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HUMAN-CENTRIC AI-ENABLED EXTENDED REALITY APPLICATIONS FOR THE INDUSTRY 5.0 ERA

D6.1 – USE CASES CO-CREATION AND PILOT SITES PREPARATION

Lead Beneficiary	IPIA
Work Package Ref.	WP6 – Apps Integration, Validation and Evaluation
Task Ref.	T6.1 – Use Cases Co-Creation and Pilot Sites Preparation
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REVISION HISTORY

Version	Date	Partner(s)	Description
0.1	2024-10-01	IPIA	ToC Version (2 months before due date)
0.2	2024-10-08	IPA	Added Methodology Draft
0.3	2024-10-11	IPIA	Added annexes with workshops documents.
0.4	2024-10-14	IPIA	Added Chapter with summarizations
0.5	2024-10-18	IPIA	Added Chapter with Synthesis
0.6	2024-10-22	IPIA	Added Chapter about Pilot site Preparation
0.7	2024-10-25	IPIA	Major Internal Revision
1.0	2024-11-11	IPIA	1st Version (1 months before due date)
1.1	2024-12-06	INNOV; SH	Version for Peer Reviews (*2 weeks before due date*)
2.0	2024-12-13	UPRC	Version for Quality Assurance (*1 week before due date*)
3.0	2024-12-20	IPIA, GFT	Version for Submission

LIST OF ABBREVIATIONS

Acronym	Description
AI	Artificial Intelligence
AMT	Aircraft Maintenance Technician
API	Application Programming Interface
AR	Augmented Reality
CBM	Condition Based Maintenance
CCTV	Closed-Circuit Television
DT	Digital Twin
EU	European Union
HMI	Human Machine Interface
IoT	Internet of Things
ISAR	Interactive Streaming for Augmented Reality
KPI	Key Performance Indicator
LTE	Long Term Evolution Model
OS	Operating System
SLB	Systemic Lisbon Battery
UC	Use Case
VR	Virtual Reality
XAI	Explainable Artificial Intelligence
XR	Extended Reality
WAIV	Wing Anti-Ice Valve

EXECUTIVE SUMMARY

Deliverable D6.1, entitled " **Use Cases Co-Creation and Pilot Sites Preparation**," is a key component of the XR5.0 project, developed under WP6: "**Apps Integration, Validation and Evaluation.**" It comprehensively synthesizes the efforts of the XR5.0 project to integrate Extended Reality (XR) and Artificial Intelligence (AI) technologies into industrial contexts, emphasizing a human-centric approach. This document demonstrates how innovative methodologies, grounded in co-creation, were applied to align the specific demands of six pilots with advanced technological solutions, ensuring both technical feasibility and practical applicability.

D6.1 begins with an overview of the Co-creation workshops, explaining why they are important to align the Pilots' needs and the projects' goals. Then the deliverable discloses the methodology used to connect Pilot Leaders, Technical Leaders, Task Leaders and XR5.0 Management, during online co-creation workshops. The Co-Creation Workshop sessions were designed to promote the flow of information between Pilot and project partners, to effectively discuss and prioritize User Stories and associated Key Performance Indexes (KPIs), XR5.0 Technical Components and Human Factors, which are the basis for the XR5.0 Project. After that, the deliverable presents the details regarding the execution of each workshop and reveal the results of the workshops in three ways:

- A Comprehensive Documents with detailed discussions occurred during each workshop.
- A Summary Documents with the most important findings for each Pilot.
- A Comparison Document, aggregating the workshops results to facilitate uncovering similarities and differences.

D6.1 also contains information about the efforts towards to fulfill Task 6.1 goals toward preparing activities to facilitate Pilots and Partners deploying and operating the Use Cases. In this scenario, we have devised a two-phased approach to collect the proper information and devise an action plan. Phase 1 is dedicated to creating a Catalogue with updated information about the adopted solutions from each Pilot and Tech Leader, their target deadlines for KPIs and a brief explanation about XR5.0 added value.

The *Deliverable D6.1* stands out as a strategic milestone for XR5.0, providing not only a record of achievements to date but also a clear roadmap for the next phase. By prioritizing a human-centered approach and practical validation of the solutions, the project is paving the way to transform industrial practices with technologies that drive efficiency, safety, and innovation, solidifying the role of Industry 5.0 as a model for more collaborative and intelligent work environments.

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1. INTRODUCTION

1.1. Objectives of the Deliverable

This document, D6.1 – Use Cases Co-Creation and Pilot Sites Preparation v1, aims to coordinate the activities related to the pilots and use cases defined under Task 6.1: "Use Cases Co-Creation and Pilot Sites Preparation." These activities involve designing use case systems, managing necessary datasets, and mobilizing experts at each pilot site. The main objective of the workshops conducted during Phase 1 (M1-M9) was to facilitate the implementation of human-centered XR and AI technologies by defining use cases, identifying technical and human requirements, and establishing performance metrics to validate and implement advanced technological solutions.

The co-creation workshops were crucial in ensuring that the technologies developed align with the practical needs of various industries. These workshops brought together professionals from multiple sectors to engage in discussions about the current state, challenges, and potential benefits of introducing collaborative AI systems. A particular emphasis was placed on how the outcomes of these systems should be visualized in XR devices and what human factors—such as cognitive load, stress, anxiety, and digital skills—could impact the tasks that workers perform in industrial settings. By integrating these factors, the workshops ensured that the solutions developed would not only be effective but also user-friendly, sustainable, and improve overall working conditions.

Through this collaborative process, the co-creation workshops provided a structured foundation for the technical development, validation, and future deployment of XR5.0 solutions, addressing both technical specifications and human-centered aspects, thus ensuring that the solutions developed are practical, usable, and aligned with industry needs.

1.2. Insights from Other Tasks and Deliverables

Task 6.1 was supported by the findings of Task 2.1: "Analysis of Reference XR Scenarios for Industry 5.0 Applications," which focused on identifying and analyzing functional and non-functional requirements for reference XR scenarios. These requirements were essential for shaping the co-creation workshops, helping define the user stories and technical priorities for each pilot.

The insights from Task 2.1 guided the co-creation workshops and provided the foundation for validating six reference scenarios and user stories. These scenarios acted as a reference for discussions about technical requirements, performance metrics, and human-related factors, ensuring that both the technological and human elements were taken into account during the solution development process.

Additionally, the insights gained from the co-creation workshops helped refine the project's focus and adjust the technological solutions to better address the real-world needs of industry. The activities described include the detailed design of the use case systems, ensuring that both technical and human requirements were fully defined and aligned with the project's objectives. For this purpose, the collection and management of the necessary datasets were carried out, a critical element to validate the proposed technologies. The mobilization of experts at the experimentation sites also played a crucial role, allowing the specific challenges of each environment to be integrated from the early stages of planning.

Furthermore, this deliverable documents how the co-creation methodology from WP2 was applied to facilitate collaboration among various partners and stakeholders, allowing for iterative refinement of user stories, KPIs, and technical factors. This collaborative approach was complemented by end-user training activities, with the aim of equipping them to interact with the developed solutions. Ultimately, the task incorporated other essential activities to ensure that the use cases were properly implemented and operated, including infrastructure support and detailed logistical planning.

The document highlights the intersection of technical, methodological, and human engagement practices, illustrating how these elements were combined to create an environment conducive to the development of innovative technologies. It not only reflects the progress made but also sets the foundation for the next steps of the project, which will include prototype testing and validation of the solutions in real operational environments.

1.3. Structure

This deliverable is organized into seven main chapters, complemented by a detailed Annex:

- **Chapter 1 -** Introduction: Presents the document's content, objectives, and integration into the project's broader framework.
- **Chapter 2 -** Co-Creation Workshop Methodology: Describes the design, organization, and guiding principles applied during the workshops.
- **Chapter 3 -** Methodology Application: Explains how the methodology was implemented across all pilots.
- **Chapter 4 -** Results: Provides a summary and update of the main findings derived from subsequent technical meetings, including the one held in Biel, from November 12 to 14, 2024. During this meeting, the initial requirements were reviewed and adjusted to align technical specifications with the capabilities and constraints identified during earlier development phases.
- **Chapter 5 -** Results Synthesis: Presents a comparative analysis of the workshop findings, highlighting commonalities and specific differences.
- **Chapter 6 -** Pilot Site Preparation: Details the steps taken to ensure the effective implementation of technological solutions, covering hardware and software updates, data management, and planning of future activities.
- **Chapter 7** – Concluding Remarks.
- **Annex**: Contains the comprehensive and detailed results of the co-creation workshops held between June 13, 2024, and July 19, 2024. The results presented in the Annex reflect the status and technical understanding as of that specific period, including identified technical requirements for software, hardware, and human factors discussed in collaborative sessions involving technical partners, pilot leaders, and industry experts.

2. Co-Creation Workshops Methodology

2.1. Introduction

Designing and implementing large and complex software systems involving diverse partners and emerging technologies is a challenging endeavor. From collecting proper requirements, to creating useful proof of concepts and to testing ideas, all phases entail collaboration, cooperation and coordination among partners. The XR5.0 project is a living example of "a challenging initiative to design and implementation" as it gathers geographically dispersed partners including 6 Pilot organizations and several technical and educational peers, to define a novel Person-Centric and AI-based XR paradigm that will be tailored to the requirements and nature of Industry 5.0 applications. In this scenario, organizing the high-level requirements and determining how technical components and human aspects can be used to deliver appropriate and quantifiable results involves defining and executing a methodology that entices innovation through co-creation.

Co-creation workshops are collaborative sessions where stakeholders, including designers, customers, users, and other relevant parties, come together to actively contribute to the creation, development, or improvement of a product, service, or solution [1] [2]. The approach is to gather diverse perspectives, insights, and expertise to foster innovation and create value that is more aligned with the needs and expectations of the end-users. The IPIA Partner, an academic institution responsible for Task 6.1 at WP6, devised a specific co-creation methodology, adapted to the context of XR5.0 partners, to enable the XR5.0 project participants that are diverse and geographically dispersed, to review and prioritize high-level requirements. The methodology also allowed participants to indicate how the technical components can be used to support requirements, how quantifiable results can be pursued and what human aspects are relevant for each pilot with regards to the personalization scenarios

The methodology was developed based on several assumptions, such as:

Collaborative Process. Co-creation implicates a participatory process where multiple stakeholders are involved in the ideation, design, or decision-making. For this reason, we devised one co-creation workshop session for each of the six Pilots and invited all XR5.0 partners to engage.

Stakeholder Involvement. Participants in co-creation workshops are not just passive observers; they are active contributors where the stakeholders' involvement is paramount. For this reason, it was mandatory to have at least one key stakeholder from the pilot attending the workshop.

Diverse Perspectives. The idea behind co-creation is to harness the diverse experiences and viewpoints of different stakeholders. This helps in understanding the problem or opportunity from multiple angles, often leading to more innovative and effective solutions. For this reason, all XR 5.0 technological partners, were invited to attend the workshops and raise questions via the associated Work Package leader.

Iterative and Explorative: Co-creation workshops are typically iterative, meaning that ideas are explored, refined, and sometimes re-examined in multiple cycles. This flexibility enables participants to rethink and reshape ideas continuously. To support iterations, the workshops were based on previous requirements gathering sessions to define the list User Stories for each Pilot. This User Stories were done in the context of task 2.1. and were supposed to be revisited and explored during the workshops and associated with KPIs, technical components and human factors. Moreover, the Pilots and partners can revise the workshops through video recordings and summarizations.

Facilitation and Structure: These workshops are typically led by a facilitator who guides the process, ensures equal participation, and helps maintain focus. Structured activities, such as brainstorming sessions, design sprints, or scenario-based discussions, are often used to guide the creative process. To support facilitation the workshop design proposes two facilitators, one for conducting and organizing the "main stage" and another to take notes and ensure all topics and members were properly addressed.

Benefits of our Methodology:

Innovation and Creativity: By bringing together diverse perspectives, co-creation workshops can lead to more creative and innovative solutions.

User-Centered Solutions: Since Pilots and Partners are often involved, the outcomes of these workshops are more likely to meet their actual needs and preferences.

Reduced Risk of Failure: Early and continuous feedback from stakeholders can reduce the risk of developing products or services that do not resonate with Pilots' principles and needs.

Ownership and Engagement: Involving Pilots and Partners early in the process fosters a sense of ownership, making them more likely to support and champion the final outcome.

Faster Iteration Cycles: The feedback gathered during these sessions allows for rapid iteration, improving the design or strategy before it goes to development.

2.2. Workshop Principles & Design

The XR5.0 project leverages cutting-edge technologies such as AI and XR to enhance the performance of pilots' workforces. The co-creation workshops were designed to bring together partners to collaboratively refine and prioritize each pilot's user stories, aligning them with key performance indicators (KPIs), technical components, and human factors.

A User Story indicates an important need from the Pilot's perspective in the form: "As a USER/PERSONA, I want to THIS, so that ..." [3], where the USER parameter indicates a role in Pilots workforce, the WANT TO part indicates the role's needs and the SO THAT indicates the reason supporting the need. For example, in the following User Story "*As a Customer I want to see the products to be manufactured digitally embedded in the production line, so that I can reduce the need for test parts and waste*", the role *Customer* exposes a need *to see products digitally embedded in a production line* for *testing* purposes. The complete list of User Stories and the method used to gather them are described at Deliverable 2.1.

A KPI is a measurable value that demonstrates how effectively the implementation and execution of the associated User Story is achieving to the Pilot's needs. Considering the illustrative User Story a possible KPI would be "*Reduce Test effort by 30%*" indicating the effort to test a product to be manufactured should be reduced by 30%.

To fulfill the Pilots' User Stories and the associated KPIs, the XR5.0 project proposes combining technical components and human-factors. A Technical Component entails emerging technologies, that can be hardware, software or any combination including Workers' Digital Twins, Personalized XR content, Human-centered XAI models, XR-enabled Active Learning, Neurosymbolic AI models, Generative AI models, Visualization of XAI explanations, Visualization of AI recommendations, Training material, Cloud-based repository, Hololight Hub and Training programs. A Human-Factor provides means for personalizing the use of technical components and they include Fatigue, Task load index, Digital Skills, User Experience and Emotion/mood, and also some physiological metrics such as Heart rate variability (stress, cognitive load, engagement), Galvanic Skin Response (stress & engagement) Capture & maintenance of attention (assessed by eye-tracker), Pupil dilation (eye-tracker) and Gaze behavior (eye-tracker). The human factors are handled by Task 3.1 at WP3.

Based on the illustrative User Story mentioned above, the co-creation effort is to confirm if the User Story "see products digitally embed" is a priority; to indicate the use of "Digital Twins" technical components; and to personalize digital content based on the "workers stress level". Moreover, the workshop should describe if the KIP "*Reduce Test effort by 30%*" is feasible.

Is summary, the goals of the co-creation workshops are:

- to confirm the User Story still holds and if it is of high priority.
- to indicate if the KPIs associated with the prioritized User Stories are achievable.
- to show which Technical Components and Human Factors associated with the prioritized User Stories should be used to support implementation.

2.3. Methodology Dimensions

The methodology adopted to support the specification and execution of the co-creation workshops is structured around several key dimensions: Workshop Goals, Phases, Organization and Flow, as well as Participants' Roles and Materials. Each dimension outlines the rationale behind its creation, providing a comprehensive framework for planning and facilitating the workshops effectively.

Workshop Goals: This dimension defines the specific objectives the workshop aims to achieve. It provides clarity on the desired outcomes and ensures all participants are aligned with the purpose of the session. Clear goals help in guiding the activities, discussions, and overall direction of the workshop, ensuring its success.

Workshop Phases: The workshop is divided into distinct phases, each with a specific focus. These phases include conception, preparation, execution, and conclusion. Each phase is designed to build upon the previous one, ensuring a logical progression toward the final outcomes. This structure also ensures the outcomes are aligned with the workshop goals.

Organization and Flow: This dimension explains how the workshop is organized and how execution flows. It involves the scheduling, coordination, and pacing of activities to maintain momentum and focus throughout the workshop. The flow ensures a smooth transition between activities and helps avoid disruptions that could deviate from the workshop's goals.

Participants' Roles and Materials: Participants' Roles represent the key stakeholders involved in or affected by the outcomes of the workshop. Defining these Participants' Roles helps focus discussions and decisions on the pilots' needs. Materials refer to any resources, tools, or information provided to participants to support the workshop activities, such as templates, documents, or digital tools. Properly preparing Participants' Roles and materials ensures that participants are well-equipped to engage and contribute meaningfully.

