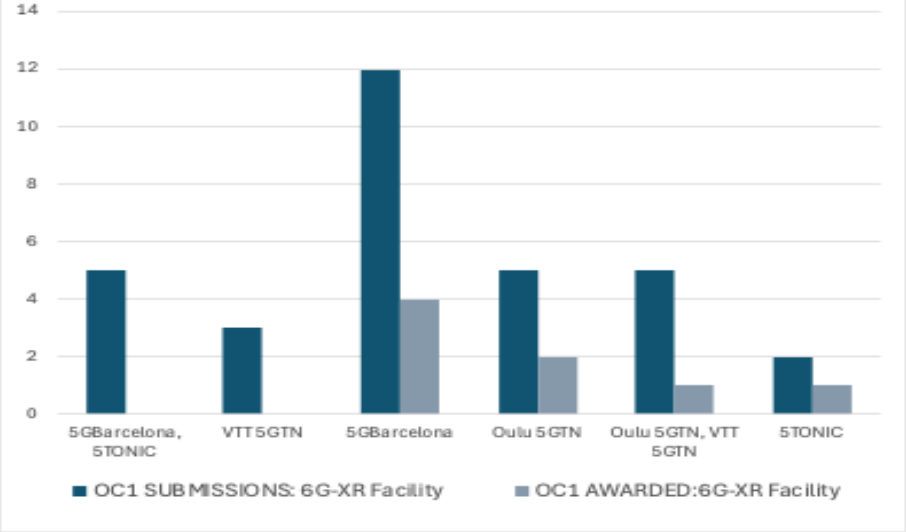

Figure 16: 6G-XR nodes and facilities in Open Call 1: submissions vs awarded

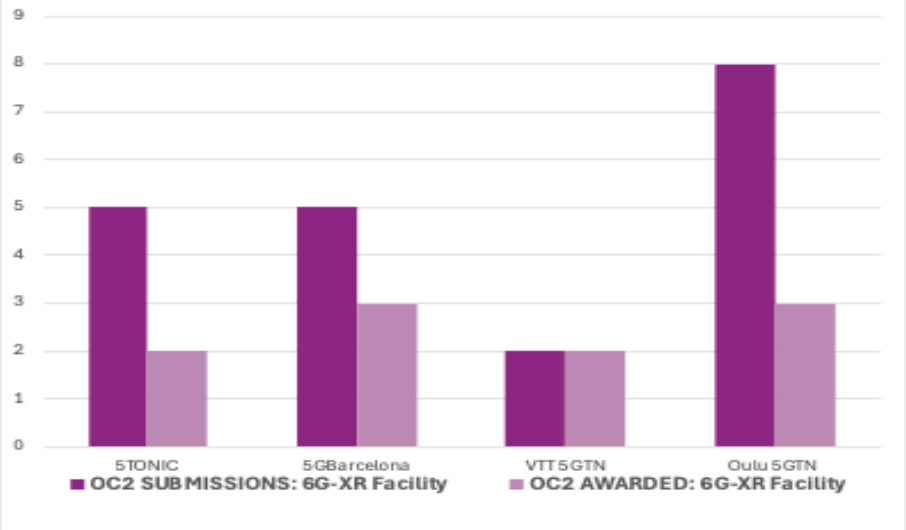

Figure 17: 6G-XR nodes and facilities in Open Call 2: submissions vs awarded

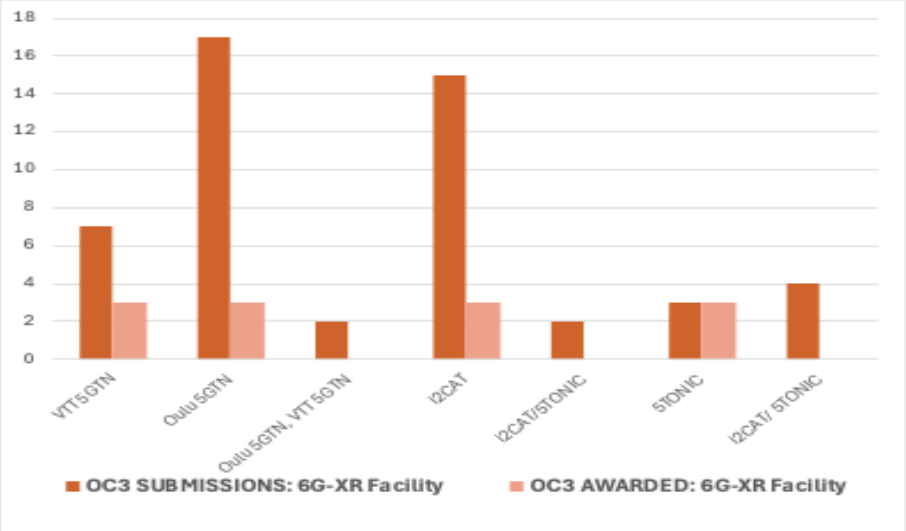

Figure 18: 6G-XR nodes and facilities in Open Call 3: submissions vs awarded

3 OUTCOMES OF SELECTED PROJECTS

3.1 KEY INFORMATION

This section summarises key information on projects funded under the three waves of 6G-XR Open Calls, offering an overview of their objectives, scope, implementation and outcomes. The following tables highlight, per Open Call and per project, the beneficiaries, project descriptions, testbeds, implementation timeframes, results and impact, offering a structured view of how these projects advance 6G-XR technologies, foster cross-partner collaboration and deliver measurable impacts at social, economic and technological levels.

3.1.1 1st 6G-XR Open Call - Platform and Network Enablers

OC Project	MST: Magos Surgical Training
Beneficiary, Country	Quanta & Qualia Greece
Project Description	While there have been notable advancements in medical/surgical training, the sector still faces significant challenges that necessitate transformation and optimization. Conventional training methods often lack realism, are constrained by physical location and infrastructure, and are difficult to simulate effectively. Every medical professional/surgeon should have the opportunity to practice, rehearse, and test their skills in a safe and controlled environment. This is where VR training can play a crucial role. While virtual training applications exist, they have been limited by technology in providing a seamless transition from traditional training to a fully immersive virtual experience. The missing element has been the ability to simulate detailed finger interactions. MST demonstrate the development of a VR collaborative medical training application based on the Magos Platform. It enables 2 surgical trainees in the healthcare industry to remotely interact using their fingers in near real-time, thanks to 6G technology. So, it provides a lifelike experience, enabling users to interact with their virtual environment as if it were the real world. This realism in finger interaction is crucial for developing the dexterity required for complex surgical tasks.
Vertical	Networking and Computing, Enablers, XR Enablers
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	February – July 2024
Results & Impact	**Results:** The MST project developed and validated a multiplayer VR medical training application enhanced by Magos haptic gloves, enabling realistic, collaborative surgical simulations. The system follows a peer-to-peer (P2P) Unity Netcode architecture that ensures low-latency, synchronized interactions. The Magos Player Netcode streams real-time data from hand and head tracking, allowing multiple users to train simultaneously with high accuracy and realism.The VR scenario focuses on endotracheal intubation, guiding trainees through the procedure in a lifelike virtual operating room. After testing different physics systems, a snap-based interaction method was adopted for stability and precision. The application streams detailed finger-joint and headset data,

	maintaining smooth, synchronized animations across participants. Key challenges—mainly in multiplayer synchronization, data streaming, and firewall restrictions—were resolved through optimized Unity network configurations and connectivity tuning. A total of ten Magos glove sets were produced; despite early manufacturing issues, redesigned PCBs and assembly processes ensured reliability. Six sets were delivered to the 6G-XR consortium for testing and integration. Integration with holograms is planned for a later phase. Overall, MST delivered a validated, networked VR training prototype combining haptics, realism, and multi-user interaction, providing a strong foundation for future 6G-XR healthcare applications. **Impact:** The MST project addresses a major global health crisis, the lack of access to affordable surgical care, affecting nearly 5 billion people. With the World Health Organization projecting a deficit of 18M medical professionals by 2030, innovation in medical training is urgently needed. The MST project accelerates the transition toward medical Virtual Reality (VR) training, offering an innovative hardware and software platform that enables hyper-realistic, collaborative surgical practice through natural hand and finger interactions using Magos haptic gloves. By digitizing touch sensation, MST enables certifiable, cost-effective, and portable surgical training, reducing reliance on expensive simulators and real operating rooms. The platform enhances time efficiency, accessibility, and training repeatability, while providing data-driven performance assessment. These capabilities improve medical skill acquisition, reduce setup time, and democratize access to high-quality training worldwide. MST lowers training costs by replacing costly physical simulators and travel with virtual, software-based environments. Socially, it promotes equal training opportunities and directly contributes to two EU priorities: protecting citizens and freedom (reducing medical errors through safer training) and strengthening Europe's leadership in VR and XR technologies, currently dominated by US players. Within 6G-XR, MST contributes by delivering six sets of Magos gloves to i2CAT for testing, deploying a high-demand VR surgical application, and enabling research into network optimization, physics, and holographic rendering. These outcomes strengthen the 6G-XR ecosystem, support cross-partner collaboration, and demonstrate the transformative potential of XR in healthcare training and beyond.
TRL	**7**

OC Project	**METAPHOR: Volumetric Capture and Transmission in Broadcast Environments**
Beneficiary, Country	Brainstorm Multimedia / Spain
Project Description	METAPHOR allows to seamlessly extend the eXtended Reality (XR) enablers from 6G-XR by integrating its resulting holographic communication platforms with InfinitySet, Brainstorm's main virtual production engine. This integration allows InfinitySet to determine optimal viewpoints and settings from a volumetric rendered scene by 6G-XR components (e.g., including multiple remote 3D holograms and other content sources) to be interfaced with an interactive virtual scenario to provide new interactive and compelling experiences to large audiences. The resulting integration enables hyper-realistic real-time dialogues between remotely captured 3D participants and presenters from broadcast settings (e.g., Chroma key rooms), seamlessly integrated within shared virtual environments, with professional quality, in an adaptive, affordable and scalable manner.

	The satisfactory performance and potential of this new XR enabler, when integrated with 6G-XR technology, has been showcased and validated in a broadcast use case. METAPHOR's new enabler will open doors to new, interactive, realistic and engaging experiences and to effectively deliver them via relevant channels, addressing challenges in the 6G domain.
Vertical	RAN enablers
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	February – July 2024
Results & Impact	**Results:** The METAPHOR project successfully demonstrated the integration of remote participants into live broadcast environments using the HoloMIT platform, in collaboration with i2CAT and Brainstorm. The validation took place in a real broadcast production setup, showcasing three modes of actor integration within a virtual scene.Local Actor with Chroma Key – An actor captured via iPad against a green background was composited in real time using Brainstorm's InfinitySet, with a live preview monitor providing immediate visual feedback.Remote Volumetric Actor – A second actor joined through the HoloMIT client using RGB-D or light-field cameras (leveraging 6G-XR Volumetric Capture enablers), enabling high-quality audio-visual interaction.Lightweight 2D Avatar Setup – A third participant used only a standard webcam, represented by a 2D head and simple avatar body, demonstrating accessibility without advanced hardware.The system architecture combined Unity and InfinitySet via NDI (Network Device Interface), ensuring seamless synchronization between virtual elements. InfinitySet managed camera tracking and scene composition, while Unity rendered specific scene components, such as interactive objects.Additionally, 6G-XR streaming enablers were integrated to provide XR video feeds and presenter billboards to remote HoloMIT participants. The final demonstration achieved high-quality, low-latency integration of multiple participants—local, remote, and lightweight—within a single interactive virtual production environment, validating the METAPHOR concept and its applicability to future immersive broadcasting. **Impact:** METAPHOR offers unprecedented benefits across a wide range of sectors, including education, entertainment, and broadcasting. By leveraging state-of-the-art interactive and immersive XR technologies, combined with advanced distributed 6G research infrastructures, METAPHOR enables new forms of real-time collaboration, creative production, and experiential learning. This integration not only enhances user engagement and content realism but also paves the way for scalable, network-aware XR applications that can transform both industrial workflows and end-user experiences.
TRL	**5**

OC Project	**BANQ: Bringing Automated Network QoS Monitoring Capabilities for Research Infrastructures**
Beneficiary, Country	**Kaitotek** **Finland**
Project Description	The project focuses on automating network quality measurements with a passive, real-time Quality of Service (QoS) solution. This enhances network quality, situational awareness, and security. Real-time measurement and monitoring allow for immediate resolution of performance issues, improving user experience and providing valuable

	data for researchers. Data analysis further enables proactive traffic monitoring, anomaly detection, and real-time threat identification.
Vertical	Networking and Computing Enablers, Sustainability Enablers
Testbed	OULU 5GTN, VTT 5GTN
Implementation timeframe	February – July 2024
Results & Impact	The BANQ project successfully implemented and validated four key experimental developments within the 6G-XR framework: - Automated QoS Monitoring: A new experimental feature was developed to enable fully automated QoS measurements controlled centrally through the Qosium Storage REST API. This significantly enhances the measurement capabilities of the North Node research infrastructure. During implementation, an additional unplanned improvement was made to GTP decapsulation, further refining network monitoring performance. - Centralized Flow Monitoring: Qosium's flow monitoring capabilities were extended to allow tracking of multiple simultaneous measurement flows, providing a strong foundation for advanced cybersecurity monitoring. This represents an important step toward integrating performance and security insights in real time. - Alerting and Reporting Engine: A completely new alerting engine was introduced, capable of real-time visualization and flexible extensions for both QoS and flow-based alerts. This feature lays the groundwork for future ticket-based or automated event systems, improving responsiveness to performance and security anomalies. - Enhanced Historical Analysis and Reporting: A new reporting view in Qosium Storage now enables automatic generation of high-level performance summaries, replacing the previous single heatmap visualization. This provides more accessible and actionable insights for research and industrial use. Extensive unit and integration testing was carried out both at Kaitotek's facilities and in the University of Oulu research infrastructure, validating the new capabilities in realistic 5G-Advanced and XR environments. While full system integration with the North Node will continue post-project, all implemented components are operational and ready for deployment. Finally, the BANQ experiment contributed to a joint 6G-XR demonstration at EuCNC 2024, showcasing multiple open call projects in an integrated setup. The demo received highly positive feedback and was the basis for a joint research publication submitted to IEEE GLOBECOM 2024.
TRL	6