2.3.1. Goals Dimension

The co-creation workshop goals are to bring together diverse, geographically dispersed network of XR5.0 partners to collaboratively refine and prioritize the Pilots' User Stories, laying a strong foundation for innovative development across the XR5.0 project. The workshops also foster and facilitate in-depth discussions to ensure these User Stories are strategically aligned with each Pilot's Key Performance Indicators (KPIs), technical requirements, and relevant human factors. This alignment will help tailor each Use Case to real-world conditions, maximizing project impact and usability.

2.3.2. Phases Dimension

To effectively organize our efforts in implementing WP 6, Task 6.1, we have structured the workshop lifecycle into four distinct phases: Conception, Preparation, Execution, and Conclusion. This phased approach ensures a clear, systematic progression from initial idea development to final wrap-up, enabling a more efficient and organized workflow.

Conception: The Co-Creation Workshop Conception Phase was intended to investigate and draw inspiration from similar initiatives namely the co-creation workshops developed at project STAR - Safe and Trusted Human Centric Artificial Intelligence in Future Manufacturing Lines - 956573 (H2020-ICT-2020-1 – Research and Innovation Action) and from scientific literature (e.g., [1] [4] [2]). The outcome from this phase combined co-creation best practices with XR5.0 specific needs and is illustrated by the *Principles and Design* (Section 2.2), and by the *Methodology Dimensions* (from Section 2.3).

Preparation: The Co-Creation Workshop Preparation Phase aimed to identify and gather the necessary stakeholders for the workshop, as well as to prepare the materials for both mediators and participants. In addition, we provided documentation to all partners on the workshop's flow and the use of associated materials. Key outcomes of this phase included finalizing the Workshop Agenda, creating a comprehensive Mailing List to ensure all partners were accommodated, developing the Slide Deck to guide the workshop's structure, and setting up the Remote Environment where the meetings took place.

Execution: The Co-Creation Workshop Execution Phase follows the established Organization and Flow, providing a structured environment for presenting and prioritizing the Pilots' User Stories. In this phase, participants work collaboratively to refine Key Performance Indicators (KPIs), technical components, and human factors to align closely with the specific needs of each Pilot. Each workshop is designed as a focused, three-hour session conducted via Microsoft Teams, allowing geographically dispersed participants to engage in real time. This format promotes a cohesive, interactive experience that ensures all aspects of the Pilots' requirements are carefully examined and aligned with project objectives.

Conclusion: The Co-Creation Workshop Conclusion Phase is focused on producing three documents: a *Comprehensive Document* explaining the workshop execution; a *Summary Document* that captures the key outcomes and insights from each co-creation workshop; and a *Comparative Analysis* where the results from all workshops and united and examined. The *Comprehensive Document* is initially developed by the IPIA team, utilizing workshop recordings and transcripts to ensure accuracy and completeness. Once the *Comprehensive Document* is drafted, it undergoes a review and refinement process by the relevant Pilot and Technical leads, ensuring alignment with project goals and addressing any specific technical nuances. This phase ensures that each workshop's contributions are documented, validated, and integrated into the project's ongoing development efforts. After that the *Summary Document* and *Comparative Analysis* are defined and presented to the Project Leaders

Figure 1 illustrates the co-creation workshops lifecycle according to the phases of our methodology. The Conception Phase is the starting point. IPIA was the main responsible for this phase, but the Project Leaders helped fine tuning the Workshop Design based on their expertise with other projects. The activities from Preparation, Execution and Conclusion were executed six times, one for each Pilot. Once again IPIA is the main driver for these phases but with support from the project's partners such as Pilot Leaders, Technical Leaders, Work-package Leaders and Task Leaders, to expose needs, refine ideas and reach the workshops goals. The IPIA Team gathered in between workshop Executions to review procedures and refine materials if need. The Conclusion phase has an extra activity to create a short version of the Comprehensive Document and include the Comparative Analysis, which was enacted by IPIA with assistance from the Project Leaders.

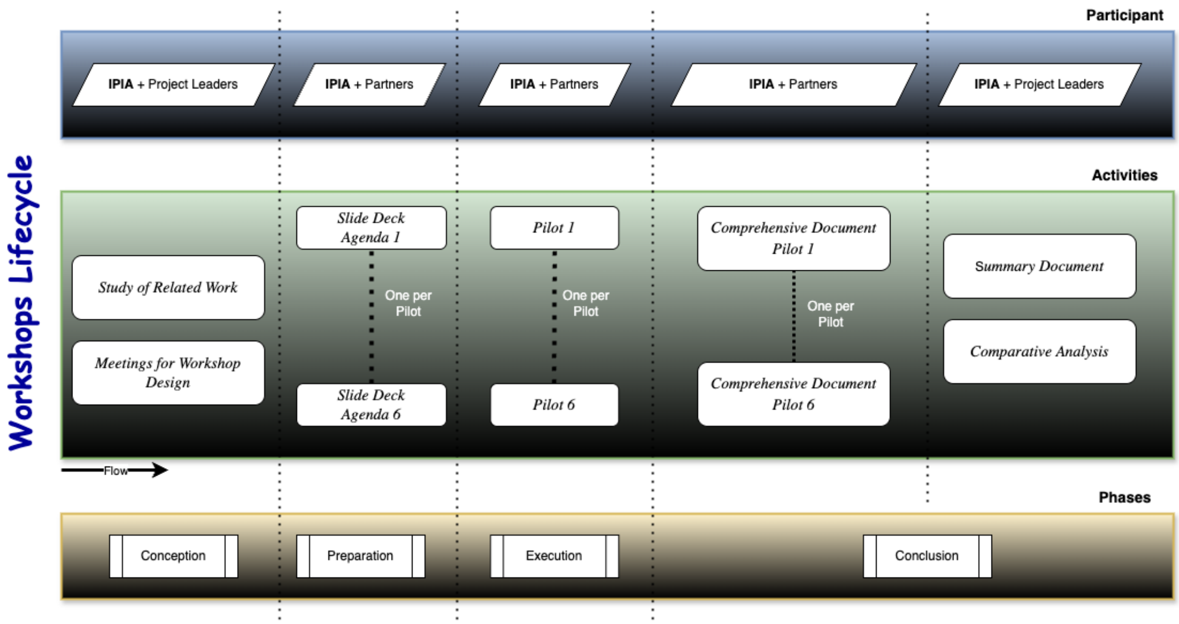

Figure 1 - Workshop Detailed Lifecycle

2.3.3. Workshop Participants' Roles & Materials

Participants' Roles and Materials are essential components of our co-creation methodology. Participants' Roles define the roles and perspectives each workshop participant assumes to collaboratively drive the workshop toward its goals. They guide participants' contributions, ensuring a balanced and comprehensive approach to addressing project needs. Materials include structured templates and resources that support these roles, providing participants with clear, role-specific tools to enhance their engagement and effectively carry out their tasks. Together, Participants' Roles and Materials create a purposeful, role-driven framework that strengthens the workshop's collaborative outcomes.

Participants' Roles

We have 8 types of roles playing a pivotal responsibility in achieving the workshop's collaborative goals, bringing diverse insights and expertise that enhance the overall effectiveness of the co-creation process.

1. **IPIA Mediator** – The Mediator is responsible for facilitating the workshop, guiding participants through the agenda, and encouraging active collaboration. They ensure each topic is thoroughly discussed, address any emerging issues, and foster a cohesive environment where all voices are heard.
2. **IPIA Supporting Team** – The Supporting Team assists the Mediator by maintaining a dynamic and engaging workshop environment. They help address gaps, respond to participant needs, and manage logistical elements, ensuring discussions flow smoothly and all critical points are covered.
3. **XR5.0 Project Leaders** – Project Leaders ensure that the workshop aligns with the broader XR5.0 project's guidelines, objectives, and compliance requirements. They oversee the workshop's adherence to the project's strategic vision and regulatory framework.
4. **Pilot Leader** – As a domain expert, the Pilot Leader clarifies specific needs related to their Pilot, helping refine and prioritize User Stories to reflect real-world applications and demands. They provide critical insights that ensure the Pilot's unique requirements are well-represented in the discussions.

5. **Technical Leader** – The Technical Leader focuses on implementing the Pilot's solution using the XR5.0 Architecture and Technical Components. They work closely with the Pilot Leader to refine requirements, explore viable technical solutions, and ensure that the technical execution meets the Pilot's objectives.
6. **Work Package Leader** – Responsible for overseeing and coordinating the tasks outlined in the Grant Agreement, the Work Package Leader ensures that the workshop outcomes are actionable and directly contribute to the fulfillment of grant-related objectives.
7. **Task Leader** – The Task Leader manages the specific tasks within each Work Package, translating workshop discussions into concrete actions. They are responsible for executing tasks that align with the goals of the work packages, ensuring accountability and progress toward project milestones.
8. **General Audience** – Any additional individuals invited to participate, providing fresh perspectives and feedback. For example, some Technical Solution Specialists for specific components such as AI, Cloud-based Repository and Training Programs may contribute and bring a broader viewpoint, enriching the discussions and validating the workshop's decisions from a wider audience perspective.

<u>Materials</u>

Materials include structured templates and resources that support Participants' Roles during the co-creation workshops. For the XR5.0 Project workshops we devised a slide deck template to that is used by the Mediators to organize the flow of the workshop and by the Pilot Leader and the Technical Leader to expose the requirements for the Pilot's use cases.

<u>Template for the Slide Deck:</u>

Description: Opening Slide with the Project's logo.

Figure 2 - Opening Slide

Description: Slide exposing the IPIA Team that will be present at the workshop, emphasizing the name of the two mediators.

Figure 3 - Slide with IPIA Team

Description: Slide with the Workshop Organization and Agenda.

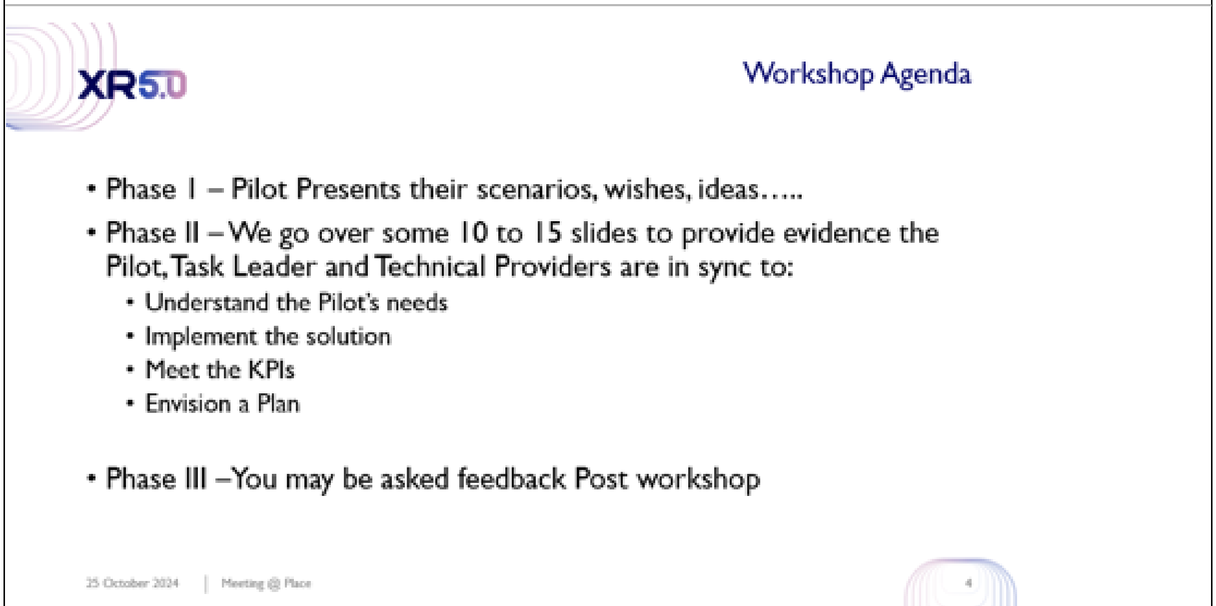

Figure 4 - Slide with the Workshop Agenda

Description: Slide indicating elements marked with this color are of extreme importance and should be handled accordingly.

Figure 5 - Slide with special information.

Description: Slide showing a slot for the Pilot's presentation. Here the Pilot and Technical leaders can explain their scenarios and needs using their own material such as slides, videos, documents, etc.

Figure 6 - Slide with Use Cases

Description: Slides with a List of Pilot Participants' Roles where the Mediator asks the Pilot Leader to confirm they still hold.

XR5.0

Pilot Personas

Persona #	Persona	Will it be considered?
1	Technician	
2	Customer	
3	Business Analyst	
...		

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Figure 7 - Slide with Participants' Roles

Description: Slides with a list of User Stories where the prioritized ones will be marked as green. The prioritization is defined by the Pilot Leader but the Mediator involves participating Tasks Leaders to validate the practicability of the prioritization.

User Stories x Scenarios

ID	As a ...	I want to ..	So That ..	Scenario
6.1	Technician	Receive step-by-step repair instructions directly in my field of vision through augmented reality glasses	I can perform maintenance tasks accurately and without errors	
6.2	Customer	receive step-by-step repair instructions directly in my field of vision through augmented reality glasses	I can perform maintenance tasks accurately and without errors	
6.3	Technician	communicate in real-time with remote experts via AR glasses	I can receive assistance and guidance during complex or unexpected situations	
6.4	Customer	communicate in real-time with remote experts via AR glasses	I can receive assistance and guidance during complex or unexpected situations	
6.5	Technician	access a database of maintenance procedures and manuals via AR glasses	I can quickly reference technical information while performing tasks	
6.6	Customer	access a database of maintenance procedures and manuals via AR glasses	I can quickly reference technical information while performing tasks	
6.7	Customer	the ability to provide feedback through the augmented reality interface	I can communicate any concerns or suggestions directly to the maintenance team	
6.8	Technician	the user experience to be intuitive and easy	I can quickly perform maintenance tasks accurately and without errors	
6.9	Customer	the user experience to be intuitive and easy	I can quickly perform maintenance tasks accurately and without errors	
6.10	Technician	Have personalized instructions	I can quickly and confidently perform maintenance tasks accurately and without errors	
6.11	Customer	Have personalized instructions	I can perform maintenance tasks accurately and without errors	
6.12	Technician	receive alerts in case of danger	I am aware of the risks and can proceed confidently	
6.13	Business Analyst	be able to track the data generated by the system	I can make analyses, drive continuous improvement, and ensure efficient resource allocation	
6.14	Technician	ensure that if I require assistance, the appropriate expert is promptly contacted	I receive the best advice in minimal time	
6.15	Customer	ensure that if I require assistance, the appropriate expert is promptly contacted	I receive the best advice in minimal time	
6.16	Customer	know the estimated duration of the entire procedure, with the option to pause and proceed later if needed	I am flexible in managing my time effectively during the maintenance task	
6.17	Technician	Have a seamless transition of the instructions if my stress level is increasing or reducing	I'm not even more stressed or distracted	
6.18	Customer	Have a seamless transition of the instructions if my stress level is increasing or reducing	I'm not even more stressed or distracted	
6.19	Technician	to register automatically the use cases and associated resolution tasks	further problems or questions can be answered rapidly	
6.20	Customer	receive alerts in case of danger	I am aware of the risks and can proceed confidently	
...				

Figure 8 - Slide with User Stories

Description: Slide with a List of Key Performance Indexes (KPIs) with space to indicate how it can be achieved (measured). Each row in the Measurable KPI column is related to a User Story and the Pilot Leader, Technical Leader and participating Task Leader should agree on the feasibility of the KPI.