OC Project	**6G-SLICE: Enabling end-to-end O-RAN slicing in 6G-XR**
Beneficiary, Country	**Allbesmart LDA** Portugal
Project Description	A network slice is a logical network comprising a set of network functions supporting the communication services for a particular use case deployed on a common physical infrastructure. In this context, the main objective of this experiment is to implement and validate end-to-end network slicing configurations for 6G-XR scenarios, leveraging the O-RAN architecture. This will be achieved by enhancing the Oulu University open-source OpenAirInterface (OAI) testbed. The OAI-based 5G lab platform at Oulu University has been enhanced to become compliant with O-RAN architecture, including Central Unit (CU), Distributed Unit (DU) and a Near-RT RIC with examples of xApps for near-real time monitoring of network

	performance and slice configuration of radio resources to ensure that Service Level Agreements (SLAs) are met. The project results were merged into the OAI public repository contributing to the overall open-source OAI community, even beyond the 6G-XR project lifetime. These contributions will facilitate experimentation with O-RAN slicing and resource allocation for 5G and beyond. Moreover, this work will be a catalyst for motivating further contributions to the OAI code from the 6G-XR community. In the context of the 6G-XR project, Allbesmart has developed and tested a new product, the OAIBOX Open RAN, including xApps for RAN slicing automation, using the Oulu University infrastructure. The participation of Allbesmart in the 6G-XR OC1 project has contributed to accelerating the development of our OAIBOX product line, allowing us to mature the technology sufficiently to offer it to our commercial partners and to approach potential new customers for proof-of-concept testing and trials.
Vertical	Networking and computing enablers
Testbed	UOulu 5GTN
Implementation timeframe	February – July 2024
Results & Impact	**Results:** The OAI-based 5G lab platform at the University of Oulu was enhanced to fully comply with the O-RAN architecture, integrating a Near-RT RIC and developing xApps for near-real-time monitoring and slice configuration to ensure SLA compliance. A web-based dashboard was created to simplify RAN slicing management, offering predefined configurations and intuitive control for 6G-XR experimenters. Validation was achieved through a joint demonstration with Allbesmart, Kaiotek, and Finwe at EuCNC & 6G Summit 2024, showcasing a “Co-creative Cyber Studio” use case. This demo connected remote VR/AR participants in a digital twin environment over a sliced 5G O-RAN network, demonstrating RAN sharing between VR and IoT applications. The slice management xApp dynamically controlled MAC scheduling and SLA enforcement, enabling differentiated throughput for eMBB and URLLC slices and validating real-time resource orchestration in multi-slice scenarios. **Impact:** The 6G-XR OC1 project accelerated the development of Allbesmart’s OAIBOX product line, resulting in a new OAIBOX O-RAN test solution featuring automated RAN slicing. The project outcomes matured the technology to commercial readiness, enabling proof-of-concept trials with partners and new customers. For exploitation, Allbesmart will leverage its global distributor network to promote advanced O-RAN capabilities integrated into its OAIBOX 5G solution. Its strategic partnership with NI (National Instruments) further extends its reach in the test and measurement market, strengthening Europe’s position in beyond-5G network innovation and accelerating the adoption of intelligent, programmable O-RAN systems worldwide.
TRL	**7**

OC Project	**REQUIEM: Research on QUIC client mobility**
Beneficiary, Country	**HUN-REN Tamogatott Kutatocsoportok Irodaja** Hungary
Project Description	Extended Reality (XR) is a potential killer application for 6G networks with use cases of Industry 5.0, medical and health services, online gaming, etc. Real-time media streaming is essential for distributed XR applications. Unfortunately, current transport

	methods and protocols such those applied in DASH or WebRTC have limited applicability for XR media. Contrarily, the recently standardized QUIC transport protocol provides novel features, creating the potential media data plane for XR applications. However, how QUIC can transmit media still holds open research questions. In this project, REQUIEM designed and implemented QUIC-based real-time media transmission suitable for the 6G-XR Remote Renderer. Standardized QUIC can migrate client connections between networks such as WiFi and cellular without breaking connections. It was developed automated measurement tools to quantify the effects of different protocol settings, which was used to evaluate the currently unknown effects of client mobility on the quality of real-time media in a Mininet based testbed and on the 6G-XR South Node. The solution has been integrated into the 6G-XR Remote Renderer. REQUIEM released code as open-source and published the key findings. The improved Remote Renderer enables inherent end-to-end security, fate sharing in control and data planes, reduced connection establishment times, improved Quality of Experience (QoE), etc. Our contributions enable novel XR applications involving client mobility.
Vertical	Networking and Computing, Enablers XR Enablers
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	February – July 2024
Results & Impact	**Results:** The project developed novel media streaming methods for the 6G-XR architecture, focusing on media transmission over QUIC. Two main implementations were achieved: - Raw media transport stream over QUIC, integrated via new GStreamer elements. - Media-over-QUIC support for the 6G-XR Remote Renderer. These required bug fixes and extensions to the Quinn QUIC library, along with an enhanced Remote Renderer and optimized segmentation algorithms for large dataframes. An automated measurement tool was developed to assess both network performance (latency, migration behavior) and video quality (using VQMTK and iqa metrics) across virtual and real testbeds. The evaluation covered multiple migration strategies: - Planned migration—where clients switch paths proactively—delivered better video quality. - Involuntary migration performance improved when using shorter keep-alive intervals. Additional tests showed that QUIC stream mode achieved higher video quality but increased latency, while datagram mode was preferable under bandwidth constraints. Further, path pre-validation (not yet implemented in Quinn) could reduce latency during migration, and re-segmentation algorithms for large frames outperformed upstream GStreamer versions. The complete QUIC-based streaming system was successfully deployed and validated in the 6G-XR South Node Kubernetes cluster (5GBarcelona), confirming consistency between virtual and real testbed results. **Impact:** Firstly, REQUIEM contributions are beneficial for the 6G-XR project as an enabler for XR applications involving client mobility thanks to seamless client migration of the QUIC protocol. QUIC also enables enhanced end-to-end security, reduced connection establishment times, etc. The work includes an extensive evaluation of client mobility over the QUIC protocol, focusing on the usefulness of this approach. As a result of our assessment, fine-tuned parameters for optimal real-time media streaming over QUIC have been shared

	Moreover, REQUIEM contributed to their open-source repositories creating multiple patches (Quinn; gst-plugins-rs: merge requests, patch; MoQ: gst, draft; VQMTK) most of which have been merged and we opened issues (Quinn: 1, 2; gst-plugins-rs) resulting in new features and fixes from the developers. These findings are useful for researchers on the distributed XR fields, and might be a basis for follow-up research collaborations.
TRL	**TRL 5 (Client mobility), TRL6 (MoQ extension to the 6G-XR Remote Renderer)**

OC Project	**ExCalibAR: User-friendly intrinsic and extrinsic calibration for multilight- field-cameras for Augmented, Virtual, and Extended Reality**
Beneficiary, Country	**Karlsruhe University of Applied Sciences** Germany
Project Description	The ExCalibAR project implements a comprehensive, easy-to-use pipeline for intrinsic and extrinsic calibration of setups with multiple light field cameras by utilizing Structure from Motion (SfM). The proposed method allows non-expert users to get reliable and swift calibrations by following an easy-to-understand process without requiring precise calibration targets. In contrast, calibrating light field cameras and other multi-camera setups following state-ofthe-art methods can be daunting for laypeople as it relies on multiple steps with many pitfalls and requires accurate calibration targets for which the exact geometry must be known. Our method starts with uncalibrated cameras and no prior knowledge. It relies on the principle of Structure from Motion (SfM), which uses images of a static 3D scene to estimate the intrinsic and extrinsic parameters of the camera(s) and furthermore obtains the 3D geometry of the scene as a byproduct. During the calibration process, a simple 2D marker is sufficient to achieve a metric scale reconstruction if the user desires. The pipeline expands existing open-source SfM projects for monocular cameras. The entire implementation is released on GitHub as an open-source project under the license terms of GNU General Public License Version 3 (GPLv3).
Vertical	XR Enablers, RAN Enablers
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	February – July 2024
Results & Impact	**Results:** The ExCalibAR project successfully developed and validated a self-calibration pipeline for light field cameras that operates without the need for calibration targets. Extensive experiments were performed using multiple camera setups with focal lengths of 12.5 mm, 16 mm, and 35 mm, and results were compared to a state-of-the-art reference calibration method. The deviation between ExCalibAR and the reference results was below 1% for nearly all parameters, confirming both high accuracy and reproducibility. A second validation used arbitrary light field camera sequences from a public dataset (Zeller et al., 2018), achieving accurate intrinsic calibration even without any structured calibration scene. This demonstrates that ExCalibAR performs robustly in real-world, unstructured environments.

	At project completion, the full ExCalibAR pipeline is operational and ready for extrinsic calibration once the 6G-XR volumetric setup becomes available. Final calibration results will be shared via the open-source GitHub repository based on 6G-XR Capturer data. **Impact:** ExCalibAR directly supports the 6G-XR objective of Advancing Heterogeneous XR Capture Systems, providing a user-friendly, open-source self-calibration pipeline for multi-camera light field systems. The software will be released under the GNU GPLv3 license for public access and reuse by all project partners. To maximize reusability, the system was designed for easy adaptation to different sensor types, including RGB-D and stereo camera setups, by modifying only the camera model and optimization metric. The project has already attracted interest from 6G-XR partners seeking to apply the pipeline to new sensor modalities, reinforcing its potential to become a standard tool for multi-sensor XR calibration within future 6G research and development efforts.
TRL	**6**

OC Project	**OpenCAMARA: Open source solution to integrate CAMARA QoD API to 5G stack**
Beneficiary, Country	**Neutroon Technologies** Spain
Project Description	In the concept of Open Gateway, OpenCAMARA implemented CAMARA Quality on Demand (QoD) APIs over Open5GS as the 5G core. AMBR, priority tagging, 5QI and slicing are 4 means to prioritize data flows, hence offering different levels of QoS. Dealing with different features for dedicating necessary network resources to obtain desired KPI is not easy for non-expert persons. The process is even more complicated once having different vendors/providers for the 5G stack elements. This project aims to facilitate this process by employing CAMARA QoD API as a standard way to enforce desired QoS configuration to the 5G stack elements. OpenCAMARA accomplished the implementation based on public QoD Transformer Function (TF), a custom-made NEF for Open5GS, and a very user-friendly GUI to set priorities. Apart from facilitation, openCAMARA also provides the possibility to dynamically adopt the QoS in an established connection. The solution is deployed in the 5GBarcelona Lab (6G-XR south node lab hosted by i2cat), so become available for use cases in the 6G-XR project and new project joining through next open calls. OpenCAMARA also evaluated network KPIs with four different UPFs; Embedded Open5GS UPF, external Open5GS UPF, eUPF and OAI UPF-VPP.
Vertical	Networking and Computing Enablers, XR Enablers, RAN Enablers
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	February – July 2024
Results & Impact	**Results:** The OpenCAMARA project provided two series of validation and technical results. - Validation and performance results while applying Camara QoD APIs. It is worth mentioning that even though we have proposed in the proposal to validate the OpenCAMARA with Amarisoft as 5G RAN, we decided during the project to expand the experience by validating the OpenCAMARA with Node-H as well. - Technical and comparison results of the performance when employing external UPF for Open5GS.

	Testing was initially carried out in Neutroon's Lab using the Nomad5G testbed, then deployed at 5GBarcelona (i2cat) for final validation.Key outcomes included:Successful AMBR and 5QI enforcement, confirming OpenCAMARA's ability to dynamically control UE throughput and prioritize traffic according to QoS profiles.Verification that Amarisoft effectively handled AMBR-based QoS, while Node-H enabled full 5QI-based prioritization, demonstrating flexibility across RAN vendors.Validation of OpenCAMARA with multiple UPFs (Embedded Open5GS, external Open5GS, eUPF, and UPF-VPP). Results showed that UPF-VPP achieved the lowest RTT and highest downlink throughput, while Open5GS UPFs performed best in uplink communications. **Impact:** OpenCAMARA implementation has been deployed at the 5GBarcelona testbed in i2CAT site, which is part of the 6G-XR south node, and will become available to experimenters applying to future 6G-XR open calls. It will be up to the 6GXR consortium and the trial site owner to study whether to open source the developed CAMARA implementation, which can benefit the research community at large because Open5GS is a very commonly used tool in research environments. With OpenCAMARA, use cases running in the 6G-XR trial site can dynamically adjust their network resource requirement. This results in saving time and resources toward a sustainable network.
TRL	**5**

OC Project	**FALADIN: FAb LAb DIgital TwiN**
Beneficiary, Country	**FINWE** Finland
Project Description	FALADIN project innovated in the field of co-creation process by developing a digital twin platform for FabLabs. The result is an online web service that facilitates seamless collaboration between users and FabLab operators, streamlining 3D model review and 3D printing process. Leveraging both traditional web technologies as well as modern immersive WebXR, the platform enables users to log in and upload their 3D models via web browser, schedule an online review session, and then use an XR headset to participate in the review meeting within an immersive 3D representation of the co-creation space. The environment facilitates 3D model examination and live adjustments with FabLab operators using avatars, voice communication and real-time hand tracking. It combines virtual and physical worlds. For example, by placing a 3D model on the print bed of a 3D printer's digital twin and pushing a virtual print button, user can start real 3D printing process on a connected physical 3D printer and observe live video feeds from multiple cameras attached to the 3D printer, within the digital twin environment. By integrating cutting-edge technology into the co-creation process using open and freely available technologies, the project created a dynamic and inclusive environment for innovation and creativity.
Vertical	XR Enablers
Testbed	UOulu 5GTN
Implementation timeframe	February – July 2024
Results & Impact	**Results:**

	To ensure inclusivity and accessibility, the developed solution was built entirely on open and freely available technologies. The core web platform — supporting user authentication, model uploads, review scheduling, and textual discussions — was implemented using Node.js and SQLite for the backend and React.js for the frontend. For the XR component, WebXR and the open-source Babylon.js framework were adopted instead of Unity to avoid licensing costs, support all major XR headsets from a single codebase, and eliminate app store delays. Real-time communication features, including voice, low-latency video streaming, screen sharing, and synchronized multi-user interactions via avatars and shared objects, were implemented using the OpenVidu system based on WebRTC protocols. A 3D printer was integrated through OctoPrint running on a Raspberry Pi, enabling seamless physical prototyping.Testing was conducted with Meta Quest 2, Meta Quest 3, and Apple Vision Pro headsets. The solution was integrated with two other 6G-XR projects, where the user (on Apple Vision Pro) and the FabLab operator (on Meta Quest 3) were connected through sliced 5G links in the 5GTN test network. Network performance was monitored using the Qosium measurement tool across several probing points.For final validation, the integrated three-project setup was demonstrated at the EuCNC & 6G Summit 2024 in Antwerp, Belgium. Visitors actively tested the live demo, which successfully showcased immersive collaboration over 5G slices and received highly positive feedback. **Impact:** The project successfully met and exceeded its objectives, demonstrating a cutting-edge multi-user digital twin environment that combines XR headsets, avatars, and hand-tracking for intuitive real-time collaboration and object manipulation. This use case serves as an ideal testbed for advanced mobile networks, given its stringent low-latency and high-bandwidth requirements driven by synchronized 3D interactions and multiple high-quality audio/video streams. A major milestone was the successful integration with two other 6G-XR projects and the live demonstration at EuCNC & 6G Summit 2024, just four months after project kick-off. The public showcase highlighted the potential of XR-enabled collaboration over sliced 5G networks and was met with strong positive feedback from visitors and industry stakeholders. The digital twin concept has since been presented to local FabLabs, generating significant interest for its applications in 3D printing education and operator training. By enabling safe, immersive, and cost-effective learning environments, the solution supports both industrial and educational adoption. The consortium is currently exploring opportunities for further public demonstrations and workshops, including participation in Mobile World Congress 2025, to expand outreach and collaboration within the broader 6G and XR ecosystem.
TRL	**7-8**

3.1.2 2nd 6G-XR Open Call – Stream B Enablers

OC Project	**AI4EE: A holistic approach for energy efficiency driven by AI-based deep understanding of the process stability**
Beneficiary, Country	**Nissatech** Serbia
Project Description	Based on a previous work on the energy optimization in the industry domain, we proposed an innovative approach for analyzing optimization potential in the 5G Test network infrastructure, applied on 6G-XR north node. The result is an energy analysis framework, which uses AI for a deep understanding of the energy consumption and

	discovering optimization potential, achieving E2E energy efficiency and self-sustainability in next generation mobile networks. The approach is validated with the energy consumption data collected from the existing energy measurement infrastructure, consisting of accurate power meters for continuous measurement of the power consumption at different network elements. The conclusion from the validation is that the tool can identify anomalies in the monitored network infrastructure's energy consumption data accurately.
Vertical	Energy measurement
Testbed	VTT 5GTN
Implementation timeframe	Sep 2024 – Mar 2025
Results & Impact	**Results:** Main result is an energy analysis tool AI4EE, which uses AI for a deep understanding of the energy consumption and discovering optimization potential, achieving E2E energy efficiency and self-sustainability in next generation mobile networks. AI4EE tool is an extension of the D2Port framework with the new methods for data analysis, which are developed as a specialization for the energy measurement provide in the 6G-XR north node. The methods are results of intensive discussions between Nissatech and energy experts and mentors from 6G-XR north node. Main goal was to detect and understand situations where some deviations in the energy consumption have occurred and validate if these situations are caused by some anomalies in energy management system. The work is based on the data collected from the energy management system installed in the 6G-XR north node. Main conclusion is that the tool can identify anomalies in the monitored network infrastructure's energy consumption data accurately. Both high load / overload and maintenance / fault situations are highlighted in the produced graphs at the expected time windows. **Impact:** Proposed energy management system (AI4EE) is based on the D2Port framework (d2port.rs), which offers set of services (data collection, observation, analysis, visualization) for the development of advanced data-driven systems. As a part of the impact creation, D2Port will be extended with new developed data analysis methods (anomaly detection) in order to offer new services for the energy market. The approach for the deployment is very general/universal and can be applied in any similar infrastructure.
TRL	**5**

OC Project	**StreamAnalyzerFor5GSlicing: Integration and enhancements of Lamda Networks' NWDAF implementation to 6G-XR for providing AI/ML capabilities for slicing**
Beneficiary, Country	**Lamda Networks** Greece
Project Description	This project addressed ML/AI challenge in the sub area AI/ML algorithm for efficient resource optimization in the 5G slicing techniques, focusing on two key objectives:(i) developing a centralized AI-based load balancer that meets UEs' bandwidth requirements, and(ii) implementing a distributed reinforcement learning scheduler to optimize 5GTN RI resource utilization under congestion in Cumucore slices.The

	resulting open-source codebase constitutes a valuable asset for the 6G-XR project and a significant contribution to the SNS Stream B "System Architecture" initiative.
Vertical	AI/ML for slicing
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	Sep 2024- Mar 2025
Results & Impact	**Results:** The AI-based centralized use case demonstrated that the admission control agent effectively restricted UE access when more than seven active UEs were connected, as it learned that additional UEs could not achieve the target bandwidth of 5 Mbps. The model also showed a preference for Slice 2 (UPF250) in specific scenarios, optimizing performance based on its training experience.For the AI-based decentralized use case, the deep reinforcement learning (DRL) UE scheduler successfully learned to optimize slice assignment decisions. The agent minimized both waiting time and slice usage time by prioritizing smaller UE requests and assigning them dynamically to the appropriate network slice (Slice 1 or 2). The results confirm that the agents learned effective scheduling policies that balance load and maximize overall system efficiency within the 5GTN testbed. **Impact:** StreamAnalyzerFor5GSlicing yielded promising results, serving as the basis for a realistic business plan. The implementation is currently integrated and operational within the 5GTN production network and is available to support other researchers and experimenters throughout the duration of the 6G-XR project. Additionally, the open-source codebase developed during the project constitutes an asset for Stream B "System Architecture" of the SNS program.
TRL	**5**

OC Project	**ENORMOUS: ENergy Optimization in multimedia tRansMission and 5G netwOrks Unified System**
Beneficiary, Country	**University of Malaga** Spain
Project Description	ENORMOUS responds to the need for energy efficiency raised in the 6G-XR OC2 initiative, specifically addressing the monitoring and prediction of the energy consumption of the different network elements within virtualized network functions during data transmission. It has developed advanced tools for real-time monitoring and measurement of energy consumption, as well as investigating AI/ML-based techniques for predicting consumption based on the network state. The aim is to enable the dynamic optimization of network resources and configuration parameters to reduce energy consumption. The techniques have been tested on the VTT infrastructure in Oulu provided by the 6G-XR consortium. The results generated are expected to provide important contributions to both operators and the scientific community, facilitating the transition towards more sustainable, resilient and efficient networks, aligned with global sustainability goals and the IMT-2030 framework. The results obtained in this project are intended to be disseminated at international congresses and published in high-impact journals.
Vertical	Energy measurement

Testbed	VTT 5GTN
Implementation timeframe	Sep 2024- Mar 2025
Results & Impact	**Results:** The ENORMOUS project developed an effective solution for monitoring and predicting energy consumption in the Central Unit (CU) and Distributed Unit (DU) within the Open5GS environment. The system combines real-time data collection, feature engineering, and supervised AI/ML models (such as LSTM, linear trees, and MAPIE) to estimate short-term energy usage. Validated through deployment in the Open5GS testbed under multimedia traffic conditions, the tool enables dynamic network adjustments that reduce energy consumption while maintaining Quality of Service (QoS). A continuous optimization feedback loop allows the models to refine predictions and improve performance over time, supporting more sustainable network operations. **Impact:** The project's outcomes, validated monitoring tools and AI/ML prediction models, provide practical mechanisms for energy-efficient network management applicable to operators, researchers, and standardization bodies. From an industrial perspective, the results allow telecom operators to optimize resource utilization, reducing operational costs while maintaining service quality. From an academic viewpoint, the methodologies and findings advance research in AI-driven network management and energy-aware system design. Furthermore, it promotes open collaboration by sharing datasets and models publicly, encouraging benchmarking, reuse, and innovation across the broader scientific and industrial communities. These contributions accelerate progress toward sustainable and efficient 6G technologies.
TRL	**3**

OC Project	**EMSEOS: Energy Monitoring System for Energy-Efficiency Optimization and Sustainability of Multimedia VNFs**
Beneficiary, Country	**IKERLAN** Spain
Project Description	The increasing energy demand of computing edge nodes and cloud services needs the development of energy-aware systems to enhance efficiency, reliability, and cost-effectiveness without degrading performance. The EMSEOS experiment addresses this challenge by implementing an energy monitoring system capable of estimating CPU and GPU power consumption for virtualized network functions (VNFs). Deployed within the 6G-XR project's infrastructure, this system leverages Kubernetes for seamless integration and Prometheus for persistent metric storage and analysis. The system has been validated through controlled experiments, analysing power consumption under synthetic workloads and real-world multimedia streaming scenarios. Results demonstrated the ability to capture consumption fluctuations, providing valuable insights into the energy efficiency of different VNF configurations. EMSEOS enhances the 6G-XR project by enabling real-time energy monitoring, fostering sustainable edge computing practices. Beyond this, the experiment contributes to the broader research community by offering a scalable methodology for power-aware resource management. The collected data serves as a foundation for future optimizations, aiding operators in reducing energy costs while maintaining performance. This aligns with the increasing need for sustainable computing in next-generation networks, where energy-efficient orchestration is critical to balancing performance, cost, and environmental impact.

Vertical	Energy measurement
Testbed	5GBarcelona (now i2CAT testbed)
Implementation timeframe	September 2024 – March 2025
Results & Impact	**Results:** The system was validated through a series of 15-minute tests, with results averaged over a 3-minute window to ensure consistency and remove initial or final fluctuations Initial tests used a synthetic CPU/GPU stress workload, confirming that energy consumption increased sharply under full load. Subsequent experiments employed a Remote Renderer VNF with varying configurations (resolution, framerate, bitrate, and mode) to analyze how these factors affect power usage. Results showed that energy consumption scales with rendering complexity, with the highest usage observed in the most demanding configuration (T4.1 – stereo 4K, 10 fps, 30 Mbps). These tests demonstrated the system's ability to accurately capture consumption fluctuations across different VNF setups, successfully meeting the experiment's objective. **Impact:** The EMSEOS experiment extends the 6G-XR project's capabilities by integrating a real-time energy monitoring system into its computing infrastructure. EMSEOS results contribute to the broader research community by demonstrating a scalable methodology for power-aware resource management in cloud and edge environments. The collected energy metrics can serve as a foundation for future optimization strategies, helping operators and developers improve energy efficiency without compromising performance. This aligns with the growing need for sustainable computing in next-generation networks, where energy-aware orchestration will play a key role in balancing performance, cost, and environmental impact.
TRL	**5**

OC Project	**6G REMIX: 6G Real-time Energy Monitoring for XR**
Beneficiary, Country	**Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.** Germany
Project Description	6G REMIX (6G Real-time Energy MonItoring for XR) aims to analyze the energy consumption of 5G networks by monitoring and visualizing real-time data. Determining energy consumption through measurements of the individual components along the streaming chain and collecting and analyzing existing operating data on power consumption are essential prerequisites for modeling an end-to-end video streaming service. To achieve this goal, 6G REMIX focuses on enhancing the 6G-XR nodes, particularly the South Node (5GBarcelona), by developing tools and procedures for collecting and measuring energy consumption throughout the streaming chain, as well as recording and evaluating existing operating data. The measurement can be done by smart Power Distribution Units (PDUs) that can be integrated into third-party systems using various protocols (JSON, Modbus/TCP, MQTT-flex, ...) with open API to collect energy consumption data off relevant components in 5GBarcelona infrastructure. In addition, 6G REMIX involves implementing an observation system that is able to show critical metrics in real time. This project represents a pivotal step toward optimizing the energy consumption of 6G-XR systems while maintaining the quality of user's experience.
Vertical	Energy measurement
Testbed	5GBarcelona (now i2CAT testbed)

Implementation timeframe	Oct 2024 - Mar 2025
Results & Impact	**Results:** Main findings and outcomes: - The gNodeB and the Edge are the most energy-intensive components. It is necessary to focus on optimizing the power usage of these components for improved energy efficiency. - The impact of the video bitrate on the UE power is minimal. We do not recommend reducing the video bitrate to save energy because of unnecessary deductions in video quality. - Edge component shows a significant power consumption increase (by 71%) when remote rendering is activated. We suggest developing and implementing strategies to limit remote rendering usage or optimize its efficiency. - Switching from 100 MHz to 40 MHz bandwidth does not significantly reduce energy consumption. It is not necessary to reduce the bandwidth to save energy. **Impact:** Potential for further developments and commercialization: - The insights gained from real-time energy monitoring can lead to the development of advanced energy management systems for 6G networks. These systems could optimize power usage dynamically, offering solutions to network operators aiming to reduce operational costs and environmental impact. The project's analysis of energy consumption across different streaming scenarios can inform the development of adaptive streaming techniques. These technologies can adjust video quality based on network conditions and energy availability, enhancing user experience while minimizing energy use.
TRL	**6**