XR5.0

Pilot KPIs

ID	Acceptance / Success Criteria	Measurable KPI Number
6.1	Instructions are presented clearly and intuitively, with visual and textual cues	
6.2	Instructions are presented clearly and intuitively, with visual and textual cues	Reduce TTC 35%
6.3	Communication is seamless and allows real-time exchange of voice, text, and images with remote experts	
6.4	Communication is seamless and allows real-time exchange of voice, text, and images with remote experts	
6.5	The database is easily accessible and searchable within the AR interface, providing relevant information promptly.	
6.6	The database is easily accessible and searchable within the AR interface, providing relevant information promptly.	
6.7	A feedback option is available for each repair step in the AR system, allowing clients to provide comments or ratings on the process's accuracy and clarity.	
6.8	Instructions should be presented clearly and intuitively, with visual and textual cues, ensuring a well-designed and fluid experience	
6.9	Instructions should be presented clearly and intuitively, with visual and textual cues, ensuring a well-designed and fluid experience	
6.10	Instructions should be tailored to my technical level (beginner, expert, etc.), presented clearly and intuitively, with visual and textual cues, ensuring a seamless experience. Additionally, stress level detection and other relevant features will help optimize the process further.	
6.11	Instructions should be tailored to my technical level (beginner, expert, etc.), presented clearly and intuitively, with visual and textual cues, ensuring a seamless experience. Additionally, stress level detection and other relevant features will help optimize the process further.	
6.12	implementing a system of alerts and ensuring a safe working environment	
6.13	The data must be recorded, readily accessible, and securely stored	
6.14	Direct link established between the issue and the team to be contacted	
6.15	Direct link established between the issue and the team to be contacted	
6.16	The system provide time to completion before starting, real-time progress updates and allow users to pause the process, save their progress, and proceed at a later time without losing any data or progress	
6.17	The adaptation of the instructions are not visible	
6.18	The adaptation of the instructions are not visible	
6.19	that the data is stored and easily accessible	
6.20	implementing a system of alerts and ensuring a safe working environment	
...		

Figure 9 - Slide with KPI

Description: Slide with a list of Technical Components that are available to create the Pilot specific solution. Here the Mediator encourages each Task Leader or Solution Specialist to support the Pilot Leader in deciding if that component can be used to implement a given UserStory.

XR5.0 Components

Task	XR5.0 Technical Component	Will it be used?	In which User Story (ID)?
T3.3	Workers' digital twins		
T3.4	Personalized XR content		
T4.1	Human-centered XAI models		
T4.2	XR-enabled Active Learning		
T4.2	Neurosymbolic AI models		
T4.3	Generative AI models		
T4.4	Visualization of XAI explanations		
T4.5	Visualization of AI recommendations		
T5.1	Training material		
T5.2	Cloud-based repository		
T5.3	Hololight Hub		
T5.4	Training programs		

Figure 10 - Slide with Components

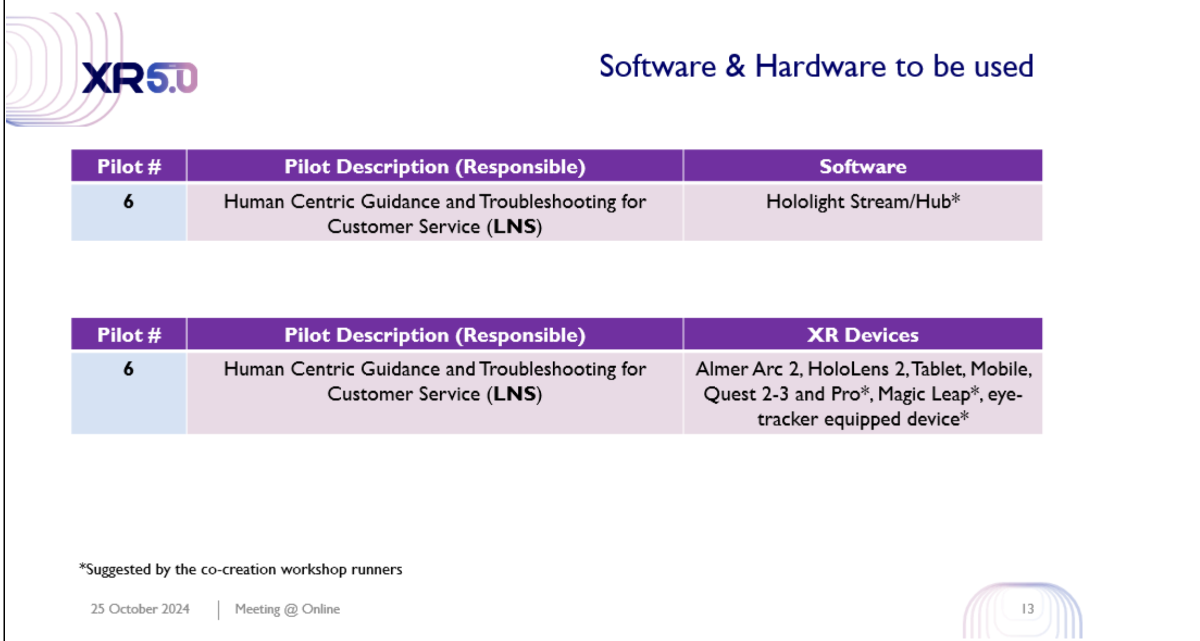
Description: Slide with a list of Human Factors that are available to create the Pilot specific solution. Here the Mediator encourages the IPIA Team to explain how the Human Factors are used and collected and then ask the Pilot Leader and Technical Leader if that factor can be used to implement a given UserStory. IPIA is the leader of Task 3.1 which is related with the definition and how to assess human factors.

XR5.0 Human Factors

XR5.0 Human Factors	Will it be used? (x)	In which User Story (ID)?
Questionnaires		
Fatigue		
Task load index		
Digital Skills		
User Experience		
Emotion/mood		
...		
Physiological metrics		
Heart rate variability (stress, cognitive load, engagement)		
Galvanic Skin Response (stress & engagement)		
Capture & maintenance of attention (assessed by eye-tracker)		
Pupil dilation (eye-tracker)		

Figure 11 - Slide with Human Factors

Description: This slide brings a list of possible devices and software systems the Pilot expects to use to create the solution for the prioritized User Stories.



Pilot #	Pilot Description (Responsible)	Software
6	Human Centric Guidance and Troubleshooting for Customer Service (**LNS**)	Hololight Stream/Hub*

Pilot #	Pilot Description (Responsible)	XR Devices
6	Human Centric Guidance and Troubleshooting for Customer Service (**LNS**)	Almer Arc 2, HoloLens 2, Tablet, Mobile, Quest 2-3 and Pro*, Magic Leap*, eye-tracker equipped device*

Figure 12 - Slide with Software and Hardware

Description: The concluding slide brigs some questions proposed the XR5.0 Project Leaders regarding the current Technical Readiness Level (TRL) and if the Pilot plans to host a General Assembly (GA) in their premises in the future.

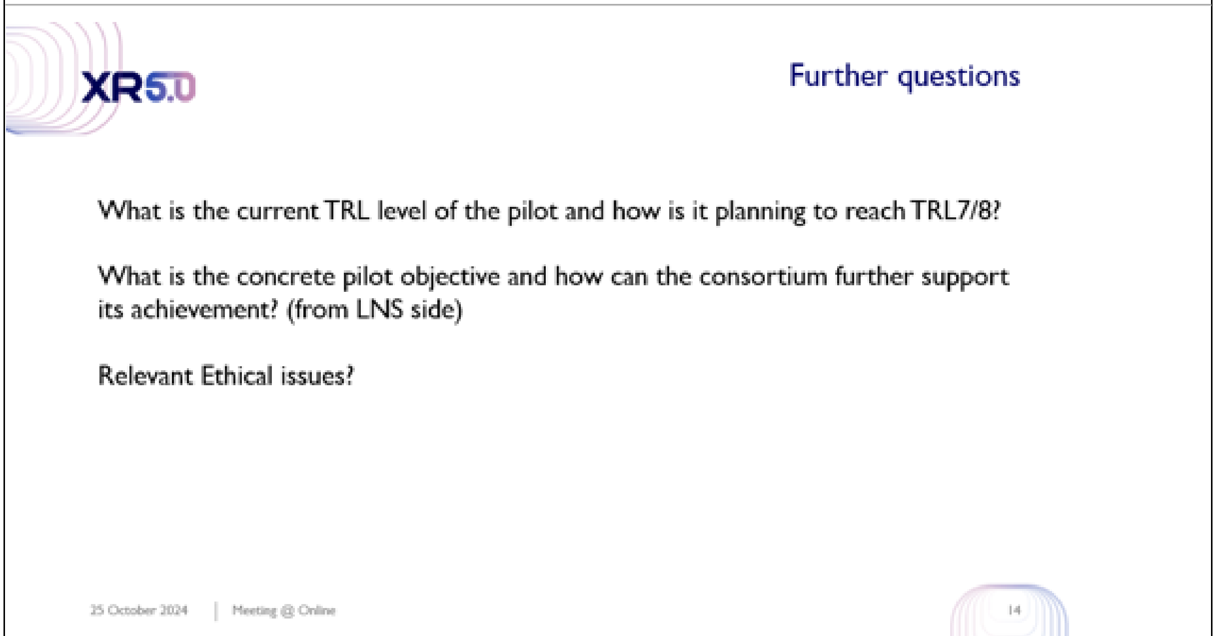
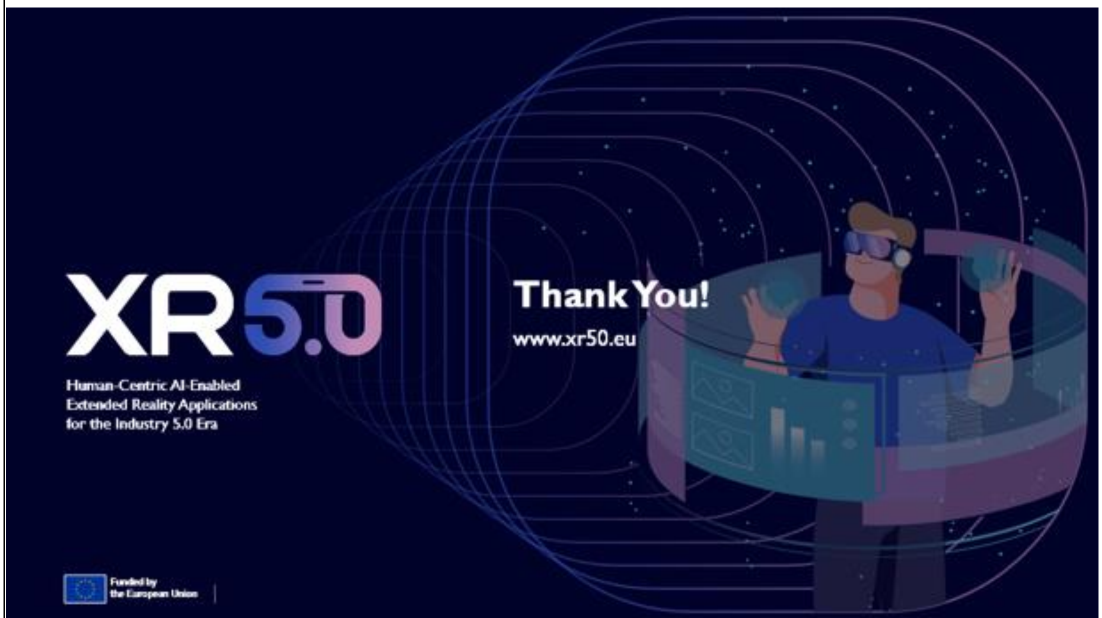


Figure 13 - Slide with Questions from Management.

Description: Closing Slide with the Project's logo.
 *Figure 14 - Concluding Slide.*

We have also created a template to report the Summary Document with the key finding from each co-creation workshops. The Summary Documents contains concise information extracted from the Comprehensive Document such as prioritized user stories, chosen XR5.0 solutions, which follows the format outlined below:

Table 1 - Structure for the Summary Document

Section Name	**Description**
Pitot Name	A header with the Pilots Name and relevant partners.
Introduction	A section to introduce the Pilot agenda.
Challenges and Key Aspects	A section with a list of challenges and key aspects that are related to XR5.0 goals, from the Pilot's perspective.
Prioritized User Stories	A section with a list of Prioritized User Stories.
Adopted Solutions	A table providing a comprehensive breakdown of the XR5.0 components, KPIs, hardware, software, and human factors adopted by the Pilot.
Conclusion	A concluding remark for the specific workshop/pilot.

2.3.4. Workshop Flow and Organization

The Workshop Flow provides a detailed outline of the tasks performed by participants throughout each stage of the workshop phases. Participants assume the roles defined in the Participants' Roles section (see Section 2.3.3), with each activity assigned to the appropriate phase. This structured approach ensures that each participant's responsibilities are clear and aligned with the workshop's progression, fostering effective collaboration and facilitating the achievement of workshop goals.

The organization of each co-creation workshop includes 2 *Mediators* from IPIA, one to conduct the workshop agenda and distribute the workload and another to take relevant notes, raise important unasked questions and rise missing points. The Workshop also included at least one *Representative from the Pilot* and one *Technical Leader*. Since the Pilot Representative and the Technical Leader work in close collaboration, they were responsible for explaining User Stories and planned technical solutions. The *Work Package Leaders*, *Task Leaders* and *Technology Solution Specialists* for the Technical Components were also present in the workshops to support matching requirements to prospective solutions. In total, each workshop gathered between 20 and 30 members in a 3-hour session via video conferencing.

The flow of each workshop was the following:

Conception Phase

Task	Participant	Task Description
Reviewing the Literature	IPIA Team	This task is focused on reviewing the state-of-the-art on designing and executing co-creating workshops that can be adapted to our needs.
Designing the Workshops	IPIA Team	This task organizes the philosophy and key concepts of our methodology in a coherent life-cycle.

Preparation Phase

Task	Participant	Task Description
Preparing Slide Deck	IPIA Team	This task prepares the template for the slide-deck used during the co-creation workshops.
Refining the Slide Deck	IPIA Team Pilot Leader XR5.0 Leaders	This task refines the slide-deck template to include Pilot specific information such as User Stories, Participants' Roles and Use Case Presentations.
Designing the Workshop Agenda	IPIA Team, XR5.0 Leaders	This task organizes the workshop agenda for the six pilots, fixing the dates and inviting the relevant participants.

Execution Phase

Task	Participant	Task Description
Mediate the Workshop	All	This task refers to executing the co-creating workshop, fostering effective collaboration and facilitating the achievement of workshop goals. Given this task central to our methodology, we have divided into 9 sub-tasks.
Sub-Task	Participant	Sub-Task Description
Introduction of the organizing team	IPIA Mediator	In this task the IPIA Mediator welcomes the audience and presents the workshops' organizing team.
Explaining the Workshop Goals	IPIA Mediator	In this task the IPIA Mediator explains the stablished goals for the co-creation workshop, emphasizing the need to support the Pilot Leader in prioritizing the User Stories.
Presenting the Agenda	IPIA Mediator	In this task the IPIA Mediator details the workshop's agenda and exposes the flow of the presentations/discussions.
Describing the Pilot's Scenarios, Personas and User Stories	Pilot Leader, Technical Leader	In this task, the Pilot Leader and Technical Leader present the Pilot's needs, detailing relevant Use Cases, Personas, and User Stories. They provide context and insights to ensure all participants have a clear understanding of the Pilot's specific requirements and objectives.
Prioritizing User Stories	IPIA Mediator Pilot Leader	In this task the IPIA Mediator presents a list of the Pilot's User Stories and invites the Pilot Leader to prioritize them according to the Pilot's specific goals and needs. This ranking helps ensure that the most critical User Stories align with the Pilot's strategic objectives.
Refining KIPs for the Prioritized User Stories	IPIA Mediator	In this task the IPIA Mediator presents the available KPIs and invites the Pilot Leader, Technical Leader and Task Leaders to discuss and confirm the KPIs feasibility for the prioritized User Stories.
Indicating Human Factors to support the Prioritized User Stories	IPIA Mediator	In this task the IPIA Mediator presents the available Human Factors and invites the Pilot Leader, Technical Leader, Task Leaders and IPIA Team Members, who are responsible for the Human Factors (Task 3.1, WP3), to discuss and choose the relevant Human Factors for the prioritized User Stories.
Indicating Technical Components to support the Prioritized User Stories	IPIA Mediator	In this task the IPIA Mediator presents the available Technical Components and invites the Pilot Leader, Technical Leader and Task Leaders to discuss and choose the Technical Components that will be used by the prioritized User Stories.
Conclusion	IPIA Mediator	In this Task the IPIA Mediator asks the Pilot's Representative "What is the current TRL level of the pilot and how is it planning to reach TRL7/8?", "What is the concrete pilot objective and how can the consortium further support its achievement?" and "Are you willing to host a GA at your premises to let us understand how your pilot really works?" These three last questions were related to gathering relevant information for the XR5.0 Project Managers. The IPIA Mediator Thanks the audience and closes the session.

Conclusion Phase

Task	Participant	Task Description
Preparing Comprehensive Document	IPIA Team, Pilot Leader	In this task the IPIA Team prepares a detailed document explaining the results of the co-creation based on the workshops transcripts and recordings. This document is then revised by the Pilot Leader and when finished, exposed in the XR5.0 Repository.
Developing Summary Document	IPIA Team	In this task, the IPIA Team prepares a short version of the Workshop Comprehensive Document to facilitate exposing the workshops results.
Developing a Comparative Analysis	IPIA Team, XR5.0 Leaders	In this task the IPA Team prepares a document comparing the results from the six co-creation workshops. This comparison is further analyzed by the XR5.0 Project Leaders.

3. Using the Co-Creation Workshop Methodology

The proposed Methodology was adopted to support co-creation workshops in revising the requirements for 6 Pilots within the scope of the XR5.0 Project. We have executed all phases of the proposed methodology according to its lifecycle, from *Conception* to *Conclusion*. The whole effort last 7 months and as illustrated by the timeline presented at Figure 15. The *Study* and *Design* tasks from the *Conception* Phase needed 2 months to complete, the *Prepare Deck* and *Agenda* tasks from the *Preparation* Phase Px took 1 month, the *Execution* task from the *Execution* Phase took 2 weeks and the *Prepare Comprehensive* and *Short* documents and the *Comparative Analysis* last 3.5 months in total.

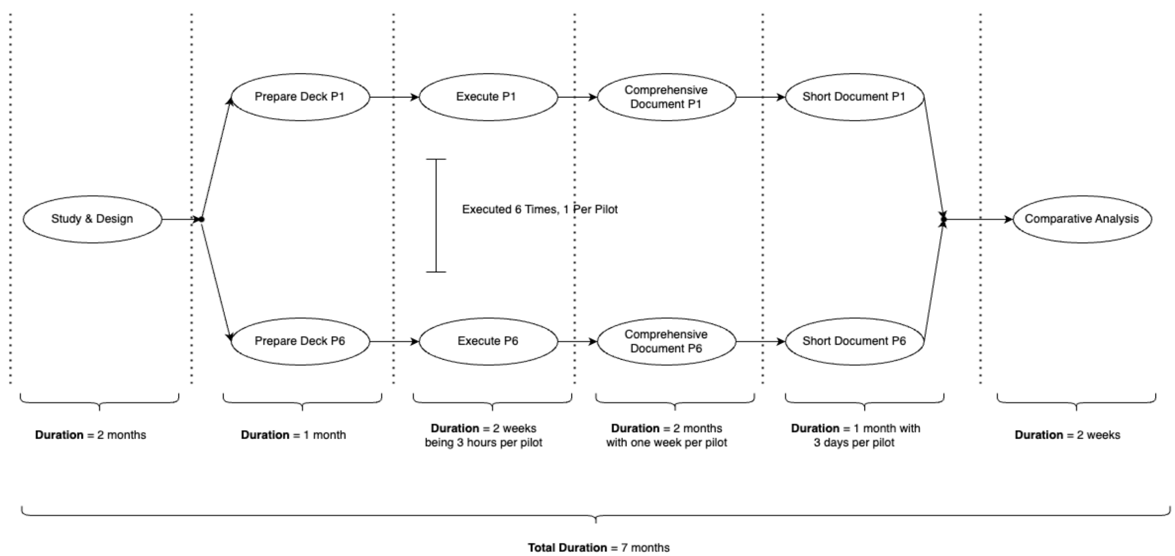


Figure 15 - Workshops timeline and durations

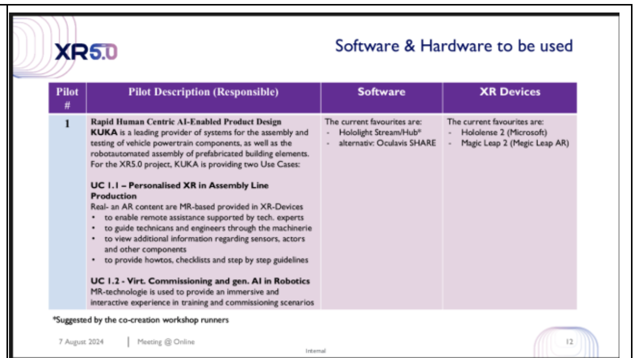
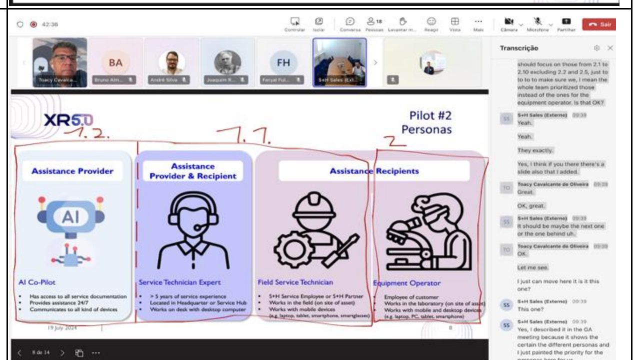
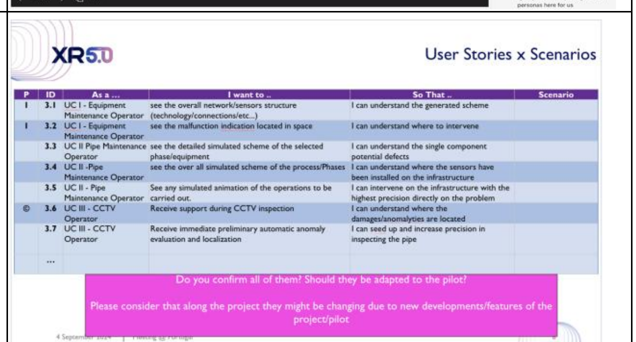
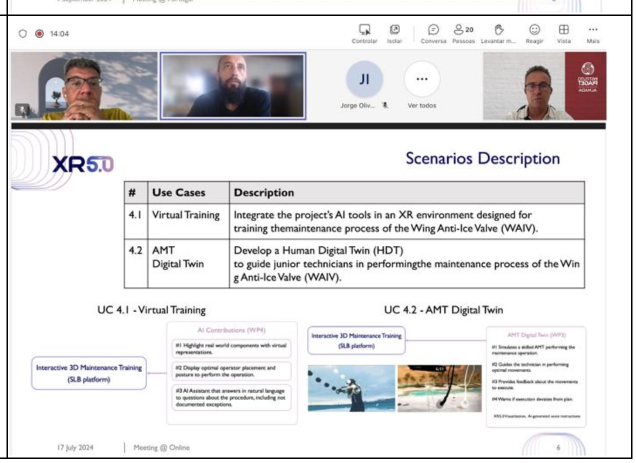
Participation across the entire workshop lifecycle reflects the number of individuals from XR5.0 partners who actively engaged in one or more tasks. Table 2 provides an overview of the partners and roles involved in each phase, indicating the number of participants. For the Execution Phase, participants are organized by individual workshop session to illustrate specific engagement levels.

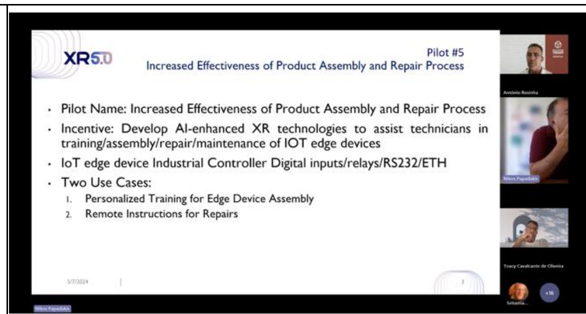
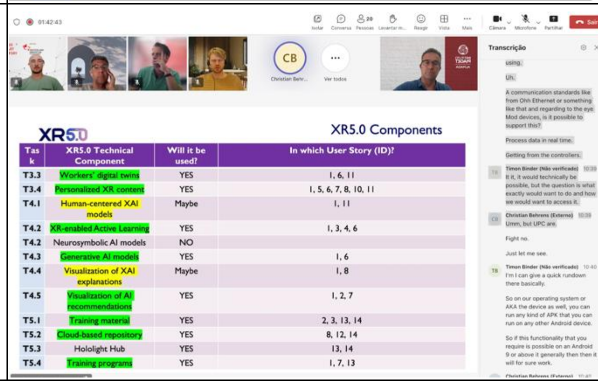
Table 2 - Workshop Participation

Conception Phase	Partner/Role: IPIA	 4 Participants
Preparation Phase	Partner/Role: IPIA XR5.0 Leaders	 4 Participants 1 Participant
Execution Phase	Partner/Role: -IPIA -Pilot1-Kuka -ATB -Task Leaders - Participants -Pilot2-SH -OCU -Task Leaders -Participants -Pilot3-EKSO -HOLO -Task Leaders - Participants -Pilot4-TAP -IML -Task Leaders - Participants -Pilot5-SPACE -SYN -Task Leaders - Participants -Pilot6-LNS -ALMER -Task Leaders - Participants	 2 Mediating, 2 Participating 2 Pilot Leader Participating 2 Tech Leader Participating 6 Participating 21 Participating 1 Pilot Leader Participating 1 Tech Leader Participating 6 Participating 18 Participating 1 Pilot Leader Participating 2 Tech Leader Participating 5 Participating 19 Participating 1 Pilot Leader Participating 3 Tech Leader Participating 5 Participating 20 Participating 2 Pilot Leader Participating 1 Tech Leader Participating 6 Participating 21 Participating 1 Pilot Leader Participating 1 Tech Leader Participating 3 Participating 21Participating
Conclusion Phase	Partner/Role: -IPIA	 1 Leading Role, 1 Participating

Each co-creation session was designed as a focused, three-hour meeting held via Microsoft Teams. Sessions were recorded to support data analysis and ensure that insights and discussions could be thoroughly reviewed and referenced. This format enabled effective collaboration among participants, providing a structured yet flexible environment for productive engagement. Table 3 brings a screenshot for each session, indicating the date it occurred and the total duration.

Table 3 - Evidence from the co-creation workshop sessions.

<table>
<tr><td>Pilot1 – Kuka
Date: June 13rd, 2024
Duration: 3:16:32</td><td>
</td></tr>
<tr><td>Pilot2 – SH
Date: July 19th, 2024
Duration: 2:08:53</td><td>
</td></tr>
<tr><td>Pilot3 – EKSO
Date: July 12th, 2024
Duration: 2:06:09</td><td>
</td></tr>
<tr><td>Pilot4 – TAP
Date: July 17th, 2024
Duration: 1:50:09</td><td>
</td></tr>
</table>

<table>
<tr>
<td>Pilot5 – SPACE
Date: July 5th, 2024
Duration: 2:47:05</td>
<td>
</td>
</tr>
<tr>
<td>Pilot6 – LNS
Date: July 16th, 2024
Duration: 2:04:53</td>
<td>
</td>
</tr>
</table>

4. Workshop Results – Summary Documents

The co-creation workshops were designed to support collaborative sessions for refining pilots' needs and technical solutions. In a nutshell the workshop goals are:

- to confirm the User Story still holds and if it is of high priority.
- to indicate if the KPIs associated with the prioritized User Stories are achievable.
- to show which Technical Components and Human Factors associated with the prioritized User Stories should be used to support implementation.

To achieve the desired outcomes, the IPIA Team developed extensive documentation by thoroughly analyzing the transcripts and footage of each workshop. The comprehensive documentation is included in the annexes attached to this deliverable. To enhance clarity and facilitate the dissemination of results, the IPIA Team also prepared a summarized version of the workshop findings in a document titled Summary Document, which follows the format outlined at Table 1 - Structure for the Summary Document.

4.1. Results for PILOT 1 KUKA (SUPSI – ATB)

Introduction

KUKA focuses on applying cutting-edge XR technologies and AI-driven solutions to enhance industrial processes, particularly in **assembly lines and robotic commissioning.** Together with SUPSI and ATB, KUKA leads this project, leveraging technologies such as **Generative AI, Digital Twins, and Virtual Commissioning** to optimize operations, improve training efficiency, and reduce human errors in real-world industrial settings. The document outlines key user cases, technical components, and human factors, while also addressing the project's current readiness and future objectives.

Challenges and Key Aspects

1. **Main Objective**: Using XR and AI technologies to optimize assembly line production and robotic commissioning, improving training and remote support.
2. **Key Challenges**: Managing real-time data, improving remote troubleshooting, and integrating generative AI with digital twins to reduce physical testing.
3. **Technologies and Key Components**: Focus on XR content, AI-powered digital twins, and real-time interaction tools for assembly and maintenance tasks.
4. **Expected Impact**: Enhancing productivity, reducing errors, and minimizing downtime in industrial operations through AI-assisted diagnostics and immersive training.
5. **Human Factors**: Addressing task load, attention capture, fatigue, and digital skills for XR-based industrial environments.
6. **KPIs and Success Metrics**: Focusing on real-time data sharing, functional digital twins, and efficient remote communication systems.

Prioritized User Stories:

User Story	**1.2**
Description	Scalable overlay between the real machine and Digital Twin to assist in maintenance, troubleshooting and commissioning.
Persona (As a…)	Robot Programmer/Technician
Need (I want…)	have a scalable overlay between the real machine and the Digital Twin, shown in my XR device

Reason (So that…)	the virtual counterpart based on a 3D model and kinematic model are displayed, only the needed perspective is filled with virtual content, and my movement is reflected in the Digital Twin, allowing it to anticipate the reference center points of the real robot

User Story	**1.4**
Description	Access to sensor data & databases to provide remote support (static & real-time data).
Persona (As a…)	On-site Technician and Remote Expert to assist the On-site Technician
Need (I want…)	have access to sensor data and databases
Reason (So that…)	I can visualize static data like data sheets and diagrams, as well as real-time sensor data such as pressure, temperature, and other dynamic variables.

User Story	**1.5**
Description	Use interactive features (How-To's, Step-by-Step guides, checklists) for commissioning
Persona (As a…)	Commissioning Technician
Need (I want…)	use interactive features
Reason (So that…)	I can see virtual How-To's, Step-by-Step instructions, and To-Do lists, helping me replace and repair components while documenting my work

Adopted Solutions:

Solutions	Description
XR5.0 Components	- **Hololight Hub** (Centralized XR platform for real-time collaboration) - **Hololight Space** (XR training application enabling hands-on interaction with smart pipe data) - **Hololight Stream** (Streaming XR content to AR glasses, reducing the need for high-performance local devices) - **Generative AI and Active Learning** (creating virtual 3D models and simulations for robotics and assembly tasks) - **Human Digital Twin** (for anticipating technicians' positions during their interaction with machines to ensure safety) - **Training programmes** (for XR-based maintenance and commissioning)
KPIs	- **Reduction of human errors** through AI-powered decision-making and real-time feedback: >25% reduction on consumption of test parts/waste - **Improvement in task efficiency:** >50% faster troubleshooting, >30% reduction on physical testing
Hardware	- **KUKA Renovation Robot** - **HoloLens 2** (hands-free, mixed reality headset for real-time guidance and interaction onsite)

Solutions	Description
	- **Meta Quest 3** (virtual reality headset for immersive experiences for off-site commissioning training).
Software	- **Hololight Stream/Hub** (streaming and managing high-quality XR content)
Human Factors	- **Fatigue and Task Load Monitoring**: Using metrics like heart rate variability and galvanic skin response to track stress and cognitive load during complex tasks - **Attention Capture**: Eye-tracking tools to monitor focus and engagement during XR-based tasks. - **Digital Skills**: Ensuring the XR system is adaptable for users with varying levels of technological proficiency.

Conclusion:

The **KUKA Pilot Project** integrates **XR and AI technologies** to enhance industrial efficiency in assembly lines and robotic commissioning. The project focuses on creating a human-centric environment that supports workers with real-time data access, remote assistance, and generative AI-based simulations, significantly improving productivity and reducing human errors.

The use of **digital twins** and **virtual commissioning** allows technicians to troubleshoot and test systems virtually before physical implementation, minimizing downtime and speeding up operational processes. **Hardware solutions** like **HoloLens 2** enables augmented, hands-free interaction with complex systems, providing workers with real-time feedback and support, and **Meta Quest 3** enables immersive training environments for off-site technicians.

Human factors such as task load, attention, and fatigue are closely monitored using physiological metrics like heart rate variability and eye-tracking, ensuring that the system adapts to the user's needs and prevents cognitive overload. This approach not only improves efficiency but also ensures that workers remain engaged and productive over extended periods of time.