OC Project	TrustNet - Trust Management Framework for 6G Networks
Beneficiary, Country	**WINGS ICT Solutions S.A.** Greece
Project Description	TrustNet aims to tackle the challenges of ensuring end-to-end trust and reliability in 6G networks, within the compute continuum, which extends computing capabilities from centralised cloud to distributed edge infrastructures, as well as up to end-user devices. This project focuses on the development and validation of a Trust Management Framework (TMF) that quantifies and manages trust. TrustNet integrates a comprehensive system for quantifying, evaluating and optimising trust in the network, compute, and application layers. Key components include the Trust Manager Control Function and Trust Evaluation Functions (TEFs), which assess and manage trust across different devices, network nodes, and data paths. The TMF is tested using the 5TONIC testbed, with capabilities exposed through open APIs for broader experimentation and the main results are reported in this report. The project aims to enhance trust quantification, optimise data paths, and ensure secure, reliable communication across multi-domain 6G ecosystems, with a particular focus on XR applications. Ultimately, TrustNet contributes to the creation of secure, trustworthy environments for future 6G networks, supporting dynamic, multi-stakeholder service provisioning.
Vertical	Security and trust mechanisms
Testbed	5GTONIC

Implementation timeframe	SEP 2024 – MAR 2025
Results & Impact	**Results:** TrustNet enabled the collection of a diverse set of trust quantification-relevant performance metrics and the evaluation of two available 5TONIC edge domains, leveraging the collected datasets. The 5TONIC-TMF integration (including extended API configurations, related to the exposure of performance KPIs, dynamic traffic load modelling, etc.) was successfully tested, while interesting preliminary results were collected. The potential for further development and commercialization of the TrustNet project lies in its ability to provide a scalable and robust Trust Management Framework (TMF) for dynamic, multi-domain 6G networks and XR applications. The TMF's capability to quantify and optimise trust in real-time can be applied to various industries, including telecommunications, smart cities, and autonomous systems. It offers significant value for service providers, application developers, and infrastructure managers who need to ensure reliable, trust-aware communication across complex networks. Further development could focus on enhancing the framework for specific use cases, such as secure edge computing or resource optimisation. The commercialization potential includes licensing the technology or offering tailored solutions for enterprise applications across a wide range of sectors. **Impact:** TrustNet, leveraging the 5TONIC infrastructure, significantly contributes to the broader community by offering real-world trust quantification experimentation outcomes as well as a novel methodology for evaluating trust at both the device and edge domain levels, addressing a key gap in current technology. This approach enables communication service providers, cloud providers, and application developers to assess the trustworthiness, reliability, and security of their networks and infrastructures, while also providing valuable insights for third-party application developers and 6G stakeholders. By quantifying and managing trust across various network domains, including the edge and device layers, TrustNet helps ensure that third-party applications and services can be integrated into 6G ecosystems with confidence, meeting the high standards required for reliable, secure, and efficient operation. This fosters a more open and collaborative environment where new applications can thrive, contributing to the long-term success and scalability of 6G networks. The validation of the TMF within the 6G-XR testbed not only enhances trust and reliability management but also sets the stage for more efficient service provisioning in the future. Moreover, the project's open specifications, including OpenAPI-compliant solutions, facilitate broader experimentation and market adoption, ensuring lasting impact beyond the project's immediate scope. The results will enhance use cases like "Routing to the Most Trustworthy Edge," benefiting both the 6G-XR consortium and the wider community.
TRL	**6**

OC Project	**5G-slAIce: 5G network SLicing enhancement using AI teChniquEs**
Beneficiary, Country	**GRADIANT - Galician Research and Development Center in Advanced Telecommunications** Spain
Project Description	The objective of 5G-slAIce is to develop an AI/ML-based system that dynamically manages the resources of the different slices of a 5G network core deployed in a Cloud-Native environment. The system will be divided into two parts as described below. On the one hand, the AI/ML block will consist of two types of ML algorithms: an

	incremental learning based algorithm, which will be responsible for predicting the number of users of each type of slice in the future; and the reinforcement learning based algorithm, which will be responsible for prescribing actions on the resources of the different slices and the 5G network core based on the current state of the network and the prediction of the IL algorithm, trying to anticipate possible situations of oversaturation or underutilization. On the other hand, the action block will consist of an agent that applies the actions prescribed by the AI/ML block to the infrastructure, verifies their correct application and feeds the AI/ML system with the current state of the network. The work carried out will provide a solution that anticipates certain undesirable situations by dynamically managing the resources of the different slices, thus facilitating progress towards the implementation of 6G mobile networks.
Vertical	AI/ML for slicing
Testbed	UOulu 5GTN
Implementation timeframe	SEP 2024 – MAR 2025
Results & Impact	**Results:** The project has produced multiple results. Firstly, in relation to the preparation of the AI/ML algorithms, we have developed the necessary tools to generate datasets with the metrics of this project (which can be extended to acquire others) using a simulator of user connections of different slices. Secondly, the AI/ML models themselves have been developed: the CL model and the RL model. These models produce the expected results for various evaluation metrics, forming the basis for resource management actions. Finally, an action controller for cloud infrastructure has been developed to implement these actions on Kubernetes, the de facto standard for cloud-native orchestration. For more details on the technical results achieved, please refer to the attached deliverable. **Impact:** The main outcomes are an automatic and dynamic resource controller in a 5GC with different slices using two specific ML techniques, and a simulator of connections to a 5G network with the possibility of creating datasets with metrics related to the 5GC and the infrastructure in which it is deployed. The potential lies in further improving the connections simulator to support a larger configuration of the environment and, on the other hand, in increasing the capabilities of the AI/ML block in several aspects: (i) predicting more variables by using the continuous learning algorithm; (ii) increasing the performance of the models. It can be commercialised as an additional module of a 5G network core deployment in the cloud.
TRL	**4**

OC Project	**OPTICALRAN: 5G/6G FWA with optical RAN**
Beneficiary, Country	**Peta Optik** Spain
Project Description	This project is about increased capacity Fixed Wireless Access (FWA) Radio Access Network (RAN) using optical frequencies instead of microwaves or millimeter waves for the FWA channel. It affects the optical links between User Equipment UE and gNodeB. - Current achieved data-rates are higher than 10 Gbps per connected FWA UE over distances of a few Kms (<2Kms). The key is that the optical spectrum can be very easily reused and communication links that are close to each other will not interfere. In the

	evolution of this technology, we expect to achieve more than 100 Gbps by refining current designs. - Wavelength will be 1500nm. - Very large optical MIMO (Multiple Input Multiple Output) channels are easier to establish than radio MIMO channels. Peta Optik has developed Digital Signal Processors (DPS), to handle such a kind of very large MIMO optical communication channels. - Peta Optik DSPs allow misalignments between both ends of the optical link. In a way that Peta Optik overcomes the most complex technical challenges in wireless optical communications. These data-rates per UE are targeting at enabling the most demanding 6G FWA implementations to be able to serve applications such as UHD holographic screens in mobile devices, digital twins, and XR/VR in a very large concentration of users.
Vertical	Increased capacity
Testbed	I2CAT testbed
Implementation timeframe	Sep 2024- Oct 2025
Results & Impact	**Results**: The project successfully demonstrated optical telecommunication links for Fixed Wireless Access (FWA) Radio Access Networks (RAN), using optical frequencies instead of microwaves or millimeter waves for the FWA channel. This approach enables high-speed optical links between User Equipment (UE) and gNodeB. Currently, the system achieves data rates exceeding 2 × 230 Mbps (460 Mbps) per connected FWA UE over distances of several hundred meters, suitable for AR/XR applications. Performance is currently limited by the drivers, which will require further refinement. The optical signals operate at a wavelength of 1500 nm. Optical signal wavelength used is 1500nm. **Impact:** The impact of these developments is significant: - Future advancements in the technology could achieve data rates exceeding 10 Gbps. The optical spectrum is highly reusable and license-free, offering flexible deployment options. New business models can be implemented on license-free technologies by companies beyond traditional telecommunications operators. These developments create opportunities to establish new standards supporting such innovative business models.
TRL	**5**

OC Project	**DYNAMICON: Dynamic Service Migration Optimization in Unified Network Continuum**
Beneficiary, Country	**E-lighthouse Network Solutions SL** Spain
Project Description	The DYNAMICON project focuses on advancing the orchestration of dynamic service migration and load balancing across the Device/Edge/Cloud continuum. This innovative venture leverages the Edge Computing Optimization Tool (ECOT) to enhance the 5TONIC MEC Orchestrator's capability in managing edge resources for efficient service distribution. It aims to refine network resource utilization and quality of service (QoS) by developing algorithms for computational load balancing, application migration, and network slice selection.

	Key to DYNAMICON's strategy is its integration with the 5TONIC testbed's existing infrastructure, which allows for real-time, slice-aware service management. By employing ECOT, the project captures detailed information about edge node locations, IT resource utilization, and active services, further aided by Network Exposure Function (NEF) APIs to monitor network slice statuses. These technologies work in concert to recommend actionable strategies for service optimization by the ECOT that are later executed by the 5TONIC MEC Orchestrator, ensuring seamless service provision and management. DYNAMICON not only aims to enhance the 5TONIC framework's service management but also seeks to explore its application in multi-site environments. The project's success helps to redefine network and service management operations, supporting a variety of high-stakes real-time applications aligned with the 6G-XR goals.
Vertical	Load balancing
Testbed	5GTONIC
Implementation timeframe	Oct 2024- Mar 2025
Results & Impact	**Results:** The DYNAMICON project achieved significant technical advancements by integrating the ECOT into the 6G-XR South Node infrastructure, validating its core functionalities: load balancing, and predictive migration. The validation process was executed in two phases: - Integration Tests: ECOT was successfully integrated with both the 5GC NEF and MEC orchestrator APIs, confirming its ability to collect the needed data properly. - Execution Tests: Demonstrated ECOT's ability to identify congestion patterns, simulate migration strategies, and recommend actions to the MEC orchestrator related to load balancing and migration operations. **Impact:** DYNAMICON has directly contributed to advancing the orchestration capabilities of the 6GXR South Node by introducing ECOT, a novel optimization tool for real-time service migration and load balancing. By integrating ECOT with the 5TONIC infrastructure, the project demonstrated a practical approach to enhancing resource utilization, ensuring service continuity, and maintaining QoS across distributed edge nodes. The experiment validated the use case showcasing how ECOT can make intelligent decisions based on real-time and predictive analysis. These contributions extend the flexibility and responsiveness of the 6G-XR architecture, particularly for the South node.
TRL	**5**

OC Project	**xDRL-RCS: Xplainable Deep Reinforcement Learning Assisted 5G/6G RAN and Core Slicing**
Beneficiary, Country	iThermAI B.V. Belgium
Project Description	The xDRL-RCS project develops an explainable deep reinforcement learning (xDRL) framework for adaptive radio access network (RAN) slicing in open 5G/6G environments. It addresses the need for intelligent and transparent resource management to support emerging immersive and digital-twin applications within the 6G-XR ecosystem. Using the OAI, FlexRIC, and OAI 5G core platforms, which are compatible with the UOulu 5GTN infrastructure, the framework enables real-time interaction between AI agents and RAN components through enhanced KPM and RC

	xApps, interconnected with the xDRL controller via REST and E2SM-RC interfaces, forming a closed-loop control workflow. In the proposed xDRL inter-slice resource management algorithm, QoS metrics—latency, throughput, and packet loss—are explicitly modeled, and SLA satisfaction is evaluated against slice-specific thresholds for these metrics. To ensure fairness among slices, a fairness parameter is incorporated into the reward function, where each slice's most critical QoS metric is weighted accordingly. Two complementary test setups were developed: a Python-based simulation environment for algorithm training and evaluation, and a OAI + FlexRIC testbed for near-real-time validation. Evaluation across simulated and near-real-time environments confirms that xDRL agents enhance resource utilization, latency, and reliability while maintaining transparency through SHAP-based explainability. The open-source releases of both implementations ensure reproducibility and provide a foundation for future AI-driven 6G network research.
Vertical	AI/ML for slicing
Testbed	UOulu 5GTN
Implementation timeframe	Feb 2024 – Oct 2025
Results & Impact	**Results:** The xDRL-RCS framework provides an explainable and adaptive solution for inter-slice resource management across RAN. Its modular architecture includes three xApps: the Enhanced KPM xApp, which gathers gNB telemetry data (PRB usage, RSRP, BLER, throughput, latency) into a MySQL database; this telemetry stream populates the xDRL state representation used by the controller for near-RT inference; the xDRL Controller xApp, which runs trained DRL/xDRL models to compute optimal resource allocations; and the RC Slice Control xApp, which applies these actions through E2SM-RC interface to dynamically reconfigure slice parameters within the OAI gNB. All modules are deployed via Docker Compose in the OAI + FlexRIC testbed, establishing a closed-loop control link between the xDRL agent and the RAN. Validation combined emulation-driven training and integrated testbed evaluation in complementary environments. A Python-based RAN-slicing simulator was used for training, hyper-parameter tuning, and explainability analysis under dynamic multi-slice traffic. PPO, A2C, and DQN algorithms were enhanced with xDRL-based SHAP feature attribution and pruning. The PPO-xDRL agent achieved the best results, improving throughput by 18 %, reducing delay by 86 %, lowering packet drops by 92 %, and increasing SLA compliance by 32 % compared with proportional-fair and round-robin baselines. Explainability analysis confirmed that latency and throughput were the dominant factors guiding decisions. A second end-to-end OAI + FlexRIC + OAI 5G Core setup—aligned with the UOulu 5GTN infrastructure—validated real-time interaction between the xDRL controller and network elements. Using *iperf*-generated slice traffic, the system demonstrated adaptive resource redistribution and low-latency inference within the near-RT RIC loop. Overall, the results verify that the xDRL-RCS framework enables dynamic, explainable, and fairness-aware slicing control across RAN and Core components, establishing a reproducible foundation for AI-native and transparent 6G network management, demonstrating alignment between algorithmic behavior in both open OAI testbed and emulation environment. **Impact:** The xDRL-RCS project delivers substantial scientific and industrial impact. Scientifically, it advances explainable AI-based end-to-end slicing by unifying learning-based

	optimization across RAN and Core layers, ensuring explainability, fairness, and SLA compliance. The open-source framework enables reproducibility and extension of xDRL algorithms on standardized OAI/FlexRIC infrastructures, promoting transparent and collaborative 6G research. Industrially, the project shows that AI-driven network automation can be effectively deployed in open 5G/6G environments. The integration of RAN and Core slicing creates a foundation for SLA-aware, trustworthy controllers supporting digital-twin, XR, and Industry 4.0 services
TRL	**4**

3.1.3 3rd 6G-XR Open Call: Vertical Replicability Enablers

OC Project	**IMMVIEX: 6G-XR-enabled IMMersive VIsiting EXperience**
Beneficiary, Country	**Universidad Politécnica de Madrid** Spain
Project Description	IMMVIEX aims to showcase and evaluate a multi-user virtual cultural tour experience of a monument. The tour features a 3D model, user avatars, and a live presenter—teleported into the scene via a volumetric video system (FVV). Remote users, wearing VR headsets, navigate the immersive Unity-based environment, with content streamed and processed over 5G/6G networks using edge servers and WebRTC. A gesture recognition module enables presenter interaction and session control. This 6G-XR-enabled setup demonstrates the potential of next-gen networks for delivering real-time, interactive XR applications in culture, education, and training.
Vertical	Immersive Services
Testbed	i2CAT testbed
Implementation timeframe	April 2025- October 2025
Results & Impact	**Results:** Three main sets of experiments were carried out to evaluate the performance: network-level, application-level, and latency measurements. Network-level: Using i2CAT's Qosium Probe system, metrics were gathered between capture servers, the edge server, and client terminals. Results showed: - High uplink throughput (up to 300 Mbps) due to video encoding, with much lower downlink traffic (< 10 Mbps per user). - Packet losses occurred during uplink spikes, likely from 5G link saturation. - Delay and jitter were acceptable for the use case. Application-level: Data from multiple performance sessions showed two scenarios: stable network and network problems. - Under stable conditions, minor segmentation errors occurred. - Under packet loss, color stream losses caused distortions, and depth stream losses broke view coherence, introducing background artifacts. - Frame rate dropped from 30 fps to 15 fps in unstable networks due to inter-camera delay differences. - Bitrate: Color streams ≈ 10 Mbps; depth stream bitrate varied with content complexity.