In terms of **KPIs**, the success of the project will be measured by the integration of **real-time sensor data** into XR environments, the ability to **overlay digital twins** with physical systems for enhanced diagnostics, and the overall reduction in **training time and operational errors**. By addressing these areas, the KUKA pilot sets a strong foundation for **sustainable and efficient industrial processes**, with a clear path toward achieving higher levels of technological readiness.

4.2. Results for PILOT 2 SH (OCU – UPRC)

Introduction:

Pilot 2 SH aims to enhance the remote maintenance of complex laboratory instruments by utilizing XR technologies combined with AI-driven functionalities. The goal is to enable expert technicians to provide virtual support to less experienced field technicians, reducing the need for on-site maintenance and increasing efficiency. The project also addresses challenges such as the shortage of skilled labor and the impending retirement of experienced workers.

Challenges and Key Aspects:

1. **Main Objective**: To optimize remote maintenance operations using XR and AI to reduce reliance on on-site interventions.
2. **Key Challenges**: Managing skilled labor shortages, developing AI knowledge bases, and providing real-time expert assistance.
3. **Technologies and Key Components**: Integration of AI, XR tools, real-time diagnostics, and remote support systems.
4. **Expected Impact**: Improved efficiency, reduced costs, and increased technician knowledge transfer across sites.
5. **Human Factors**: Addressing task load, remote assistance fatigue, user experience, and digital skills.
6. **KPIs and Success Metrics**: Focusing on reducing on-site maintenance, enhancing user satisfaction, and improving overall process efficiency.

Prioritized User Stories:

User Story	**2.4**
Description	Remotely view equipment status via AR visualizations, to diagnose issues accurately without being physically present
Persona (As a…)	Service Technician Expert
Need (I want…)	remotely view equipment status via AR visualizations
Reason (So that…)	I can diagnose issues accurately without being physically present.

User Story	**2.8**
Description	Communicate in real-time with Service Technician Experts, to get immediate assistance and clarification during critical tasks
Persona (As a…)	Field Service Technician
Need (I want…)	communicate in real-time with Service Technician Experts
Reason (So that…)	I can get immediate assistance and clarification during critical tasks.

Adopted Solutions:

Solutions	Description
XR5.0 Components	- **AI-Enhanced XR Environments**: AI provides real-time suggestions and solutions, simulating expert knowledge. - **Virtual Assistance Software**: XR-enabled systems allow experts to inspect, guide, and troubleshoot remotely. - **Neurosymbolic AI & Generative AI**: Used to enhance decision-making, provide predictive maintenance, and improve troubleshooting.
KPIs	- On-premise AI is setup and operational. - Remote maintenance environment is setup and operational. - Software and hardware is tested and validated in field studies and is ready to be used operational. **- Reduce on-site maintenance by 50%** through AI-powered virtual inspections and remote guidance. - **Decrease time to complete tasks** by providing real-time assistance. - **Enhance technician satisfaction** by offering tailored step-by-step instructions via XR.
Hardware	**Microsoft HoloLens 2**: Used to provide hands-free AR overlays, step-by-step maintenance guides, and real-time expert support. **Smartphones/Tablets** (e.g., iPad Pro): Used by field technicians to access remote support dashboards, communicate with experts, and view AI and XR content if smart glasses are not available. **Laboratory Instruments:** Analytical instruments requiring periodic calibration and troubleshooting, now supported remotely via AR guidance
Software	- **OCU SHARE Software**: An XR-based solution enabling real-time collaboration between experts and field technicians. - **OCU MR SHARE**: XR APP developed specifically for the HoloLens2 and Magic Leap 2. Will be advanced to display step-by-step instructions and AI instructions to support SH´s service workers.. - **Local AI Hosting**: AI systems are hosted locally to ensure data security and prevent cloud dependence (ChromaDB for hosting a local vector storage and a local deployed LLM).
Human Factors	- **Task Load and Fatigue Monitoring**: The project considers the potential workload of field technicians using XR devices for extended periods. - **Digital Skills**: Ensures that both experienced and novice technicians can navigate the XR environment with ease. - **User Experience**: Continuous feedback from users to improve XR interfaces and reduce cognitive overload.

Conclusion:

The **Pilot 2 SH** project introduces **AI-powered XR tools** to transform the way industrial instruments are maintained, aiming to **reduce on-site service work by more than 50%**. By enabling remote expert guidance, **neurosymbolic AI** models assist technicians in solving complex issues in real time, minimizing downtime and enhancing overall efficiency.

The system is designed with **human factors** in mind, ensuring that both the **task load** and **digital skills** of the technicians are considered to prevent fatigue and cognitive overload. Through **AI-enhanced virtual assistance**, field technicians can receive real-time troubleshooting support, complete with **augmented reality (AR) content** that guides them through complex repairs.

The **KPIs** established for this project include **reducing maintenance costs and time**, increasing the **knowledge base for technicians**, and improving **user satisfaction** with the XR tools. By integrating **smart glasses**, **mobile devices**, and **local AI systems**, the project ensures both security and flexibility in managing industrial assets remotely.

Ultimately, **Pilot 2 SH** demonstrates how XR and AI can collaborate to solve industry-wide challenges, particularly in optimizing the utilization of expert knowledge, reducing service costs, and improving operational efficiency in remote and complex environments.

4.3. Results for PILOT 3 EKSO (HOLO – INNOV)

Introduction:

This Pilot outlines an innovative approach to training maintenance technicians for smart water pipes using XR and AI technologies. The training aims to equip workers with the skills necessary to maintain and inspect advanced pipe systems in a safe, efficient, and cost-effective way. The project, involving key partners like EKSO, HOLO, and INNOV, integrates several advanced technologies to address the main challenges in pipe maintenance, such as human errors, delayed fault identification, operator fatigue, and varying digital skills.

Challenges and Key Points:

1. **Main Objective**: Training water network technicians in predictive maintenance and anomaly detection using XR and AI technologies.
2. **Key Challenges**: Addressing digital literacy, minimizing operator fatigue, and integrating AI into traditional inspection methods.
3. **Technologies and Key Components**: Highlighting XR platforms, AI-driven anomaly detection, AR glasses for immersive training, and software tools like Hololight Stream and Generative AI.
4. **Expected Impact**: Reducing human errors, speeding up failure detection, and improving technician satisfaction.
5. **Human Factors**: Managing workload, attention capture, and stress during long training sessions.
6. **KPIs and Success Metrics**: Evaluating the project's effectiveness through predefined KPIs, including reduction in training time and costs, and technician satisfaction.

Prioritized User Stories

User Story	3.1
Description	See the overall network/sensors structure for understanding the system architecture, leading to better operational efficiency
Persona (As a…)	Equipment maintenance operator
Need (I want…)	see the overall network/sensors structure
Reason (So that…)	I can understand the generate scheme

User Story	3.2
Description	See malfunction indication in space for quick and precise interventions. This story directly improves maintenance speed and accuracy by enabling operators to identify problems faster.
Persona (As a…)	Equipment maintenance operator
Need (I want…)	see the malfunction indication located in space
Reason (So that…)	I can understand where to intervene

User Story	3.5
Description	Receive support during CCTV inspection so that I can understand where the damages/anomalies are located
Persona (As a…)	Equipment maintenance operator
Need (I want…)	to see any animation of the operations to be carried out
Reason (So that…)	I can intervene on the infrastructure with the highest precision directly on the problem.

Adopted Solutions

The following table provides a comprehensive breakdown of the XR5.0 components, KPIs, hardware, software, and human factors described in the document. It highlights how these elements come together to achieve the project's objectives and address key challenges:

Solutions	Description
XR5.0 Components	- **Hololight Hub** (Centralized XR platform for real-time collaboration) - **XR training application** enabling hands-on interaction with smart pipe dat - **Hololight Stream** (Streaming XR content to AR glasses, reducing the need for high-performance local devices) - **AI-powered anomaly detection** (automates fault detection and speeds up maintenance tasks).
KPIs	- XR object latency: < 1 second - Average reduction in training time and costs: > 30% - Industrial processes supported by training: >= 3 - Technician satisfaction on a 5-point scale - Reduced human errors (using AI and real-time data) - Reduced failure identification time through real-time anomaly detection.
Hardware	- **HoloLens 2** (augmented reality glasses, overlaid real-time data for training and inspections) - **Magic Leap** (AR glasses for immersive maintenance training) . - **Mobile devices** (tablets, smartphones for portable access to XR content) - **Eye-tracking devices** (to monitor user engagement and attention during XR training).
Software	- **Hololight Stream/HUB** (central for enabling XR content streaming and real-time interactions) - **Generative AI** (for assisting the training) - **Neuroymbolic Learning** (for anomaly detection and real-time analysis of inspection videos).
Human Factors	- Fatigue (long XR training sessions) - Task load (balance between cognitive and physical tasks, monitored via workload metrics) - Stress levels (tracked through physiological metrics like heart rate variability and galvanic skin response) - Attention capture (monitored using eye-tracking technology) - Digital skills (varied user levels) - UX (user experience).

Conclusion:

The **Operator 5.0 Training for Smart Water Pipes** project represents a cutting-edge solution that merges XR and AI to enhance technician training and streamline maintenance processes. The integration of **AI-powered anomaly detection** not only reduces human error but also accelerates the identification of faults, enabling more efficient and timely maintenance.

By leveraging **Hololight Stream/HUB** software, technicians can interact with complex XR content in real time, supported by hardware like **HoloLens 2** and **Magic Leap** AR glasses, which overlay virtual data directly onto real-world equipment. This enhances the hands-on training experience, allowing for practical, immersive learning without the need for physical equipment.

Human factors such as **fatigue, stress levels, task load**, and **attention capture** are carefully monitored to ensure that the training environment is optimized for the best possible outcomes. Using physiological tracking devices, such as **eye-tracking technology** and metrics like **heart rate variability**, the system ensures that operators remain focused and do not experience cognitive overload during extended XR training sessions.

The project's success will be evaluated through a range of **KPIs**, including **reductions in training time**, **cost efficiency**, and **increased technician satisfaction**, all of which align with the core objectives of the project. By prioritizing human factors alongside technological innovations, this initiative demonstrates a holistic approach to modernizing maintenance operations for smart water networks, making it a pioneering model for the future of industrial training.

4.4. Results for PILOT 4 TAP (IML - UNP – IPIA – SUPSI)

Introduction:

Pilot 4 TAP, focusing on enhancing the training process for maintenance of the Wing Anti-Ice Valve (WAIV), a critical aircraft component, through AI-enhanced XR environments. The pilot seeks to support junior engineers at TAP by providing immersive, AI-assisted training tools to optimize the maintenance process, improving accuracy, reducing errors, and preventing maloperation under high-stress conditions.

Challenges and Key Points:

- **Main Objective:** Optimizing the maintenance of the WAIV using XR technology and AI-driven training tools.
- **Key Challenges:** Ensuring accuracy during high-stress maintenance tasks, managing stress, and improving the efficiency of junior engineers.
- **Technologies and Key Components:** Integration of XR tools, Human Digital Twins (HDT), AI-enhanced simulations, and real-time feedback systems.
- **Expected Impact:** Increased maintenance efficiency, reduction in errors and maloperation, and enhanced knowledge transfer.
- **Human Factors:** Addressing stress, cognitive load, and user experience for technicians, especially focusing on the challenges faced during complex maintenance operations.
- **KPIs and Success Metrics:** Reducing maintenance downtime, improving technician performance under stress, and increasing overall operational efficiency.

Prioritized User Stories:

User Story	**4.9**
Description	Ensure that safety measures are clear, preventing risks during maintenance. Critical for protecting both the technician and the equipment
Persona (As a…)	Aircraft Maintenance Technician
Need (I want…)	know which are the safety measures to handle a WAIV device maintenance
Reason (So that…)	I do not put in risk myself and the device

User Story	**4.10**
Description	Provide guidance on accessing the valve device, for effective maintenance and training.
Persona (As a…)	Aircraft Maintenance Technician
Need (I want…)	know how to access the WAIV device
Reason (So that…)	I get to know what I need to do in order to reach the WAIV valve

Adopted Solutions:

The following table provides a comprehensive breakdown of the XR5.0 components, KPIs, hardware, software, and human factors described in the document. It highlights how these elements come together to achieve the project's objectives and address key challenges:

Solutions	Description
XR5.0 Components	- **AI-Assisted Training Environments:** AI and XR simulate maintenance processes, guiding technicians through immersive, real-time simulations and ensuring adherence to optimal procedures. - **Human Digital Twin (HDT):** Virtual replicas of skilled AMTs provide personalized training and feedback on optimal movements and sequences during maintenance tasks. - **AI Assistant:** Answers real-time maintenance questions, providing feedback and referencing undocumented cases, helping technicians in complex situations.
KPIs	- **Task Completion Time:** Reduce WAIV maintenance time by providing step-by-step AI-guided instructions. - **Error Reduction:** Decrease maloperations by offering real-time AI feedback and posture correction through HDT. - **Stress Reduction:** Measure technician stress using physiological sensors (e.g., heart rate variability) to track improvements.
Hardware	- **VR Headsets:** Used to simulate the aircraft's maintenance environment and train on the WAIV. - **Wearable Sensors:** Monitor technician stress and physical fatigue while performing tasks in XR environments.
Software	**- IML's VR Platform:** A pre-existing VR platform enhanced with AI and XR tools for the WAIV maintenance process, integrating augmented reality components to highlight real-world elements. - **AI-Driven XR Content:** Provides real-time guidance and instructions, simulating realistic scenarios, including feedback on errors and performance.
Human Factors	- **Task Load & Stress Management:** Focus on reducing stress caused by high-pressure maintenance environments through immersive XR simulations and real-time feedback. - Real**-Time Feedback:** Technicians receive guidance on optimal positioning and movements to ensure safety and precision. - **Cognitive Load:** Addressing potential fatigue and user overload through task simplification and AI assistance during maintenance.

Conclusion:

The Pilot 4 TAP project leverages AI-enhanced XR tools to significantly improve the training and maintenance processes for critical aircraft components like the WAIV. Through immersive virtual simulations, Human Digital Twins, and real-time AI assistance, the project aims to improve maintenance accuracy, reduce stress for junior engineers, and ensure compliance with safety regulations.

The project focuses on human-centered design, considering technician stress and the high-pressure nature of their tasks. The KPIs are focused on reducing downtime, increasing safety, and improving the technician's overall performance. By integrating smart technologies like VR headsets, physiological monitoring, and AI-driven content, this project sets out to transform traditional maintenance training processes, ensuring reliability and efficiency in aircraft operations.

4.5. Results for PILOT 5 SPACE (SYN)

Introduction:

Pilot 5 SPACE is focused on improving the efficiency and safety of assembling and repairing edge devices through XR technologies. The pilot aims to empower SPACE's technicians by providing personalized instructions for assembling, maintaining, and repairing complex devices, with training content tailored to different skill levels, ranging from beginners to intermediate technicians.

Challenges and Key Topics:

- **Main Objective:** Increase effectiveness and safety in edge device assembly and repair using XR and AI for personalized training and support.
- **Key Challenges:** Providing personalized training, enabling efficient remote support, and adapting processes to technicians with varying skill levels.
- **Technologies and Key Components:** Integration of AI, XR tools, real-time remote support, and interactive training modules.
- **Expected Impact:** Improved technical competence, reduced training time, enhanced safety and quality in assembly, and higher staff engagement.
- **Human Factors:** Managing cognitive load, simplifying interactions with digital tools, and providing real-time feedback tailored to the user.
- **KPIs and Success Metrics:** Reducing assembly and repair time, increasing technician engagement, and improving overall operational efficiency.

Prioritized User Stories

User Story	5.1
Description	Create personalized training workflows using AI to enhance efficiency and engagement
Persona (As a…)	Training Manager
Need (I want…)	the ability to create training workflows personalized to individual technician skill level
Reason (So that…)	I can minimize technician training time

User Story	5.2
Description	Need for accessible, cloud-based training materials to support ongoing learning and quick access.
Persona (As a…)	Assembly Technician
Need (I want…)	be shown personalized feedback during assembly training
Reason (So that…)	I can learn faster

User Story	5.5
Description	Focuses on providing quick configuration instructions to increase productivity and reduce setup time.
Persona (As a…)	Assembly Technician
Need (I want…)	be offered with instructions to fast preform device commissioning
Reason (So that…)	I can finish the set up faster

Adopted Solution:

The following table provides a comprehensive breakdown of the XR5.0 components, KPIs, hardware, software, and human factors described in the document. It highlights how these elements come together to achieve the project's objectives and address key challenges:

Solutions	Description
XR5.0 Components	- **Personalized XR Training:** Develop interactive and immersive content with AR/MR, tailored to different skill levels (beginner and intermediate). - **Real-Time Remote Support:** Technicians connect with remote experts via AR to receive visual instructions and corrections during repairs. - **AI for Personalization:** AI algorithms adjust the complexity of the training in real-time based on the technician's performance. - **Hololight HUB and Stream:** Tools for managing and delivering XR content in real-time, centralizing and optimizing the distribution of training modules. - **Cloud-Based Repository:** Stores updated training materials, allowing quick and easy access for technicians across different locations **- Human Digital Twin:** Use the XR5.0 to store/process technician information and smartwatch measurements
KPIs	- **Assembly Time Reduction:** The goal is to reduce the time needed to assemble devices by at least 20%. - **Increased Engagement:** A target of increasing engagement among less experienced technicians by 50%. - **Repair Time Reduction:** Repair times are expected to be significantly reduced through remote support and AI-assisted diagnostics. - **Cost Reduction:** Average Reduction of the Cost of the Assembly and Repair Processes>20%
Hardware	- **VR Headsets (Quest 2/3, Quest Pro):** VR devices used for immersive simulations of assembly and repair tasks. - **AR Devices (Smartphones/Tablets):** Provide real-time, on-site visual overlays and dynamic instructions for technicians. - **Smartwatch (Google Fit):** Used to collect biometrics to be used for personalizing training. -**MDUINO 19R PLUS Industrial Controller:** Programmable – customizable industrial controller
Software	- **Unity Game Engine:** 3D Game engine used for the development of the pilot XR applications. - **Hololight HUB and Stream:** Tools for managing and delivering XR content in real-time, centralizing and optimizing the distribution of training modules. - **Cloud-Based Repository:** Stores updated training materials, allowing quick and easy access for technicians across different locations. **- Clawdite:** Human Digital Twin Platform - **Generative AI:** Used to produce training scenarios/repair instructions based on technician skill/level as represented in the Digital Twin

Solutions	Description
Human Factors	- **Cognitive Load and Fatigue:** The cognitive workload of technicians is monitored to ensure extended use of XR does not result in overload. - **Digital Skills:** The XR interface is designed to be intuitive and accessible to technicians with varying levels of digital skills. - **Stress Monitoring:** Physiological factors such as heart rate variability and galvanic skin response are used to measure stress during training. - **User Experience and Feedback:** Continuous feedback through questionnaires and physical sensors is used to adjust the interface and modules based on technician experience. - **Perception of Effectiveness:** Technicians assess the perceived usefulness of personalized workflows, a key factor for training acceptance and effectiveness.
AI & Real-Time Support	- **Generative AI Models:** Create random training scenarios for technicians to practice various potential real-world situations. - **Remote Support with AI:** AI offers personalized repair suggestions based on historical data and technician performance. - **Neurosymbolic AI Models:** Combine neural networks and symbolic reasoning to guide decisions and provide solutions in complex maintenance scenarios.

Conclusion:

Pilot 5 SPACE showcases the use of AI-enhanced XR technologies to transform the assembly and repair processes of edge devices. The core strategy is personalized training modules and real-time remote support, ensuring that technicians at various skill levels can work efficiently and safely.

The integration of AI for adjusting content and providing real-time feedback during operations is designed to improve task execution speed and accuracy. The use of VR/AR devices enables immersive training environments and real-time support, while tools like the Hololight HUB facilitate centralized content distribution and management.

The KPIs focus on reducing assembly and repair times while increasing engagement for less experienced technicians. By integrating advanced technologies and personalizing the instructions, the project aims to optimize operational processes at SPACE.

4.6. Results for PILOT 6 LNS (ALMER – SSF)

Introduction:

Pilot 6 LNS is focused on enhancing maintenance and troubleshooting processes for complex machines using XR technologies combined with AI-driven functionalities. The goal is to provide personalized, real-time support for technicians during troubleshooting and planned maintenance, adapting the guidance based on individual skills

Challenges and Key Points:

- **Main Objective:** Improve efficiency and quality of maintenance and troubleshooting using AI and XR, providing personalized guidance to technicians.
- **Key Challenges:** Lack of personalized instructions during equipment downtime, and the time-consuming creation of tailored troubleshooting processes.
- **Technologies and Key Components:** XR tools, AI-driven personalization, remote support systems, and real-time skill-level adjustments.
- **Expected Impact:** Improved technician efficiency, reduced downtime, enhanced customer satisfaction, and faster onboarding for new technicians.
- **Human Factors:** Addressing technician cognitive load, and providing real-time personalized support based on experience level.
- **KPIs and Success Metrics:** Reducing troubleshooting time, improving task documentation efficiency, and increasing user satisfaction.

Prioritized User Stories:

User Story	**6.1**
Description	Receive step-by-step instructions directly in my field of vision through AR glasses
Persona (As a…)	Technician/Customer
Need (I want…)	receive step-by-step repair instructions directly in my field of vision through augmented reality glasses
Reason (So that…)	I can perform maintenance tasks accurately and without errors

User Story	**6.3**
Description	View real-time data during maintenance for more informed decision-making
Persona (As a…)	Technician/Customer
Need (I want…)	communicate in real-time with remote experts via augmented reality glasses
Reason (So that…)	I can receive assistance and guidance during complex or unexpected situations

User Story	**6.12**
Description	The system to log all task information, including time & details of future or pending tasks
Persona (As a…)	Technician
Need (I want…)	receive alerts in case of danger
Reason (So that…)	I am aware of the risks and can proceed confidently

Adopted Solution

The following table provides a comprehensive breakdown of the XR5.0 components, KPIs, hardware, software, and human factors described in the document. It highlights how these elements come together to achieve the project's objectives and address key challenges:

Solutions	Description
XR5.0 Components	- **AI-Enhanced XR Environments:** AI customizes XR troubleshooting guidance to the technician's skill level. - **Remote Support:** Technicians can request real-time assistance from remote experts through AR glasses for complex troubleshooting. - **Personalized Maintenance Instructions:** The system provides detailed, step-by-step guidance for beginners and streamlined information for experienced technicians.
KPIs	- **Troubleshooting Time Reduction:** A target of reducing troubleshooting time by over 35% for new and intermediate technicians. - **Documentation Efficiency:** Aim to reduce documentation time by 50% for experienced technicians, allowing more focus on hands-on tasks. - **Learning Time Reduction:** Decrease onboarding time for new technicians by over 20% through guided learning in the XR environment.
Hardware	- **AR Glasses (Almer AR Glasses):** Used to provide real-time, visual troubleshooting guidance and display tailored instructions. - **Smartphones/Tablets:** Allow mobile access to XR tools and troubleshooting assistance during remote operations.
Software	- **AI-Driven XR Interface:** Tailors troubleshooting instructions based on real-time feedback on technician expertise 22†source22†source. - **Cloud-Based Documentation:** Automates the documentation of maintenance tasks, logging detailed records for later analysis 22†source22†source. **- BynderSync DAM**: Digital Asset Management tool for centralizing documentation, videos, and troubleshooting procedures. **- TicketFlow CRM (Salesforce)**: Ticketing system powered by Salesforce for managing and tracking service requests and incidents. **- SmartChat Assist (Chatbot)**: Intelligent chatbot for accessing documentation via links or creating tickets directly in Salesforce. **- MyLNS Portal**: User portal for tracking tickets, submitting requests, and accessing a centralized knowledge base. **- PowerInsights Suite**: Analytics toolkit including Power BI, Power Apps, and Power Automate for data analysis, automation, and interactive dashboards.
Human Factors	- **Task Load Optimization:** Reduces cognitive load by simplifying troubleshooting instructions when signs of overload are detected 22†source22†source. - **Adaptive Learning:** The system adjusts the level of detail in instructions based on the technician's experience, ensuring they are not overwhelmed.

Conclusion:

Pilot 6 LNS utilizes AI-enhanced XR technologies to revolutionize maintenance and troubleshooting processes, particularly focusing on personalization and real-time support. By tailoring instructions to the technician's skill level, the system not only improves efficiency but also reduces downtime and increases technician satisfaction.

The real-time monitoring of task load allows the system to dynamically adjust guidance, preventing overload and enabling less experienced technicians to perform complex troubleshooting with minimal external intervention. Key performance indicators (KPIs) include significant reductions in troubleshooting and documentation time, alongside faster onboarding for new employees, all of which contribute to more efficient and streamlined operations.

This human-centric approach ensures that both the mental well-being of technicians and the operational efficiency of maintenance processes are optimized through advanced XR and AI technologies.

5. Workshop Results - Synthesis

An important objective of the XR5.0 Project is to establish a shared body of knowledge that accelerates the industry adoption of advanced technologies, such as XR and AI. This initiative aims not only to promote technological innovation but also to ensure that solutions are thoughtfully designed to address human needs and tailored to individual states, enhancing usability and impact across diverse applications.

To ensure practical relevance and support data-aggregation, the outcomes of the six co-creation workshops were synthesized and presented in Table 3. This table provides a consolidated view of the selected Key Performance Indicators (KPIs), human factors, software tools, hardware requirements, and XR5.0 components, offering a clear framework that integrates technical, human-centric, and performance considerations. This synthesis serves as a foundational resource for aligning project outcomes with industry expectations while maintaining a strong focus on user-centric design and operational efficiency

Table 3 - Synthesis

Points	Pilot 1 - KUKA	Pilot 2 - SH	Pilot 3 - EKSO	Pilot 4 - TAP	Pilot 5 - SPACE	Pilot 6 - LNS
XR5.0 Components	Hololight Hub/Stream, Generative AI, Active Learning Human Digital Twin, Training Programmes	AI-enhanced XR environments, Virtual Assistance Software, Neurosymbolic AI	Hololight Hub, Hololight Space, Hololight Stream, AI-powered anomaly detection	AI-assisted training environments, Human Digital Twin, AI assistant	Personalized XR training, Real-time remote support, AI for personalization	AI-enhanced XR environments, Real-time remote support, Personalized maintenance instructions
KPIs	>50% faster troubleshooting >30% reduction on physical testing >25% reduction on consumption of test parts/waste	Reduced on-site maintenance, Decreased task completion time, Enhanced technician satisfaction	XR object latency < 1s, 30% training time reduction, Reduced failure identification time	Reduced maintenance time, Error reduction, Stress reduction	20% assembly time reduction, 50% increased engagement, Reduced repair time	35% troubleshooting time reduction, 50% documentation efficiency, 20% reduced learning time
Hardware	KUKA Renovation Robot HoloLens 2, Meta Quest 3	Smart Glasses (. HoloLens 2), Smartphones/Tablets	HoloLens 2, Magic Leap, Mobile devices, Eye-tracking devices	VR headsets, Wearable sensors	VR headsets (Quest 2/3), AR devices (Smartphones/Tablets), Eye-tracking devices	AR glasses (Almer AR Glasses), Smartphones/Tablets
Software	Hololight Stream/Hub, Generative AI Active Learning Human Digital Twin Training Programmes	OCU SHARE software, Local AI hosting	Hololight Stream/HUB, Generative AI	IML's VR platform, AI-driven XR content	XR5.0 platform, Hololight HUB and Stream, Cloud-based repository	AI-driven XR interface, Cloud-based documentation ByndrSync DAM TicketFlow CRM (Salesforce) SmartChat Assist (Chatbot) MyLNS Portal PowerInsights Suite
Human Factors	Fatigue and task load monitoring, Attention capture, Digital skills	Task load and fatigue monitoring, Digital skills, User experience (UX)	Fatigue, Task load, Stress, Attention capture, Digital skills, User experience (UX)	Task load and stress management, Real-time feedback, Cognitive load management	Cognitive load and fatigue monitoring, Digital skills, Stress monitoring, User feedback, Perception of effectiveness	Task load optimization, Adaptive learning based on real-time feedback

Common Points:

- XR5.0 Components:
  - All pilots implement XR platforms like Hololight Hub, Stream, or similar solutions for immersive experiences.
- KPIs:
  - Across all pilots, a focus on **reducing errors**, **increasing efficiency**, and **cutting down operational times** (e.g., troubleshooting, maintenance, or assembly times) is common.
- Hardware:
  - All pilots utilize VR/AR devices like HoloLens, Magic Leap, and other mixed reality headsets for real-time guidance and simulations.
- Software:
  - Most pilots integrate **XR platforms** like **Hololight Stream/Hub or similar** for managing content and enabling interactions between physical and digital environments.
- Human Factors:
  - Monitoring **fatigue** and **task load** is a common factor in all pilots. Pilots emphasize minimizing cognitive load and ensuring that the human experience is optimized.

Different Points:

- XR5.0 Components:
  - While **XR platforms** are common, the specific technologies differ:
    - *Generative AI and Digital Twins* are emphasized in **Pilot 1 KUKA**.
    - **Pilot 3 EKSO** focuses on AI-powered anomaly detection.
    - **Pilot 4 TAP** introduces *Human Digital Twins* for training.
- KPIs:
  - The exact KPIs are tailored to each pilot's context:
    - **Pilot 2 SH** focuses on on-site maintenance reduction.
    - **Pilot 3 EKSO** targets training cost reduction and XR object latency.
    - **Pilot 5 SPACE** highlights increased technician engagement.
- Hardware:
  - Though **VR/AR devices** are common across pilots, certain pilots emphasize unique hardware:
    - **Pilot 3 EKSO** and **Pilot 5 SPACE** employ *eye-tracking devices* for monitoring user engagement.
    - **Pilot 6 LNS** uses *AR glasses* from Almer for real-time support.
- Software:
  - **Pilot 1 KUKA** and **Pilot 3 EKSO** integrate *Generative AI* solutions, while **Pilot 4 TAP** focuses on *AI-driven simulations for aircraft maintenance*.
- Human Factors:
  - **Pilot 6 LNS** places a distinct focus on *real-time adaptive learning* based on user feedback, which is less prominent in other pilots.

6. Pilot site Preparation

6.1. Rationale

Task 6.1 from Work Package 6 is also devoted to some preparation activities to facilitate Pilots and Partners deploying and operating the Use Cases. In this scenario, we have devised a two-phased approach to collect the proper information and devise an action plan, when needed.

<u>Phase 1 - Catalogue</u>

In this phase we are cataloguing an updated version of the adopted solutions from each Pilot and Tech Leader, their target deadlines for KPIs and a brief explanation about XR5.0 added value as indicated in Table 4.

Table 4 - Requested Actions

Requested Actions
1. HW and SW Update: a) Each pilot is requested to prepare an updated list of hardware (HW) and software (SW) currently being utilized. b) Provide brief descriptions on the hardware and software.
2. KPI Submission: Each pilot leader is requested to send a list of Key Performance Indicators, including the associated deadlines and the expected targets leading up to the next General Assembly (GA) and the midterm review.
3. XR5.0 Value Slide: Each pilot is to prepare and add a single slide addressing the following: "What is the value for the participation of the pilot to XR5.0?"

<u>Phase 2 – Materials</u>

In this phase we will prepare a questionnaire to collect further information on the Pilot's site including:

- Place where the Use Cases will be performed.
- People involved in executing the Use Cases.
- If/How people involved in executing the Use Cases are trained.
- If/How datasets are being managed.

It is important to indicate, Phase 2 is still a work in progress, and we may add other elements to the list.

6.2. Results

To obtain the information specified at Table 4, we have sent the following email to the Pilots and Tech leaders:

> Following the recent requests from WP1 and the upcoming deliverable D6.1, we have the following three action points that require your attention and completion (please check the deadlines on each action point individually).
>
> Action Points for **Pilot leaders** (KUKA, SH, EKSO, TAP, SPACE, LNS) and **Pilot Technical Responsible** (ATB, UPRC, HOLO, IML, SYN, SSF):
>
> 1. HW and SW Update (deadline **04.12.2024**):
>
>   a) Each pilot is requested to prepare an updated list of hardware (HW) and software (SW) currently being utilized.
>   b) Provide brief descriptions on the hardware and software. This information is crucial for the upcoming deliverable D6.1.
>
>   [Please check the shared online document linked below for the current list for each pilot.]
> 2. KPI Submission (deadline **06.12.2024**):
>
>   Each pilot leader is requested to send a list of Key Performance Indicators to GFT.
>   Please ensure that the KPIs include associated deadlines and the expected targets leading up to the next General Assembly (GA) and the midterm review.
>   [Please check the shared online document linked below for the current list for each pilot.]
>
>   3. XR5.0 Value Slide (deadline **06.12.2024**):
>
>   Each pilot is to prepare and add a single slide addressing the following:
>   "What is the value for the participation of the pilot to XR5.0?"