	E2E latency: Measured between real and virtual scenes (using both laptop and Meta Quest 3). - Delays were low—suitable for videoconferencing. - 5G performed slightly better than Wi-Fi. Overall summary: The system performs well under stable network conditions, maintaining low latency and acceptable video quality, but suffers from bitrate spikes and reduced frame rates when network congestion or packet loss occurs. In all cases, the delays are low enough for the videoconferencing case, and 5G obtained slightly lower delays than Wi-Fi. **Impact:** The completion of the experiment has tested the capabilities of the cutting-edge i2CAT 6G testbed under challenging situations, obtaining outstanding results even in long sessions. To that end, it has improved and consolidated the integration of technologies that enable live XR services, specifically the Free Viewpoint (FVV Live) system, WebRTC, Unity, Kubernetes, and artificial intelligence-based modules, around 5G/6G equipment and infrastructure in a key vertical sector, also providing multi-user interactivity, and scalability. Collectively, these efforts have contributed to the development of an innovative and unique immersive solution for culture, entertainment, tourism, and other verticals.
TRL	**6**

OC Project	**LCEVC-6G-XR: LCEVC for Enhanced 6G-XR Holographic Streaming Services**
Beneficiary, Country	**Fluendo S.A.** Spain
Project Description	The proposed experiment aims to advance holographic communication platforms by integrating the MPEG-5 Low Complexity Enhancement Video Coding (LCEVC) standard. LCEVC is an innovative enhancement layer that enhances the performance of base codecs without replacing them, thus ensuring backward compatibility. By enhancing widely used codecs such as H.264, LCEVC bridges the gap between legacy solutions and next-generation XR applications. This integration improves encoding and streaming performance for high-resolution, immersive multimedia applications in real-time holographic communication scenarios.
Vertical	Real-Time Holographic Communications
Testbed	i2CAT testbed
Implementation timeframe	April 2025- October 2025
Results & Impact	**Results:** The project successfully achieved its core technical objectives, demonstrating the integration and validation of an LCEVC-enhanced streaming pipeline within the 6G-XR infrastructure. Detailed results, figures, and analysis have been moved to the Annexes to adhere to page length requirements, while a summary of them is as follows. **LCEVC Encoder Enhancement (Server-Side):** The primary technical result was the development of the "Lynx" GStreamer plugin, which enhances a standard OpenH264 codec with LCEVC. Objective evaluations showed significant gains, notably a **-30.93% BD-Rate (VMAF)** compared to the baseline H.264/AVC encoder. This performance approaches HEVC/x265 efficiency (-33.23% BD-Rate) but at a substantially lower computational cost (38.6% CPU increase vs. 123.3% for HEVC).

	LCEVC Decoder Integration (Client-Side): A critical achievement was the successful compilation of the open-source *lcevcdec* GStreamer element to WebAssembly (WASM). This allowed for high-performance, real-time decoding of 1080p 30fps LCEVC-enhanced streams directly within a standard web browser, meeting the low-latency requirements for XR. **Low-Latency Transport (QUIC/WebTransport)**: To achieve low latency, the pipeline utilized QUIC/WebTransport via dedicated GStreamer elements (specifically, *quinnwtserversink* on the Linux server and *webtransportsrc* in the *gst.wasm* browser client). This modern transport mechanism was successfully integrated with the LCEVC encoding/decoding pipeline, providing an efficient transport path for the base and enhancement layers. **Integration with 6G-XR and E2E Latency:** Systematic end-to-end (E2E) latency tests on the 6G-XR infrastructure confirmed the solution's viability. The addition of LCEVC introduced a measurable latency increase that scales with resolution (e.g., +22.40 ms encoding-only, +39.00 ms E2E at 1080p). The analysis concludes that the solution is viable for **720p (118.77 ms E2E)** and **1080p (156.23 ms E2E)** resolutions, placing it within the operational range of commercial interactive services. At 4K (373.35 ms E2E), while the latency also falls within acceptable parameters for interactive services, the test revealed a system-level bottleneck (not the codec itself) that caused a disproportionate increase from 1080p. This indicates a need for further pipeline optimization beyond the scope of this work **Impact:** The project generated significant technical, scientific, and commercial impact across these areas. Impact on the 6G-XR Project: - New Web Player: Developed and validated a WebTransport-based Web Player, expanding 6G-XR capabilities beyond existing Native, WebRTC, and DASH players to enable efficient browser-native immersive experiences. - Improved Performance and QoE: The AVC-LCEVC "Lynx" encoder achieved HEVC-like quality at lower bitrates with reduced CPU load, allowing higher user density and better Quality of Experience. - Seamless Integration: Fully interoperable with the Remote Renderer architecture, simplifying integration into current and future XR streaming pipelines. - Low-Latency Transport: Leveraging QUIC/WebTransport supports ultra-low latency goals for interactive XR use cases. Industrial, Scientific and Commercial Value: - Benchmarking Framework: Established a reusable framework for evaluating live encoding workloads, contributing to the research community. - Encoding Presets: Defined practical encoding configurations for high quality, low complexity, and compression efficiency use cases. Transferability: The developed tools and principles extend to other low-latency, bandwidth-sensitive domains like cloud gaming, remote graphics, and DaaS streaming.
TRL	**6**

OC Project	**FSXR: Fluid Simulation in eXtended Reality**
Beneficiary, Country	**Luxembourg Institute of Science and Technology** Luxembourg
Project Description	Extended Reality (XR) devices face significant limitations in running fluid simulation (FS) algorithms due to their high computational demands and the difficulty of maintaining

	real-time performance. To address this, we previously proposed offloading the particle position computations of the Position Based Fluids (PBF) method to a remote server, resulting in improved frame rates compared to fully local processing on devices such as the HoloLens v2. However, local rendering continued to constrain performance. The main challenge for remote rendering lies in the large size of rendered frames that must be transmitted to the XR device. To overcome this, FSXR leverages 6G-XR infrastructure, providing low latency and high bandwidth communication between the server and XR devices. This enables seamless, real-time fluid simulation visualisation, paving the way for more advanced and interactive XR applications.
Vertical	Collaborative 3D Digital Twin-like Environment
Testbed	Oulu 5GTN
Implementation timeframe	April 2025- October 2025
Results & Impact	**Results:** The comparative evaluation of the Obi fluid simulation across O-RAN-based 5G SA and 5G Wi-Fi Router networks shows that network architecture and deployment context strongly affect performance. Latency: The 5G Wi-Fi Router network achieves lower latency and faster MTP times since the XR device connects locally rather than via the public Internet, as in the O-RAN setup. Both networks experience increased latency at higher resolutions due to larger data payloads. Jitter: The O-RAN-based 5G SA network provides predictable, scalable jitter—ideal for real-time XR and outdoor cloud rendering. The Wi-Fi Router network shows lower jitter on average but becomes unstable under heavy load, reflecting its local routing advantages but limited scalability. FPS: Frame rate performance depends mainly on client-side decoding rather than network throughput. The iPhone 14's hardware decoding limits prevent visualization beyond 1920×885 on the Wi-Fi Router setup, unlike the Quest 3, confirming device bottlenecks over network constraints. Overall, the 5G Wi-Fi Router offers lower latency and jitter under local conditions, while the O-RAN-based 5G SA setup provides more stable, predictable performance and greater deployment flexibility for outdoor use. **Impact:** The FSXR project introduces a novel pipeline for visualizing fluid simulations on XR devices over O-RAN-based 5G SA networks, contributing significantly to XR and fluid simulation research. It also offers a comparative analysis of O-RAN 5G SA and 5G Wi-Fi Router performance, yielding insights into network efficiency for compute-intensive XR workloads. The FSXR pipeline generalizes to any remote, high-computation visualization use case, supporting 6G-XR's "Collaborative 3D Digital Twin-like Environment" goals, particularly under "TOP2.3: Visualization and data sharing." Strategically, FSXR aligns with Luxembourg's Smart Growth agenda and LIST's priorities—Digital Twin, Smart Space, and Industry 4.0—by enabling complex fluid simulations as integral components of scientific and industrial digital twin systems.
TRL	**5**

OC Project	**EMASS: Energy measurement as a service**
Beneficiary, Country	**GRIDNET** Greece

Project Description	Energy consumption and carbon footprint are critical considerations in O-RAN-based telecom systems, influencing costs, sustainability, and scalability for future 5G/6G networks. O-RAN's modular, software-driven architecture enables real-time energy management aligned with global carbon goals. The 6G-XR project builds on this by introducing an intelligent energy measurement framework for O-RAN test sites, aiming to optimize energy use in XR applications and support integration of sustainable energy sources. However, challenges remain in verifying whether energy data accurately reflects network conditions. Proper calibration and validation are essential but underdeveloped. To address this, an experiment using the O-RAN (North Node / VTT 5GTN) testbed will deploy AI-powered energy meters and centralized data systems to ensure: Validation – Accurate reflection of network processes, Verification – Reliable and precise metering, and Calibration – Standardized measurements. The modular design supports scalability, making it applicable across other facilities for enhancing energy-efficient telecom systems.
Vertical	Energy Measurement Framework for Energy Sustainability
Testbed	VTT 5GTN
Implementation timeframe	April 2025- October 2025
Results & Impact	**Results:** The EMAS project successfully developed and validated a real-time AI-based energy calibration and anomaly detection pipeline on the VTT 5GTN infrastructure, enabling accurate, dynamic validation of energy metrics across 5G O-RAN components (CU, DU, RU). Key Technical Achievements 1. Metrics Collection and Storage: power consumption and per-UE KPI metrics were collected at 1 Hz via an MQTT collector and stored in InfluxDB, forming a unified time-series database for all EMAS components. 2. Inference and Calibration Models: - RU Model (XGBoost): Predicts power consumption based on aggregated KPIs (e.g., data rates, HARQ acks/nacks, SNR). If prediction deviates >2% from measured values, recalibrates the metric using the prediction. Achieved MAE = 0.652 W, RMSE = 1.095 W, R^2 = 0.8254, and 100% anomaly detection accuracy. - DU Model (Hybrid XGBoost + CatBoost): Handles idle and traffic conditions separately, correcting baseline offsets every 10 minutes. Calibration triggered if residual >2%. Achieved MAE = 1.954 W, RMSE = 2.120 W, R^2 = 0.735, detecting all injected and two genuine anomalies. - CU Model (Autoencoder + Regression Head): Operates on 15-second intervals due to co-location noise (with 5GCN & RIC). Uses rolling statistics (mean, std) to capture short-term variability. Achieved MAE = 2.657 W, RMSE = 2.853 W, R^2 = 0.756, with 100% anomaly detection rate and additional genuine anomaly identification. - Across all models, an anomaly classification mechanism flags over/underconsumption and triggers alerts after 30 consecutive anomalies. 3.Monitoring Service - A React + Grafana-based Power Monitoring Dashboard visualizes real-time measured, calibrated, and anomaly metrics for RU, DU, and CU nodes. - Enables interactive analysis, anomaly visualization, and data export for research use. Validation Experiments

	Conducted using real-world 5G datasets replayed over VTT's testbed. Artificial anomalies (+8–12% power increase) were injected to verify detection accuracy. All models successfully identified anomalies, validating the robustness of the system. **Impact:** EMAS offers a replicable, open-source methodology for energy-aware experimentation in 5G/6G networks.The pipeline enhances measurement reliability, energy calibration, and sustainability insights, aligning with global efforts to reduce telecom carbon footprints.Its open-source release enables adoption and replication in other testbeds, supporting future research and operational energy optimization.
TRL	**5**