As a result, we have gathered the following preliminary information from each pilot to further refine the project's direction and ensure alignment with each pilot's unique needs and goals. The data collected are presented in the following sub-sections.

- Pilot 1 - KUKA

Pilot 1 Hardware and Software

Pilot Name	**Rapid Human Centric AI-Enables Product Design**
Hardware	● Laboratory environment: KUKA renovation robot ● XR Devices: HoloLens 2, Meta Quest 3
Software	● Hololight Space/Stream/Hub ● KUKA.SIM Software ● Human Digital Twin Platform (SUPSI) ● Generative AI - LLM Chat Assistant (INNOV) ● Active Learning (UPRC) ● Training Platform (IML)

Hardware Description

KUKA Renovation Robot The renovation robot serves as the test laboratory, exemplifying advanced automation capabilities. It shall autonomously navigate and perform complex tasks in construction. During the development KUKA simulates real-world scenarios within a controlled laboratory environment on their shop floor.

At the moment, the renovation robot is initially positioned approximately relative to the wall to be processed, with precise positioning achieved through distance sensors and a tilting sensor. The movements of the robot and its crane are controlled by the KRC4 robot controller and a PLC, which also transmits job information via Profinet and facilitates programming using TIA Portal V17.

The renovation robot excels in preparing surfaces for electrical installations, including milling sockets for outlets and switches with precision. It can also perform tasks such as taking accurate measurements and applying paint evenly across surfaces. Additionally, the robot is capable of sanding surfaces to ensure a smooth finish, adjusting its intensity based on the material and desired outcome.

XR Devices HoloLens 2 is an advanced augmented reality (AR) device that integrates digital content into the physical environment. This technology facilitates real-time collaboration and interaction by enabling users to visualize and manipulate the 3D-representation (digital twin). The desired application is particularly advantageous in industrial contexts, such as virtual commissioning, where pre-testing and troubleshooting can be conducted virtually. This process minimizes operational downtime and accelerates the deployment of physical systems.

Meta Quest 3 is a device supporting both virtual reality (VR) and mixed reality (MR), allowing users to engage with both virtual and physical spaces seamlessly. This technology is beneficial for training and simulation purposes, providing immersive experiences that enhance learning and skill development. Additionally, it supports applications involving AI-powered interactive device-features, which contributes to reducing human errors and improving task efficiency.

Pilot 1 seeks technology-agnostic solutions that are compatible with various devices, including mobile phones and tablets. This approach ensures that our applications are accessible, functional and high-performing across different platforms, thereby enhancing user convenience and flexibility. By prioritizing device-agnostic development, Pilot 1 aims to provide seamless and consistent user experiences regardless of the hardware used.

Software Description

Hololight Space In Pilot 1, both an AR application and a VR application called Hololight Space will be built using Hololight Stream. The AR application will enable 3D models of KUKA robots and machinery, static and dynamic data related to this machinery, and on-site step-by-step training programmes to be streamed to XR devices like the HoloLens 2. The VR application, designed for Meta Quest 3, will provide personalized off-site training for machine commissioning.

Hololight Hub The AR and VR applications developed within Pilot 1 will be hosted on the cloud-based XR5.0 training platform that is based on Hololight Hub.

KUKA.SIM Software KUKA.SIM is a software tool that enables the pre-testing and troubleshooting of robotic systems in a virtual environment before their physical deployment. This process minimizes downtime and accelerates operational processes, ensuring a smoother transition from virtual to physical systems. In Pilot 1, this software will consolidate simulation data from KUKA assembly lines and the XR5.0 Human Digital Twin Platform.

Human Digital Twin Platform The HDT, aka Clawdite, is an extensible and flexible IIoT - Industrial Internet of Things - based platform supporting the creation of customised data representations of production systems and their entities, including humans. Clawdite features a modular infrastructure with interchangeable components, which ease the digital twin instantiation and ramp-up. The whole platform's architecture has been designed in order to be interoperable, extensible, scalable and customizable.

Clawdite's reference model describes a HDT including human-centred elements but also contextual elements, relevant to characterise the workers and the surrounding environment in a production system. The advantage for the adopters of the HDT model is two-fold: they can rely on a model built on the robustness of a scientific result; they are provided with ready-made packages of entities to instantiate their own HDT, by including also human-centred aspects (e.g., interactions, events), and software-based computations (e.g., output of functional models predicting the state of factory entities). There are 3 main types of data which are managed in Clawdite: measurements (dynamic data), characteristic (quasi-static data) and states (the output of functional modules).

In Pilot 1, the HDT component will be utilized to analyze the positions of technicians operating within the same environment as the KUKA robots and predict their next positions. This data will be integrated into the KUKA.SIM software to assess whether the technician is working safely within the designated safety zones around the robot.

Generative AI - LLM Chat Assistant

Integrated into the XR system, the LLM Chat Assistant provides real-time feedback and assists users in interacting with the XR devices. It optimizes task efficiency by offering intelligent suggestions and automating routine tasks, thereby enhancing overall productivity. In the end it should be possible to interact with the device by voice-control and get answers to corresponding queries. In Pilot 1, the LLM Chat Assistant will be integrated with the AR and VR applications to provide the user with augmented guidance to interact with the AR robot overlays, training programs for commissioning and machine maintenance, remote access to documents and check-lists within the AR app, and to provide step-by-step instructions as a response to the user prompt.

Active Learning

In Pilot 1, Active Learning will be utilized for the recognition of flexible robotic objects and other machine components at an assembly line. Active learning involves a camera detecting assembly line components in real-time, which subsequently triggers the corresponding equipment to show available metadata. This process enhances the system's responsiveness and efficiency by enabling immediate interaction between the machine component and the equipment. The approach aims to develop a workflow capable of reading new product variants, allowing us to work with newly generated datasets rather than existing ones.

Training Platform

The Training Platform developed by IML provides XR-based on-site and off-site training for commissioning and service technicians. This platform enhances the learning experience by offering immersive and interactive training modules that improve skill acquisition and retention. Additionally, the training platform provides questions and records the pass or fail status to enable a comprehensive assessment of the trainees. In Pilot 1, the training platform will be implemented for on-site training for machine maintenance and off-site training for commissioning.

- Pilot 2 – SH

Pilot 2 – Human Centered Remote Maintenance and Asset Management

Hardware and Software

Pilot Name	Human Centered Remote Maintenance and Asset Management
Hardware	● **Microsoft HoloLens 2**: Used to provide hands-free AR overlays, step-by-step maintenance guides, and real-time expert support. ● **Smartphones/Tablets** (e.g., iPad Pro): Used by field technicians to access remote support dashboards, communicate with experts, and view AI and XR content if smart glasses are not available. ● **Laboratory Instruments:** Analytical instruments requiring periodic calibration and troubleshooting, now supported remotely via AR guidance.
Software	● **OCU SHARE Software**: An XR-based solution enabling real-time collaboration between experts and field technicians. ● **OCU MR SHARE**: XR APP developed specifically for the HoloLens2 and Magic Leap 2. Will be advanced to display step-by-step instructions and AI instructions to support SH´s service workers. ● **Local AI Hosting**: AI systems are hosted locally to ensure data security and prevent cloud dependence (ChromaDB for hosting a local vector storage and a local deployed LLM).

Hardware Description

The pilot use cases utilize a combination of advanced hardware to enhance operational efficiency and support:

1. **Microsoft HoloLens 2**: Augmented reality headset used for hands-free operation. It overlays step-by-step instructions, visual maintenance guides, and system diagnostics directly in the technician's field of view. The device also supports real-time remote assistance by enabling video streaming and expert guidance.

2. **Smartphones/Tablets (e.g., iPad Pro)**: Portable devices equipped with support dashboards and communication tools. These are used to access remote assistance platforms, view AI and XR content, and facilitate diagnostics or troubleshooting when smart glasses are unavailable. Their high-resolution displays and computational capabilities make them suitable for detailed visualization and remote collaboration.

3. **Laboratory Instruments**: Analytical devices integrated into the pilot for remote support. These instruments require periodic calibration and troubleshooting, which are performed using augmented reality guidance and remote monitoring capabilities, reducing the need for on-site expertise.

Software Description

The software utilized in the pilot use cases integrates XR and AI technologies to enhance real-time collaboration, task execution, and data security.

1. **OCU SHARE Software**: A cross-platform XR-based collaboration tool designed to connect experts and field technicians. It facilitates real-time remote guidance by streaming AR environments, allowing experts to provide visual annotations and instructions directly within the technician's operational context. This ensures accurate and efficient task execution.

2. **OCU MR SHARE**: A specialized XR application developed for the Microsoft HoloLens 2 and Magic Leap 2. This app supports immersive AR experiences by delivering step-by-step instructions and AI-generated insights tailored to SH's service workflows. Its development focuses on enhancing service efficiency by integrating procedural guidance and diagnostics directly within the technician's field of view.

3. **Local AI Hosting**: The AI systems are deployed locally to maintain strict data security and avoid dependence on cloud-based solutions. ChromaDB is used for local vector storage, supporting fast and secure access to AI-processed information. Additionally, a locally deployed Large Language Model (LLM) enables advanced AI functionalities, such as natural language understanding and contextual support, while ensuring compliance with data protection regulations.

- Pilot 3 – EKSO

Pilot 3 - Hardware and Software

Pilot Name	Operator 5.0 Training for Smart Water Pipes based XR Streaming
Hardware	● Magic Leap 2 XR Device ● Rovion Robot Crawler
Software	● Hololight Stream ● Hololight Hub ● CYENS XR Application ● Outlier/Anomaly Detection with Active Learning (UPRC) ● Neurosymbolic AI Module (UPRC) ● LLM Chat Engine (INNOV) ● MageAI ETL pipelines (SIE)

Hardware Description

Magic Leap 2 XR Device The Magic Leap 2 is an advanced augmented reality (AR) headset designed primarily for enterprise use. The AR application will be hosted on the cloud-based XR5.0 training platform and streamed to Magic Leap 2 via application streaming.

Rovion Robot Crawler

The iPEK Rovion crawler is a robotic inspection system designed for pipeline and sewer inspection. It features a durable, remotely controlled crawler with a camera for capturing high-quality visuals, enabling efficient monitoring and assessment of underground infrastructure. Within use case 3, the video from the crawler will be analysed by UPRC for anomaly detection and the processed video feed/frame will be displayed in the AR application.

Software Description

Hololight Stream Hololight Stream is a remote rendering solution designed to stream high-quality XR experiences from local servers or cloud-based infrastructure to XR end-devices. It is provided as an SDK or Unity-plugin for XR application developers. Within Pilot 3, CYENS' AR Application will be built using Hololight Stream such that contextual training content such as 3D models and step-by-step training programmes can be streamed to XR devices like Magic Leap 2.

Hololight Hub Hololight Hub is a cloud-based system that hosts, manages, and streams XR applications in real time to XR devices. It ensures high-quality, low-latency streaming, enabling smooth experiences regardless of device capabilities. Features like application version control, user management, analytics, and robust security protocols make it an efficient solution for industrial training. The AR application developed within Pilot 3 will be hosted on the cloud-based XR5.0 training platform that is based on Hololight Hub. In addition, the Hub will also provide access to the cloud repository (T5.1), for end-users to manage training assets and materials, and access to the training programme tool (T5.4), for end-users to develop and create training programmes for the trainees with the option to link the steps to the materials in the cloud repository. With this feature, the AR application will be able to provide the training in an AR immersive environment.

CYENS XR App The CYENS XR App is an innovative solution that combines AR, AI, and anomaly detection to support workers in the field. It offers system monitoring, task assistance, and anomaly visualization, making it an invaluable tool for industries that require precise, efficient, and safe operations. Its integration of advanced technologies like LLMs, Active Learning (AL) , sensor networks, and AR visualization ensures a seamless and effective user experience.

LLM Chat Engine The LLM Chat Engine is a Generative AI-based conversational assistant designed to enhance the XR-based training and inspection processes in Pilot #3. Powered by large language models (LLM) and integrated into the XR5.0 training platform (HololightHub), this engine is capable of understanding natural language commands, processing domain-specific instructions and documentation for delivering contextually relevant guidance and explanations to the trainees. It bridges the gap between human operators and advanced AI functionalities, making it more intuitive for the workers to interact with complex datasets, technical documents and 3D models within the XR training environment. In this pilot, the LLM Chat Engine will receive input from various data streams, such as training objectives, user experience levels, voice commands via the XR device, and technical documentation to dynamically generate natural language responses or instructions. For example, when a trainee points at a part of the smart pipe and issues a voice command requesting more information, the LLM Chat Engine leveraging Retrieval Augmented Generation (RAG) can provide background knowledge, maintenance procedures, or step-by-step instructions.

Active Learning - Outlier Detection module The Active Learning (AL) component is a complement to the Outlier/Anomaly Detection developed for Pilot 3 (Use Case 3) and its use case involving the CCTV inspection of EKSO's pipeline network. It aims to automatically detect outliers/anomalies/defects on the pipelines and alert operators by providing a Human in the loop element of the AI algorithms to assist human actors further improve their efficiency and accuracy. At the current stage, the Outlier Detection (OD) is performed in an offline (not streaming) manner by splitting the provided videos to a series of frames. The output of the OD is a series of pictures that have been characterized as outliers. The end user/operator is given the possibility to change the tag of the image (outlier/inlier) after inspection in which case the AL component is triggered to modify the algorithms' parameters. Furthermore, the AL component measures the uncertainty of a given algorithmic prediction and requests user input when necessary, thus providing a Human in the loop concept. The current limitation of the approach lies in the fact that the solution can identify whether a frame is an anomaly or not but cannot identify the nature/reason of the outlier (e.x. leakage, corrosion, etc.). Therefore, the NSAI module will be a great asset towards extracting more knowledge from the videos and enhancing human cognition.

NSAI Module The NeuroSymbolic AI (NSAI) module will be used for the CCTV inspection of EKSO's pipeline network (Pilot 3 - Use Case 3) to extract semantic information, enhance the Outlier Detection task and assist EKSO's operators in order to enhance efficiency and human cognition. NSAI module includes a NeuroSymbolic AI model that will be responsible to identify the features of an image or video, identify if there is an anomaly in the image and also it would be capable of recognizing the type of the anomaly (since it would be regarding water pipes, some example type of outliers would be corrosion, leakage, cracks, etc). In order to communicate with the model, there would be an API where videos of the inspection would be sent and then the result of the model process will be communicated back to the request. This module would include a pretrained model for image recognition along with a Logic Tensor Network layer (LTN is a Neuro-Symbolic framework that effectively incorporates deep learning and logical reasoning). This layer would be fed and trained with various rules (image features) that would help the model identify the different types of outliers and also give explainable outputs. At the current stage, the input to the model is the images that have been created from a video (like in Active Learning). Those videos mainly come from the Robot Crawler. In those images, the NSAI model will be applied in order to be able to recognize the type of outlier and respond to the user along with its reasoning about the outlier.

MageAI ETL pipelines The MageAI ETL pipeline is designed to efficiently identify and localize anomalies in the water pipe systems by integrating data ingestion, transformation, and export functionalities. The pipeline's integration with an API service enables efficient communication with external systems. The API provides three endpoints: one for pipeline infrastructure information, another for sensor geolocation and pipe associations, and a third for anomaly geolocation relative to the pipe. This API-driven design ensures seamless data exchange and accessibility. The MageAI ETL pipeline offers two distinct approaches for detecting and localizing anomalies in pipeline systems, catering to different data collection methods and scenarios:

CCTV Inspection-Based Anomaly localization - This approach leverages data gathered during on-site CCTV inspections conducted by technicians. The pipeline is triggered after an inspection and processes a dataset comprising the distance traveled along the pipe where the anomaly was observed, combined with the geolocation data of the pipe's sensors. The MageAI ETL pipeline utilizes this information to compute the precise anomaly location by correlating the distance traveled with the geolocation data. This process provides an accurate mapping of anomalies relative to the pipeline's structure. To simulate real-world scenarios, a synthetic data generator is used to create datasets representing pipelines, sensors with geolocation data, and anomalies identified by their distance along the pipeline. These datasets trigger the MageAI pipeline, allowing for validation and performance testing.