OC Project	**EVIT: Electric Vehicle Infrastructure Twin**
Beneficiary, Country	Parity Platform P.C. Greece
Project Description	EVIT enhances electric vehicle charging station (EVCS) installations by integrating Augmented Reality (AR) with 3D scanning and real-time diagnostics to support electrical engineers. The system improves safety, reduces errors, and boosts efficiency during complex installations. Key features include: live 3D scans using devices like the Creality CR-Scan Ferret Pro or smartphones, real-time feedback and safety alerts via 5G to an edge server, AR-guided instructions for accurate installation. Testing is conducted in the South node, leveraging its private 5G network and edge computing for sub-10ms latency, enabling: Seamless streaming of 3D scans and MR annotations, Synchronization with IoT platforms (e.g., EV Loader) to display charger status, Immediate alerts and system readiness updates within the AR field of view. EVIT combines AR, 3D scanning, and 5G to deliver a safer, smarter, and more efficient EVCS installation process.
Vertical	Immersive Services
Testbed	5TONIC
Implementation timeframe	April 2025- October 2025
Results & Impact	**Results:** The EVIT experiment was conducted on the 5TONIC private 5G infrastructure in Madrid to test real-time 3D streaming and AR-based guidance for electrical installations. The setup used the FR2 (26 GHz) cell connected through an Ethernet-based CPE and a Wi-Fi 6E router (Parity Platform), enabling simultaneous connections of AR devices such as Meta Quest 2 headsets and Creality Ferret 3D scanners with ultra-low latency. Network performance was benchmarked using Wireshark, showing: - Average latency: 8 ms - Upload throughput: >200 Mbps (sustained even during heavy 3D streaming) - Download throughput: 350–400 Mbps Compared with conventional 4G/Wi-Fi networks, the private 5G FR2 network achieved: • ~90% lower latency (from 80–120 ms to 8–10 ms) • >5× higher upload throughput (from 20–40 Mbps to 200–250 Mbps) • >6× higher download throughput (from 50–70 Mbps to 350–400 Mbps)

	This performance enabled real-time AR overlays, instant feedback, and seamless 3D model streaming of large (>500 MB) assets, confirming the 5TONIC infrastructure's suitability for industrial-grade XR applications. Ericsson and Capgemini configured the trial environment, with Askey NUQ3000M 5G NR ODUs acting as CPEs under the madrid-low profile (5QI 9) and using TDD operation (100 MHz bandwidth, 256 QAM enabled). Traffic analysis showed stable throughput between client and server CPEs, with a sustained uplink rate of ~103 Mbps and total data transfer of ≈11 GB. Overall, the trial validated the feasibility of interactive, high-bandwidth 3D digital twin streaming in industrial scenarios using private 5G networks. **Impact:** The EVIT project contributes concretely to the 6G-XR initiative by demonstrating how advanced XR and 5G technologies can directly improve safety, quality, and inclusiveness in industrial electrical work. By enabling real-time 3D scanning and AR-assisted guidance, EVIT provides field technicians with immediate visual feedback and context-aware alerts (e.g., incorrect wiring placements, handling of powered components), significantly reducing the risk of electrical accidents and human error. This safety layer, made possible through the low-latency, high-throughput connectivity of the 6G-XR infrastructure, ensures that installers receive precise, real-time information directly in their field of view during complex installations. The solution also enhances the overall quality and consistency of electrical installations. By generating accurate 3D digital twins of each project, EVIT allows teams to document and verify every installation step, ensuring compliance with design specifications and safety standards. Remote experts can review, annotate, and approve installations based on high-fidelity 3D models, establishing a reliable and auditable record of work quality. Furthermore, EVIT promotes inclusivity and workforce participation by allowing experienced engineers, older professionals, or those with mobility limitations to contribute their expertise remotely. Through the use of immersive digital twins, these experts can validate, correct, and guide field installations without being physically present, ensuring their valuable knowledge remains active in the workforce.
TRL	**7**

OC Project	**LEARN-6G: Learning with Holograms over future 6G networks**
Beneficiary, Country	**Universitat Politecnica de València** Spain
Project Description	Real-time holographic communication is revolutionizing remote interaction by enabling immersive experiences essential for future collaboration and teleportation applications. However, deploying these systems at scale poses technical challenges, particularly around performance metrics like bitrate, latency, and reliability. To address these, telecom and standards bodies (e.g., ITU-R IMT-2030, 5G-MAG, 3GPP) are defining requirements for next-gen networks that can support immersive technologies. LEARN-6G involves a cross-site education and training use case between UPV and i2CAT's South Node, using technologies like edge computing, network slicing, and federated networking to enable real-time holographic communication. UPV will provide its immersive communications lab and private 5G network, integrated with i2CAT's infrastructure and commercial off-the-shelf (COTS) hardware. The goal is to

	demonstrate real-world feasibility, gather insights into quality of service (QoS) and quality of experience (QoE), and validate the 6G-XR platform.
Vertical	Immersive Services
Testbed	i2CAT testbed
Implementation timeframe	April 2025- October 2025
Results & Impact	**Results:** The project successfully managed to develop and deploy the application on the testbeds. To do this, the project followed an iterative approach, adding new features until the completion of the application. Once the application's main features were implemented, the lab network testing began. Once the lab network testing was completed, a real-world scenario with i2CAT's testbed was performed. During this session, the teacher application was deployed at UPV, and the student app was deployed at i2CAT. The two testbeds were connected by using UPV's private VPN server and certificates. Regarding testbed validation, during the final trial, several network measurements were taken, to further confirm that the testbed and the VPN manage to provide the throughput requirements of the media and control streams. These measurements were taken with Wireshark, iperf3 and the statistics from VDO.ninja. The following summarizes the results obtained, in terms of KPIs: - Maximum DL/UL throughput of client PC connected to 5G CPE: 630 Mbps DL, 40 Mbps UL on average (with fast.com) - Iperf3 throughput between client PC connected to 5G CPE and VPN to UPV's iperf3 server : 30 Mbps average (iperf3 server limitation) - Measured real-time hologram bitrate: 35 Mbps average - Measured on-demand hologram bitrate: 13.4 Mbps max peak, no steady bitrate over time - Measured received XR stream bitrate: 5 Mbps average (1280x720p60) - Measured pose update bitrate from client to host and host to client: 31 Kbps peak c-h ,17 Kbps peak h-c From these results, we can observe that there are a few discrepancies between the observed application behavior and the measured bitrates. Result #1 indicates that i2CAT's testbed can provide the needed throughput to receive all immersive media streams. However, result #2 indicates that not even the real-time hologram reception cannot occur, as 30 Mbps < 35 Mbps. This does not explain the observed behavior, as at least the real-time hologram and XR stream could be easily received and played without stalls or noticeable playout times. This is suspected to be due to a limitation of UPV's iperf3 server. The client app was able to update player pose, receive real-time hologram and XR stream at the same time without issues. Result #4 is in-line with the observed behavior, as the unstable throughput observed would explain the stalling and large playout time issues. This is suspected to be due to the Evercoast plugin implementation and memory management on Unity. **Impact:** The project has provided insight into the requirements of holographic and XR technologies, helping to shape future 5G/6G networks. It also demonstrated that collaborative XR applications have the potential to enhance future, remote classrooms, with easy-to-use technology, although widespread use is still limited by the lack of head-mounted displays availability. However, the developed application also offers regular PC, game-like controls, which trades immersiveness for accessibility. The project

	also demonstrated that the target 6G-XR platform at i2CAT can deliver the performance needed to provide a smooth multi-user experience.
TRL	**6**

OC Project	**DREAMS: Dynamic Radio Access Network (RAN) Energy-Aware Management System**
Beneficiary, Country	**Future Connections España Soluciones de Conectividad SL** Spain
Project Description	DREAMS integrates microgrid control systems with flexible RAN management to optimize energy use in telecom networks. The system uses DREAMS Agents for distributed, intelligent edge-cloud energy control, incorporating data like renewable energy forecasts, electricity prices, CO_2 emissions, and network load to balance performance, efficiency, and cost. A central DREAMS Controller manages policies and provides real-time monitoring across the network. DREAMS will test a forecast-driven decision algorithm within DREAMS Agents. This algorithm analyzes energy and network data to optimize RAN configurations, with testing planned on an O-RAN deployment within the North Node. It will also develop visual dashboards for real-time monitoring of energy usage, production, and network performance to validate the algorithm's effectiveness.
Vertical	Energy Measurement Framework for Energy Sustainability
Testbed	VTT 5GTN
Implementation timeframe	April 2025- October 2025
Results & Impact	**Results:** The DREAMS project successfully delivered a fully functional prototype of a Dynamic RAN Energy-Aware Management System integrated into the 6G-XR experimental infrastructure. The implementation was validated through a set of experiments combining real-time RAN data, historical traffic patterns, and open energy datasets. From a technical perspective, the main achievement was the adaptation and extension of the DREAMS control logic to include external energy-related parameters provided through 6G-XR interfaces. The original algorithm—based solely on network load predictions—was enhanced to incorporate Consumed CO_2, Solar Yield Forecast, and Elspot Prices data. This integration enables the algorithm to make context-aware energy management decisions, dynamically identifying and expanding low-traffic windows where specific RAN elements can be powered down or reconfigured for energy saving. The impact of each parameter was evaluated independently and in combination: - Solar Yield Forecasts increased the identified low-load windows during daylight hours by up to 30%, promoting a more sustainable energy balance. - Electricity spot prices influenced the scheduling of energy-intensive operations, shifting them to lower-cost periods. - CO_2 intensity data allowed prioritization of actions with the highest environmental benefit. A configurable user interface (UI) was developed using Tooljet, allowing operators to adjust thresholds for these parameters. The configuration changes apply instantaneously to the next algorithm execution cycle, providing full control and adaptability without requiring code modification or service interruption. Validation was conducted on the 6G-XR RAN infrastructure, leveraging MQTTX-based data collection

	for KPI retrieval (traffic load, throughput, resource usage) and energy measurements. The system demonstrated reliable interoperability with 6G-XR APIs, confirming its capability to retrieve, process, and act upon heterogeneous datasets in real time. These results confirm the feasibility of an energy-aware, forecast-driven control mechanism for RANs operating in a distributed edge-cloud environment. The DREAMS prototype establishes a foundation for future integration into 6G testbeds, supporting the development of AI-assisted, green network orchestration systems. **Impact:** The project supports global sustainability goals in telecommunications by integrating innovative energy management with adaptive network solutions, enabling efficient and eco-conscious edge-cloud ecosystems for 5G and beyond. It provides a scalable, cost-effective approach that lowers operational costs and environmental impact while maintaining high service quality. Through the application of microgrid control principles and advanced forecasting, the initiative connects renewable energy use, smart management, and dynamic RAN optimization, advancing Future Connections' vision of creating adaptive, energy-efficient networks ready for complex services. The experiment will strengthen Future Connections' competitiveness and business growth by positioning it as a leader in sustainable telecommunications, expanding market opportunities, and attracting eco-conscious partners. It will enhance operational efficiency by reducing energy costs, carbon emissions, and improving flexibility, thus contributing to global decarbonization efforts Ultimately, it will deliver the 6G-XR project a validated decision-support model for energy-smart RAN management with significant technical and environmental benefits
TRL	**5**

OC Project	**6G4proQ**
Beneficiary, Country	**Nissahub** Serbia
Project Description	Modern manufacturing needs fast, proactive quality control despite diverse, fast-changing, and multimodal data sources. This requires efficient 5G-based anomaly detection and the ability to identify completely new, unseen anomalies. The AI4Resiliance method within the D2Port Framework addresses this challenge using deep learning. 6G4proQ aims to test this system in complex manufacturing environments, validate edge/remote AI deployment, and ensure it meets key SLAs. It focuses on 3 objectives: (i) setting up a 5G-enabled experimentation environment (6G-XR + D2Port), (ii) deploying AIResiliance and associated simulation tools in the testbed, (iii) validating performance through KPI-based evaluation of alarm speed and quality.
Vertical	Artificial Intelligence
Testbed	UOULU 5GTN and VTT 5GTN
Implementation timeframe	April 2025- November 2025
Results & Impact	**Results:** the AI system relies on fast, uninterrupted 5G data transfer to support real-time anomaly detection in the cloud. Testing focused on two areas: 5G network performance and cloud-based anomaly-detection efficiency. Service performance analysis have been executed on: - Time consumption: Worker service is the slowest; anomaly-detection services show similar processing times.

	- Optimization potential: Combination service is the most efficient; worker and mc2pca services can be improved. - Memory usage: Change point detection shows signs of memory leaks; other services remain stable. The key 5G-based findings are 5G reliably supports high-volume and real-time shop-floor data transfer. RTT is consistently under 15 ms with minimal jitter, showing low latency and stable performance—significantly better than 4G. The key cloud-based findings show that: the overall anomaly-detection time can be reduced by optimizing the worker service; the system stability improves with further debugging of change point detection and the execution speed of all detection methods can be improved by optimizing KMeans. **Impact:** The proposal enhances monitoring quality by focusing not only on alarm delivery but also on performance characteristics such as latency, alarm limits, and system stability by supporting emerging "data observability" practices. The technology provider can expand its SME manufacturing market offering with proactive 5G-enabled quality control. With hundreds of SMEs in the region, the project expects: 10% market share in Central Europe in year one, 15% market share in Eastern Europe within 3-5 years. Adopting Industry 4.0 can reduce maintenance costs by up to 50% through predictive capabilities.
TRL	4

OC Project	**RACE-6G: Robotic Autonomous agents with Cognitive Enhancements over 6G**
Beneficiary, Country	**Buontech Solutions srl** Italy
Project Description	RACE-6G addresses modern manufacturing challenges—such as rapid product changes and mass customization—by using LLM-powered multi-agent AI systems to coordinate factory and warehouse robots in real time. Running on GPU-powered edge servers within a 5G network, the system enables dynamic task allocation, HD video streaming, and seamless robot integration, minimizing downtime and supporting scalable, reconfigurable production. Key features include Plug & Produce, self-learning, and centralized multi-step planning. The experiment, to be conducted at VTT 5GTN infrastructure, will demonstrate how 5G/6G connectivity, edge computing, and network slicing enable ultralow latency and high-throughput operations for AI-supervised robotics. RACE-6G contributes to 6G-XR goals by showcasing a replicable model for intelligent, adaptive manufacturing and advancing Europe's leadership in Industry 4.0 innovation.
Vertical	Artificial Intelligence
Testbed	VTT 5GTN
Implementation timeframe	April 2025- October 2025
Results & Impact	**Results:** The experimental validation at VTT 5GTN confirmed that modern wireless infrastructure delivers the performance required for both autonomous and human-controlled industrial operations. Measurements across diverse operational scenarios validated the network's ability to support critical manufacturing applications. Performance metrics exceeded requirements for responsive control. Latencies consistently measured 10-15ms during both AI orchestration sequences and human

	teleoperation tasks. This low latency proved crucial when operators remotely navigated forklifts through narrow warehouse passages, requiring immediate response to steering inputs. Similarly, precise manipulation of robotic arms working on conveyor pieces demanded instantaneous feedback, which the infrastructure delivered reliably. Bandwidth capabilities supported rich visual feedback essential for remote operations. Each HD video stream sustained 15-20 Mbps throughput, enabling operators to clearly observe workspace details while controlling equipment. During pallet transfer operations, drivers relied on multiple camera angles streaming simultaneously without quality degradation. The network maintained this performance level with four concurrent streams throughout extended testing periods. Human teleoperation trials demonstrated practical viability of remote industrial control. Operators successfully completed complex sequences: navigating forklifts between storage racks, lifting and transporting pallets from conveyor endpoints to designated warehouse locations, and executing precise assembly operations on moving workpieces using multi-axis arms. These tasks, previously requiring on-site presence, were performed remotely with confidence thanks to the responsive control and clear video feedback. The edge computing configuration processed AI decisions in 150-200ms while maintaining seamless handoffs between autonomous and manual control modes. System stability remained consistent under varying loads, whether coordinating 8 robots autonomously or supporting multiple human operators, validating that wireless infrastructure can reliably serve diverse industrial requirements. **Impact:** The RACE-6G validation prove that cable-free, real-time industrial operations are now achievable. The validation confirms that current wireless networks meet the latency, bandwidth, and reliability demands for immersive and teleoperated manufacturing within the 6G-XR ecosystem. Operators successfully completed complex remote tasks with confidence and precision, highlighting potential benefits such as remote expert assistance, centralized control rooms, and flexible workforce deployment. By enabling skilled workers to operate machinery across distributed sites, the solution addresses labor shortages, enhances safety, and ensures operational continuity during access disruptions. The experiments establish a foundation for future 6G-enabled human-AI collaboration, paving the way for more advanced, resilient, and sustainable industrial systems.
TRL	**5**

OC Project	**SafeDriveXR: Enhanced Driver Awareness through Cooperative XR Technologies**
Beneficiary, Country	**AviSense.ai** Greece
Project Description	SafeDriveXR aims to enhance road safety by developing a 5/6G-enabled system that integrates Cooperative Intelligent Transport Systems (C-ITS) with Extended Reality (XR) interfaces for Connected and Automated Vehicles (CAVs). The project leverages real-time XR visualizations of traffic, road conditions, and obstacles to boost driver situational awareness, decision-making, and response times. Using heterogeneous devices, distributed signal processing, and cloud-edge coordination, SafeDriveXR ensures low-latency communication and meets human reaction time requirements. It also focuses on accurate detection of vehicles, road hazards, and Vulnerable Road Users (VRUs), while employing adaptive XR interfaces and QoE evaluation to personalize

	information delivery based on user context. The solution supports the EU's vision for scalable Cooperative, Connected, and Automated Mobility (CCAM)
Vertical	CCAM
Testbed	5TONIC
Implementation timeframe	April 2025- October 2025
Results & Impact	**Results:** The SafeDriveXR system integrates advanced cooperative perception and real-time visualization capabilities built on the 6G-XR platform for orchestration and deployment. All components were containerized and deployed as Kubernetes Helm charts, ensuring modular configuration, scalability, and automated management of distributed resources. The IEAP (MEC Orchestrator) onboarded all edge devices under a unified deployment, while the MQTT broker and Cooperative Fusion Server were managed separately to enable fine-grained control of data flow and compute allocation between edge and cloud nodes. The system adopts a distributed cloud–edge architecture, where edge devices perform initial sensor data processing and local inference, generating preliminary object detections that are transmitted via the 5G network to the Cooperative Cloud Server for global fusion and correction through the Collaborative Multi-Object Tracking module. This setup enables adaptive workload distribution and low-latency communication between perception components. Data pipeline was validated using synthetic multimodal sensor streams—including LiDAR, GNSS, and IMU signals—transmitted to three edge devices over a dedicated 5G link to emulate real driving scenarios. The edge devices produced noisy detections that were refined at the cloud level, while results were visualized in real time through a VR headset, displaying both raw and corrected bounding boxes under realistic operational conditions. Following integration and validation, trial testing was conducted at the 5TONIC 5G facility in Madrid. The experiments were configured via the Unified Web Portal of the 6G-XR Trial Controller, with parameters and resource allocations managed centrally. Two main trials were executed through the South Web Portal: (i) deployment of SafeDriveXR edge applications on Edge 1 for local inference, and (ii) deployment of the MQTT broker and Cooperative Fusion Server on Edge 2 for cloud-level coordination. The trials confirmed the system's technical readiness and performance, achieving 17.3% Average Multi-Object Tracking Accuracy (AMOTA) and 15.99% Average Multi-Object Tracking Precision (AMOTP)—surpassing comparable cooperative perception frameworks. The 5G network slice sustained 100 Mbps bandwidth and 15 ms round-trip latency, demonstrating full compliance with real-time vehicular perception and communication requirements. Overall, the trials validated the 6G-XR platform's ability to efficiently orchestrate distributed, AI-driven perception tasks, supporting reliable, low-latency cooperative awareness for future connected and autonomous mobility applications. **Impact:** Industrial and Economic Impact: SafeDriveXR enhances AviSense's leadership in AR/XR and AI-driven perception, accelerating commercialization of AR-based driver awareness tools and fostering innovation, collaboration, and job creation in Europe's XR and CCAM sectors. Scientific and Technological Impact: It advances 5G/6G cooperative perception and localization, introducing distributed multimodal fusion, dynamic cloud-edge orchestration, and explainable XR interfaces, directly contributing to 6G-XR objectives for safety-critical, ultra-low-latency applications.

	Societal and Environmental Impact: By delivering adaptive XR feedback that enhances driver awareness, reduces distraction, and supports Vision Zero road safety goals, SafeDriveXR promotes trustworthy human–machine interaction. It also contributes to eco-driving and reduced emissions through smarter, cooperative traffic management.
TRL	**5**

OC Project	**MechEye: Industrial Machine Sentinel**
Beneficiary, Country	**INESC TEC** Portugal
Project Description	The MechEye project is a proof-of-concept system designed to enhance industrial safety and efficiency by combining video analysis, object detection, and contextual data. It aims to proactively detect manufacturing errors using AI-driven sensor processing. Given the system's high compute and bandwidth demands, the project will benchmark its performance across different edge computing scenarios, exploring trade-offs between compute placement, communication, and latency. MechEye represents a relevant future industrial workload, and its experimentation will be supported by 6G-XR infrastructure, which offers advanced edge computing, high-capacity networks, and ultra-reliable low-latency communication. The results will inform the development of next-gen cloud/edge AI solutions for industrial environments.
Vertical	Artificial Intelligence
Testbed	Oulu 5GTN
Implementation timeframe	April 2025- October 2025
Results & Impact	**Results:** The MechEye project developed and validated an AI-assisted monitoring system for industrial environments. Use Cases: Demonstrated value in safety audits, training evaluation, and incident investigation through AI-generated summaries and keyframe capture. System Pipeline: A full Edge–Cloud monitoring pipeline was implemented using a publish/subscribe architecture (NATS), enabling flexible deployment and experimentation with different topologies. Model Evaluation: Systematic testing of vision-language and reasoning models identified llava-13b as optimal for image captioning and deepseek-r1-14b for reasoning. Open-source models currently achieve 39–59% accuracy under the Model-as-a-Judge framework. Dataset Contribution: Introduced a new industrial IQA dataset of 100 triplets across five categories, addressing a major dataset gap for industrial visual tasks. Network Slicing: 5G slicing tests confirmed its value for latency control and synchronization under network congestion. Performance Insights: Continuous real-time monitoring is currently infeasible due to GPU-bound captioning (80–95% of processing); multi-camera setups require 2–3 GPUs. Network latency remains low (<5% E2E delay), with slicing providing key QoS guarantees. **Impact:** MechEye advances the 6G-XR goals by demonstrating a real industrial use case that stresses next-generation network and compute capabilities.

	Industrial Relevance: Showcases AI-enabled workflows with high processing demands typical of future smart industry systems. Cloud-Edge Continuum: Validates that hybrid edge–cloud orchestration outperforms static deployments, suggesting that future 6G systems should enable dynamic workload migration across compute layers. Infrastructure Validation: Demonstrated network slicing, edge ML acceleration, and multi-component integration on the 5GTN testbed, confirming 6G-XR infrastructure readiness. Identified Bottlenecks: Highlights VLM inference latency as the main limitation for real-time operation; future designs should focus on faster models or tiered processing architectures. Methodological Contribution: Established a repeatable framework for orchestrating, monitoring, and benchmarking AI-driven workloads in 6G-XR environments.
TRL	**4**

OC Project	**AViD-NMP: Adaptive Video Delivery for Network Music Performance**
Beneficiary, Country	**AUEB-RC** Greece
Project Description	The AViD-NMP project explores Network Music Performance (NMP) using the 6G-XR infrastructure, focusing on ultra-low latency and high-bandwidth requirements that are only achievable with 5G/6G networks. It integrates audio, video, and volumetric data for immersive, XR-enabled multiparty NMP sessions. To meet performance needs, the project leverages 5G RAN for low-latency communication and MEC (Multi-access Edge Computing) resources for real-time media processing, including volumetric video and SFU/MCU bridging close to end users. The primary goal is to support training and education, evaluating QoS and QoE of XR-enabled NMP across advanced 6G-XR testbeds. The project will showcase a fully operational multiparty NMP setup as a demonstrator of 5G/6G and XR's potential for enhancing real-time, immersive remote collaboration.
Vertical	Immersive Services
Testbed	5TONIC
Implementation timeframe	April 2025- October 2025
Results & Impact	**Results:** Experiments were conducted in the 5TONIC 5G testbed to assess the performance of volumetric video, audio, and 2D video for Networked Music Performance (NMP) teaching scenarios, focusing on Quality of Service (QoS) and initial Quality of Experience (QoE) evaluation. Volumetric Video: Three configurations were tested—Peer-to-Peer (P2P), Selective Forwarding Unit (SFU), and Multipoint Control Unit (MCU)—using three 5G-connected endpoints (two producers and one consumer). Results show that producers maintained consistent 30 FPS performance with ~48 ms end-to-end latency, mainly affected by frame capture (19 ms) and transmission (16 ms). The SFU added negligible delay, while the MCU introduced ~40 ms of extra latency but reduced bandwidth usage by up to 90%. With two producers, bandwidth sharing and limited MEC computing caused frame loss and increased latency (up to 200 ms). Overall, P2P achieved the lowest latency, SFU

	provided stable relaying, and MCU was viable when bandwidth savings outweighed added delay. Audio and 2D Video: Using the Aretousa application, audio delays measured 53–60 ms (slightly above the 40 ms live NMP threshold), with the SFU adding minimal extra delay. 2D video delays were significantly higher (172–195 ms), making synchronized audiovisual teaching impractical. Quality of Experience (QoE): A live two-user NMP test confirmed that ~50 ms one-way audio delay hindered synchronization. Participants rated system usability and satisfaction as moderate (2–3 on a 5-point scale), identifying delay as the main issue. **Impact:** The project validates the potential of 5G for telepresence and NMP but highlights challenges in meeting ultra-low-latency requirements. Volumetric video achieved 30 FPS with <50 ms latency on standard hardware. SFU added negligible delay; MCU added ~40 ms but reduced bandwidth drastically. Audio latency (55–75 ms) was acceptable for music teaching, not for live performance. 2D video latency (>150 ms) made it unsuitable for real-time synchronization. Thus, NMP-based teaching is feasible in two-party P2P or SFU/MCU setups, but multiparty streaming needs more bandwidth and MEC resources.
TRL	**6**

3.2 CHALLENGES AND LESSONS LEARNT

The Open Call Steering Committee provided valuable insights into the operational and strategic aspects of managing third-party experimentation through the implementation and mentoring of Open Call projects within the 6G-XR framework. Several recurring challenges relating to technical integration, governance, timing and support processes emerged from this perspective. At the same time, these experiences generated important lessons that can inform the design of future Open Calls, improving efficiency and enhancing the overall impact of third-party engagement within SNS-aligned initiatives.

Challenges

- Ensuring the protection of testbed confidential information while still providing sufficient access for third parties to perform their Open Call project tests is essential.
- Identifying areas of overlap between 6G-XR and the Open Call projects, particularly OC1 and OC2, and managing potential duplication of efforts when technical scopes overlap.
- Aligning the level of mentoring support with the diverse experience of third-party applicants, ranging from newcomers to highly experienced participants in previous open calls, is key.
- Navigating complex governance and administrative processes: inconsistent templates and non-standardised procedures created inefficiencies and slowed implementation.
- Dealing with timing misalignments: Open Call schedules were not always synchronised with SNS JU work programme cycles, which limited continuity and reduced opportunities to scale successful third-party outcomes.

- Running several Open Call projects in one platform presents challenges for both the platform and the Open Call participants.

Lessons learnt

- The two-stage proposal submission process, consisting of a feasibility stage followed by a final submission, proved effective in increasing the likelihood of high-quality proposals.
- Obtaining a clear understanding of each Open Call project's technical scope from the outset is essential for providing relevant early-stage feedback and preventing integration issues later in the process.
- Clearly defining the capabilities and limitations of the test facilities in the call documentation is critical. This prevents extensive proposal revisions following the feasibility assessment and helps applicants to design realistic experiments.
- Simplified, transparent and standardised administrative procedures, including common legal, financial and technical templates provided by SNS JU, significantly improve efficiency and enable broader participation.
- Synchronising Open Call timelines with SNS JU facilitates smoother transitions and enhances the potential for promising third-party innovations to evolve into larger SNS projects.

3.3 FEEDBACK FROM PARTICIPANTS

The selected projects collectively demonstrate the versatility, maturity and future potential of the 6G-XR research infrastructures. Their outcomes reveal several cross-cutting technical, operational and organisational insights, which are important for understanding the challenges and opportunities facing the sector. Here below are reported the key feedback grouped per topic.

XR Technologies and Media:

- Successful integration of human–computer interaction components, haptic devices, and advanced rendering tools.
- System refinement improved modularity, performance, and scalability across XR applications.
- Identified opportunities for enhancing immersion through richer environments, multi-stream media, improved tracking, and more realistic media

Network and Edge Performance:

- Across multiple trials, 5G-based infrastructures provided sufficiently high throughput and stable uplink performance for demanding XR applications; however, peak load situations still triggered packet loss or increased latency.
- Comparisons between network configurations revealed that jitter stability and consistent scheduling behaviour are as important as raw bandwidth for real-time XR.
- Edge computing resources enabled high-performance AI inference and real-time processing, though several teams noted that expanded edge capacity would further improve responsiveness under multi-device load.

Integration challenges and recommendations for testbeds evolution:

- Several projects advised expanding technical documentation, API descriptions, versioning, and configuration guidelines to reduce onboarding time and avoid ambiguity.
- Network access procedures, VPN solutions, and remote access policies sometimes slowed down experimentation. Direct or more flexible access mechanisms were suggested.
- More granular monitoring, unified logging interfaces, and pre-configured performance-measurement tools would facilitate validation of latency, QoS, and energy metrics.

Data handling, measurement and AI-driven optimisation:

- Measurement tools provided valuable data for analysing application behaviour, detecting anomalies, and supporting adaptive or AI-based network optimisation. Real-time data collection pipelines worked well but would benefit from more robust buffering to avoid data loss during outages at the consumer side.
- Energy consumption measurement emerged as a crucial theme: several projects explored end-to-end energy profiling of network components and highlighted the importance of integrating energy intelligence into future network architectures.
- Suggest having buffering improvements needed to avoid data-loss in pipelines. Energy-consumption metrics and AI-based optimisation highlighted as important areas

Security, reliability and robustness:

- Network-level data provided useful insights for detecting both performance anomalies and potential cyber-security threats via machine-learning-based analysis of traffic patterns.
- Reliability concerns included overload scenarios, highly variable peer-to-peer traffic patterns, and the need for robust recovery mechanisms in high-bitrate XR streaming workloads**.**

Collaboration, mentorship and cross-projects synergies:

- Mentorship from the different 6G-XR facilities was consistently described as responsive and technically strong, enabling efficient problem solving and system tuning.
- Cross-project cooperation, particularly with regard to joint demonstrations, helped to reveal synergies and encourage future research partnerships.
- Clear governance structures via regular meetings, fast communication loops were a major success factor across nearly all projects**.**

Recommendations for Future Testbed Extensions

- Support for emerging hardware such as intelligent surfaces, beamforming arrays, or advanced radio units.
- Enriched datasets and predefined workloads to accelerate experimentation in AI, slicing, and optimisation.
- Additional mobility scenarios, multi-user configurations, and outdoor deployment options for more realistic field-testing.

- Expanded compatibility layers to integrate non-cellular XR devices more seamlessly into 5G/6G infrastructures.

3.4 OPEN-SOURCE CONTRIBUTIONS

This section provides an overview of the open-source outputs generated through the 6G-XR Open Calls. For each call, and for each third-party project where applicable, the subsections summarise the type of open-source contribution, its functional relevance, and the platform or repository where the artefact is maintained.

The tables below lists the open-source contributions produced respectively under Open Call 1, Open Call 2 and Open Call 3 including a brief description of each item and a direct link to the corresponding repository.

3.4.1 1st 6G-XR Open Call - Platform and Network Enablers

Table 6: Open-Source contributions from Open Call 1

Project	Type of Open-source	description	Link to repository
MST	NO		
METAPHOR	NO		
BANQ	NO		
6G-SLICE	Software	*Contributions to the open-source OpenAirInterface (OAI) 5G stack*	*https://gitlab.eurecom.fr/oai/openairinterface5g/-/merge_requests/3461*
		Contributions to improve the stability and performance of the OAI 5G radio access network.	*https://gitlab.eurecom.fr/oai/openairinterface5g/-/merge_requests/3281*
		Contributions to the OAI code base, developed by Allbesmart's team, merged in the OAI code, and publicly available in GitLab	*https://gitlab.eurecom.fr/oai/openairinterface5g/-/merge_requests/3423*
REQUIEM	Software	*Contributions related to the measurement scripts and configurations that allows to reproduce the executed measurements. The measurement framework can work on a Mininet-based virtual controlled environment that we developed and on a Kubernetes cluster (e.g., 6G-XR South Node, Kubernetes cluster at Barcelona test facilities).*	*https://github.com/SNS-JU/6gxr-requiem*
	Software	*Extension of the existing 5G benchmarking tool, TIPSY, see the source code repository. TIPSY collects and stores measurement results and metadata (e.g., date, software versions config params) in JSON files and enables advanced visualization options.*	*https://github.com/hsnlab/tipsy/tree/general-cmd*
	Software	*Introduced the following forks containing project-specific changes:* *- Quinn, QUIC library in Rust* *- latency-clock, measure video latency in GStreamer*	*https://github.com/SNS-JU/6gxr-quinnhttps://github.com/SNS-JU/6gxr-latency-clock*

		- *gst-plugins-rs, GStreamer plugins in Rust:*	*https://github.com/SNS-JU/6gxr-gst-plugins-rs*
ExCalibAR	Software	*An open source library for the accurate calibration plenoptic cameras without complex calibration targets*	*https://github.com/RobotVisionHKA/LiFCal*
OpenCAMARA	Software	*A Java implementation of the NEF ASSessionWithQoS API that is integrated with Open5Gs. The implementation has been validated with Amarisoft gNBs in the lab*	*https://github.com/Fundacio-i2CAT/ASSessionWithQoS*
FALADIN	Software	*Bug reports and fix instructions to open source Babylon.js*	*https://github.com/BabylonJS/Babylon.js*

3.4.2 2nd 6G-XR Open Call – Stream B Enablers

Table 7: Open-Source contributions from Open Call 2

Project	Type of Open-source	description	Link to repository
AI4EE	NO		
StreamAnalyzerFor5GSlicing	Cater for different 5G Cores, our source code is released as Released under GNU General Public License Version 3.	Implementation contains: (i) a centralized AI-based learning load balancer respecting UE's bandwidth requirements and (ii) a distributed reinforcement learning scheduler for optimal 5GTN RI resources' use when Cumucore slices are congested.	*https://github.com/lamdanetworks/StreamAnalyzerFor5GSlicing*
ENORMOUS	Dataset, AI models (Python Scripts)	Dataset for training the AI models for energy consumption prediction. We are planning to publish the AI/ML models for different network elements (CU and DU) and the datasets	Available soon in conjunction with a scientific publication currently under review
EMSEOS	GNU AGPL 3.0	Scripts for automated deployment of the monitoring system and documentation for manual deployment.	*https://github.com/mirazola-ik/6G-XR_OC2_EMSEOS/*
6G REMIX	Software	Our visualization tool is a web application that visualizes energy and load data from a specified JSON endpoint. It fetches data from a PowerPDU device and displays the energy consumption and load for four outputs in a graphical format.	*https://github.com/minhkstn/6GREMIX-Visualisation*
	Dataset	This dataset consists of the energy consumption of the 5G system at i2CAT with various test scenarios.	https://owncloud.fraunhofer.de/index.php/s/0n6DoqcGFaU2qyw
	Software	Our measurement app fetches data from a specified NETIO JSON endpoint URL at regular intervals and logs the output to CSV files.	https://owncloud.fraunhofer.de/index.php/s/e6egFQBCCchf0U7

TrustNet	Dataset	The project includes an open-source contribution in the form of a dataset. A CSV file containing collected metrics, which are used as input to the TMF, along with the output trust scores, can be provided upon request.	Submitted to Zenodo (under review).
5G-slAIce	Dataset	In the repository "AI-ML-models", two datasets can be found. These datasets can be open-sourced if 6G-XR is open to it.	AI-ML-models under submission
	Software	In the repository "AI-ML-models", the software related to the creation of the models can be open-sourced.	AI-ML-models under submission
	Software	In the repository "creation-dataset", the software related with the user simulation framework can be open-sourced	creation-dataset under submission
	Software	In the repository "Network-Slicing-Controller", the software related with the controller can be open-sourced.	Network-Slicing-Controller under submission
OPTICALRAN	NO		
DYNAMICON	NO		
xDRL-RCS	Software	xDRL-based framework for adaptive RAN/core slicing, including enhanced KPM and RC xApps and a Python simulation environment for xDRL training and performance evaluation.	https://github.com/iThermAI

3.4.3 3rd 6G-XR Open Call Vertical Replicability Enablers

Table 8: Open-Source contributions from Open Call 3

Project	Open-source type	description	Link to repository
IMMVIEX	NO		
LCEVC-6G-XR	Software	Contributions primarily focused on integrating MPEG-5 LCEVC decoding capabilities and enhancing WebTransport functionality within the GStreamer WebAssembly (gst.wasm) environment. This included adding LCEVC decoder support, implementing a WebTransport source element, enabling multiple stream handling for WebTransport, and addressing associated memory usage, buffer management, and stream status issues.	https://github.com/fluendo/gst.wasm
LEARN-6G	NO		
EVIT	3d model streaming script, 3d model examples	Standardized docker container to enable streaming of large size 3d models and video files	https://github.com/Parity-Platform/6gxr-evit
SafeDriveXR	NO		

AViD-NMP	Dataset	The dataset contains logs from the volumetric streaming applications developed during the AVID-NMP project, as tested in the 5TONIC testbed.	https://zenodo.org/records/17513091
	Dataset	The dataset contains logs from the audio and 2D video streaming applications developed during the AVID-NMP project, as tested in the 5TONIC testbed.	https://zenodo.org/records/17525905
	Software	The project includes the CPP source code of the volumetric video streaming applications that were initially developed during the TENEMP project and enhanced during the Avid-NMP project.	https://github.com/mmlab-aueb/nmp/tree/master/volumetricstreamingapp
	Software	The project includes the CPP source code of the audio/2D video streaming applications that were initially developed during the TENEMP project and enhanced during the Avid-NMP project.	https://github.com/mmlab-aueb/nmp/tree/master/av-delay-measurements-v2
EMASS	Machine Learning Models, scripts for calibration	EMAS contributions are packed as docker containers including all the ML models and measurement calibration performed during the project. The components packed in the repository are ensuring reproducibility of the experiment, allowing our contributions to be deployed in any other testbed. The only pre-requisite is the existence of a local InfluxDB deployment that hosts the KPI measurements, as they are served by the VTT MQTT broker. More information is provided under Section E – Method of Replicability in the current document.	https://bitbucket.org/gridnetdkefalas/emas/
DREAMS	NO		
RACE-6G	NO		
FSXR	NO		
6G4proQ	NO		
MechEye	Dataset and Source Code	**Dataset Development**: The team created an industrial IQA dataset with 100 triplets across five categories addressing a gap in available industrial datasets. **Proof of Concept Pipeline**: implementation of modules for a full system to monitor industrial processes. The system architecture enables flexible component placement across Edge and Cloud resources.	https://osf.io/rvx94/overview?viewonly=b365516a77b94af182397ed31c879fe4

4 CONCLUSIONS

The cascading funding activities under 6G-XR successfully mobilised a diverse ecosystem of innovators across Europe, demonstrating the value of open, federated research infrastructures for advancing next-generation immersive communication technologies.

Across the three Open Calls, the project attracted a consistent and growing level of interest, engaging SMEs, research organisations, and academic teams from a wide geographical spectrum. The selected experiments addressed critical technological challenges aligned with the project's objectives. These challenges covered areas such as real-time holographic communication and XR interaction mechanisms to energy-efficient networking, AI-driven slicing, trust management and advanced RAN/transport-layer enablers. The sub-grant projects delivered tangible technical results, validated on the North and South Node facilities, and created open-source contributions that will remain available to the research community. These outcomes will significantly extend the capabilities of the 6G-XR research infrastructure and strengthen the project's contribution to the broader SNS JU roadmap.

The key conclusions can be drawn:

- **The cascading funding scheme proved highly effective** in supporting targeted, high-quality experimentation that complemented and expanded the internal 6G-XR R&D activities.
- **The thematic progression across the three Open Calls was successful**, moving from infrastructure and platform enablers (Open Call 1), to Stream-B-aligned innovation (Open Call 2), and finally to replicability of XR vertical use cases (Open Call 3). This staged approach ensured increasing maturity and alignment with both project priorities and external stakeholder needs.
- **The experiments demonstrated high technological relevance and impact**, validating advanced features such as QUIC-based media streaming, O-RAN slicing automation, energy measurement frameworks, multi-modal XR capture, deterministic networking, and collaborative digital twin environments.
- **The open-source outputs significantly enhance reusability**, enabling experimenters, researchers, and industry stakeholders to continue building on 6G-XR results beyond the project lifetime.
- **Cross-project synergies were a clear value-add**, with multiple experiments integrated and showcased together in joint demonstrations (e.g., EuCNC & 6G Summit 2024, One6G Summit), reinforcing the coherence of the 6G-XR ecosystem.
- **The Open Calls strengthened the strategic positioning of European small players such as SMEs and start-ups**, enabling them to accelerate TRL, validate commercial prototypes, and access high-end research infrastructures that would otherwise remain out of reach.

Overall, the 6G-XR Open Calls successfully encouraged innovation, reinforced Europe's position as a leader in 6G technology enabled by XR, and increased the project's impact across technical, scientific, and industrial domains. The results achieved through these funding actions provide a robust foundation for future large-scale experimentation and standardisation activities, as well as continued collaboration within the SNS JU community.