Time Series Anomaly Observation Localization - This approach continuously processes sensor measurements streamed into the ETL pipeline. The data consists of vibration amplitude readings captured by sensors placed along the water pipe infrastructure. In this scenario machine learning techniques are used in the ETL process to analyze the time series, with the focus on the patterns found in vibration amplitudes relative to the distances between sensors. Deviations from expected patterns are flagged as anomalies, and their locations are computed with high precision. This approach is particularly suited for continuous monitoring, enabling proactive detection of issues before they escalate.

- Pilot 4 – TAP

Pilot 4 - Hardware and Software

Pilot Name	Worker Centric Aircraft Maintenance Training (Pilot #4)
Hardware	● Wing Anti-Ice Valve (WAIV) ● Meta Quest 2 / Meta Quest 3 ● Pine Time Smart Watch (delivered by UNP)
Software	● Mixed Reality Application for Virtual Training (VT) ● Virtual Reality Application for Aircraft Maintenance Technician Digital Twin (AMT-DT) ● HoloLight Hub / Stream (HOLO) ● Training materials (IML) ● Training programs (IML) ● Cloud-based repository (SYN) ● Generative AI models (INNOV) ● XR-enabled AL & NSAI models (UPRC) ● Human Centric Digital Twins (SUPSI) ● Personalized XR content (SUPSI) ● Workers' data collection & analytics (UNP)

Hardware Description

The Wing Anti-Ice Valve (WAIV) is a crucial component of modern aircrafts, as it prevents the formation of ice in the wings during flight. A proper functioning of this component is critical for aerodynamic efficiency and safety, being also a key component of the aircraft's Minimum Equipment List (MEL).

The Meta Quest 2 and Meta Quest 3 are standalone VR headsets designed by Meta to deliver immersive Virtual Reality (VR) and Mixed Reality (MR) experiences without requiring a PC or console connection. With hand tracking for natural interaction and passthrough technology for mixed reality experiences, these headsets are well-suited for the pilot use cases. This hardware component will be used to deliver XR applications designed for aircraft maintenance training.

PineTime is an open-source smartwatch that runs custom open-source operating systems and features heart rate detection and step counting. This hardware component will be used to monitor technicians' physiological data during virtual simulations to evaluate stress and fatigue levels.

Software Description

The Mixed Reality Application for Virtual Training (VT) and the Virtual Reality Application for the Aircraft Maintenance Technician Digital Twin (AMT-DT) are both XR applications developed with Unity based on the Interactive 3D Maintenance Training Tool (SLB platform) by Immersive Lives. This tool provides a virtual environment with step-by-step instructions for disassembling the Wing Anti-Ice Valve (WAIV).

The VT application provides on-the-job training using an interactive 3D model of the WAIV with the necessary operational steps and tools in a Mixed Reality environment.

The AMT-DT application provides off-the-job training using an interactive simulation, allowing the operator to disassemble the WAIV in a Virtual Reality environment.

Both applications will be extended with common and specific XR5.0 Components to integrate AI tools and Digital Twin features. These applications will incorporate the following common components:

- The applications will be hosted in HoloLight Hub and streamed to client devices using the HoloLight Stream.
- The applications will use the Training Platform, accessing the Training Materials and Training Programs stored in the Cloud-based repository.
- The Workers' data collection & analysis will enable monitoring the technicians' physiological data to evaluate stress and fatigue levels.
- Each application will also incorporate specific XR5.0 Components. The VT application will incorporate the following specific components:
- The Generative AI models enable a speech-based voice assistant that answers questions about the procedure.
- The XR-enabled AL & NSAI models enable a visual recognition tool that identifies and highlights the components for operation.
- The AMT-DT application will incorporate the following specific components:
- The Human Centric Digital Twin enables tracking the operator movements and suggests optimal gestures and postures for performing the procedure.
- The Personalized XR Content enables training content adaptation based on the user profile.

- Pilot 5 - SPACE

Pilot 5 - Hardware and Software

Pilot Name	**Increased Effectiveness and Safety of Product Assembly and Repair Processes**
Hardware	● **VR/AR Devices (Quest 2/3 Headsets, Smartphones/Tablets):** VR/AR devices used for immersive simulations of assembly and repair tasks. ● **Smartwatch (Google Fit):** Used to collect detailed performance data and personalize training adjustments. ● **MDUINO 19R PLUS Industrial Controller:** Programmable – customizable industrial controller
Software	● **Unity Game Engine:** 3D Game engine used for the development of the pilot XR applications. ● **Hololight HUB and Stream:** Tools for managing and delivering XR content in real-time, centralizing and optimizing the distribution of training modules. ● **Cloud-Based Repository:** Stores updated training materials, allowing quick and easy access for technicians across different locations ● **Clawdite:** Human Digital Twin Platform ● **Generative AI:** Used to produce training scenarios/repair instructions based on technician skill/level as represented in the Digital Twin

Hardware Description

MDUINO 19R PLUS: Programmable – customized controller used for many industrial applications: Enables integrated surveillance rule-based incident response with a market focus on the banking sector: controlling ATM rolling shutter (e.g., triggering alarms, locking of doors and safes, siren lighting control, etc.). Provides Integrated Ethernet Interface, USB port, SD card, digital inputs, relay, RTC (Real Time Clock) μSD Socket (using SPI port) 100x75x115mm DIN Rail mounting, 12/24V power supply.

VR/AR Devices (Quest 2/3 Headsets, Smartphones/Tablets): Quest 2/3 are standalone (and thus suitable for training) VR headsets that support AR/MR features developed by Meta. On top of that, commercially available smartphones/tablets will be used to provide technicians with repair instructions on the field (Use Case 2).

GOOGLE FIT: A commercial Smartwatch that will be used to measure vitals that will be used for input to the Human Digital Twin Platform.

Software Description

Unity Game Engine: A Game Engine widely used to create VR/AR/MR applications. It will be the primary tool utilized to develop the pilot application.

Hololight HUB and Stream: Hololight hub is an enterprise platform provided by Hololight that will host the pilot applications. Holo Stream will be utilized to distribute/stream the application to the target XR Devices.

Cloud-Based Repository: An extension of the Own cloud sharing platform customized for the needs of the XR5.0 project. Used to store both XR-based and traditional training materials (documents/videos/presentations)

Clawdite*:* A Human Digital-Twin platform developed by SUPSI. Its role will be to store information about technicians (e.g., skill level or domain knowledge), log biometric data via the use of smart devices (smartwatches), infer the technician's current status (for example, stress level or engagement)

Generative AI: Used to dynamically create training scenarios based on parameters derived from the aforementioned Human Digital-Twin model (Use Case 5.1: Personalized Training for Edge Device Assembly) and as a chatbot application that can provide personalized instructions to the technician to achieve faster assembly/repairs (Use Case 5.2: Remote Instruction for Edge Device Repairs)

- Pilot 6 - LNS

Pilot 6 - Hardware and Software

Pilot Name	**Human-centric Guidance and Troubleshooting for Customer Service**
Hardware	● **AR Glasses (Almer AR Glasses):** Used to provide real-time, visual troubleshooting guidance and display tailored instructions. ● **Smartphones/Tablets/Computers:** Allow mobile access to XR tools and troubleshooting assistance during remote operations.
Software	● **Bynder Sync DAM**: Digital Asset Management tool for centralizing documentation, videos, and troubleshooting procedures. ● **Ticket Flow CRM (Salesforce)**: Ticketing system powered by Salesforce for managing and tracking service requests and incidents. ● **Smart Chat Assist (Chatbot)**: Intelligent chatbot for accessing documentation via links or creating tickets directly in Ticket Flow. ● **My LNS Portal**: User portal for tracking tickets, submitting requests, and accessing a centralized knowledge base. ● **Power Insights Suite**: Analytics toolkit including Power BI, Power Apps, and Power Automate for data analysis, automation, and interactive dashboards.

Hardware Description

AR Glasses (Almer AR Glasses): The Almer AR Glasses serve as the primary tool for real-time, hands-free guidance during maintenance and troubleshooting tasks. In UC 6.1, these glasses are used to provide technicians with visual troubleshooting support, delivering step-by-step instructions and context-aware guidance directly in their line of sight.

For beginners, this includes detailed instructions, while more experienced technicians receive only the necessary details to perform the task efficiently. In UC 6.2, these glasses facilitate preventive maintenance by guiding technicians through scheduled machine checks.

The instructions adjust based on the technician's expertise, ensuring that beginners receive more detailed, step-by-step guidance, while experienced workers see simplified instructions and fewer interruptions.

The AR glasses are connected to the XR system, which adapts the information displayed according to real-time data from the maintenance task, improving the technician's accuracy and reducing cognitive load. Additionally, if a technician appears overwhelmed or makes mistakes, the system can adjust the guidance or suggest remote support options.

Smartphones/Tablets/Computers: Mobile devices such as smartphones, tablets, and computers provide flexible access to XR tools and troubleshooting assistance, enabling technicians to remain connected to the XR environment while performing tasks. These devices are crucial for UC 6.1, where technicians need to access troubleshooting documentation, track progress, and communicate with remote experts. For example, when a technician encounters a particularly difficult problem during customer service troubleshooting, they can use a smartphone or tablet to pull up more detailed documentation or open a service ticket in Salesforce. In UC 6.2, these devices support remote support sessions. Technicians can use them to view more detailed machine diagnostics or interact with experts through video calls or real-time chat if needed. Tablets and computers also serve as secondary interfaces, enabling technicians to track maintenance schedules, submit reports, and interact with other business systems. These devices ensure that technicians can always access the right tools, regardless of where they are, thus supporting the overall goals of personalized maintenance and troubleshooting.

Software Description

Bynder Sync DAM: The Bynder Sync DAM (Digital Asset Management) system is a central component for storing and managing all maintenance documentation, videos, troubleshooting guides, and procedure manuals.

In UC 6.1, it acts as the repository for the dynamic, context-aware troubleshooting content that the AR glasses will display to technicians. When a technician faces a customer service issue, they can quickly access the relevant documentation through the AR glasses, which pulls real-time content from Bynder Sync DAM.

In UC 6.2, Bynder Sync DAM houses maintenance procedures that are vital for preventive maintenance tasks. Technicians can easily pull up procedures for specific maintenance routines or search for troubleshooting steps if a machine requires urgent attention. As the system is integrated with cloud technology, updates to documentation can be made in real-time, ensuring that technicians always have access to the latest information.

This system ensures a seamless flow of information between the technician and the tools they are using, keeping the technician on track without needing to search for critical documents externally. With its ability to store and categorize large volumes of technical content, Bynder Sync DAM provides the backbone for both guidance systems, ensuring that technicians have the most relevant, up-to-date information at their fingertips.

Ticket Flow CRM (Salesforce): Salesforce, is a comprehensive ticketing and service management system used to track and manage all service requests and incidents. In UC 6.1, itis used for tracking customer service tickets, ensuring that maintenance and troubleshooting tasks are properly logged and managed. Technicians use Salesforce to create new tickets for problems encountered during customer service interactions, ensuring that each issue is resolved and tracked in real-time. When a technician identifies an issue that requires further investigation, they can easily escalate the ticket, assign it to the appropriate expert, or track its resolution status. In UC 6.2, Salesforce helps monitor and manage preventive maintenance tasks. When a machine is due for maintenance, a technician can open a ticket in Salesforce to schedule the maintenance and track its progress. The system helps ensure that all tasks are performed according to schedule and that any preventive measures are properly documented for future reference.

Smart Chat Assist (Chatbot): Chatbot facilitates quick access to documentation and ticketing services. In UC 6.1, the chatbot acts as a first line of support for technicians. If a technician is unsure of how to resolve a customer service issue, they can interact with Chatbot to receive instant answers, retrieve relevant documents, or even create a new ticket in Chatbot. The chatbot simplifies the troubleshooting process by guiding technicians to the right information quickly, allowing them to focus on solving the problem at hand rather than searching for resources. In UC 6.2, Chatbot provides technicians with immediate access to preventive maintenance procedures or helps them raise tickets for more complex maintenance tasks.

My LNS Portal: The My LNS Portal is a user-friendly web interface that allows users to manage and track their service tickets, access knowledge bases, and submit service requests. In UC 6.1, users can log into the portal to view and track service requests, submit new requests, and monitor the progress of existing tickets. The portal provides an easy-to-navigate interface that allows technicians to manage tickets and follow up on unresolved issues. In UC 6.2, the MyLNS Portal allows users to access a comprehensive knowledge base containing maintenance guides. The portal centralizes all service-related information in one place, ensuring that technicians can stay on top of their responsibilities and easily find the information they need to complete maintenance tasks successfully.

Power Insights Suite: The Power Insights Suite is an analytics toolkit that includes Power BI, Power Apps, and Power Automate for data analysis, automation, and dashboard creation. In UC 6.1, Power Insights Suite is used to monitor the performance of service requests, track key metrics such as response times, issue resolution rates, and technician efficiency. The analytics provided by Power BI help management make data-driven decisions about resource allocation and performance improvement. In UC 6.2, the Power Insights Suite helps track preventive maintenance performance, analyze trends, and predict when machines are likely to require service.

7. CONCLUSIONS

The **Deliverable D6.1 "Use Cases Co-Creation and Pilot Sites Preparation"** comprehensively synthesizes the efforts of the XR5.0 project to integrate XR and AI technologies into industrial contexts, emphasizing a human-centric approach. This document demonstrates how innovative methodologies, grounded in co-creation, were applied to align the specific demands of six pilots with advanced technological solutions, ensuring both technical feasibility and practical applicability.

The adopted methodological structure, encompassing the phases of conception, preparation, execution, and conclusion, was pivotal in organizing activities, refining user stories, identifying key performance indicators (KPIs), and incorporating human factors. These elements were crucial in developing adaptable, effective, and scalable solutions that address the unique needs of each pilot. The results highlight not only the shared elements among the pilots but also their distinctive features, underscoring the project's value as a benchmark for technological innovation within Industry 5.0.

The pilots shared commonalities, such as the use of XR technologies (e.g., *Hololight Hub* and *Stream*), AR/VR devices (*HoloLens 2*, *Magic Leap*), and a consistent focus on error reduction, operational efficiency, and overall performance optimization. Additionally, the monitoring of human factors, including cognitive load, fatigue, and digital skills, ensured that the solutions were accessible and tailored to user needs. However, each pilot also presented unique approaches that reflect their specific industrial challenges and priorities.

In *Pilot 1 (KUKA)*, the combination of Digital Twins and generative AI optimized industrial processes, enabling greater precision in robot commissioning and remote maintenance. *Pilot 2 (SH)* innovated by leveraging AI and XR environments to provide real-time remote support for technicians maintaining complex laboratory instruments, reducing the need for on-site interventions and enhancing knowledge transfer. In *Pilot 3 (EKSO)*, AI-powered anomaly detection technologies improved the inspection and maintenance processes for water networks, significantly reducing the time required to identify faults and increasing operational efficiency. *Pilot 4 (TAP)* excelled with the use of Human Digital Twins and XR simulations to train engineers in the maintenance of critical aircraft components, such as de-icing valves, minimizing errors under high-pressure conditions. In *Pilot 5 (SPACE)*, personalized training workflows tailored by AI to the technicians' skill levels demonstrated how individualization could boost engagement and efficiency in assembling and repairing electronic devices. Finally, *Pilot 6 (LNS)* featured adaptive real-time support, adjusting instructions based on technicians' skill levels and stress indicators, reducing problem-resolution times, and enhancing operator confidence.

The next critical step for the XR5.0 project is the testing phase for the prototypes, which are already under development. These tests will validate the solutions in real-world environments, allowing for adjustments and refinements based on data collection and user feedback. Additionally, preparing the test sites will be a strategic priority, considering the need to adapt the technological infrastructure, configure appropriate physical spaces for immersive interactions, and train local teams. This preparation includes deploying XR devices, ensuring low-latency network connectivity, and implementing continuous monitoring tools that are essential for collecting real-time data during testing.

The project also aims to explore new opportunities to enhance existing solutions, with a focus on human factors such as engagement, user experience, and cognitive load reduction. Furthermore, scalability will be assessed to adapt the technologies to different industrial sectors, expanding their impact beyond the specific conditions of the current pilots.

The *Deliverable D6.1* stands out as a strategic milestone for XR5.0, providing not only a record of achievements to date but also a clear roadmap for the next phase. By prioritizing a human-centered approach and practical validation of the solutions, the project is paving the way to transform industrial practices with technologies that drive efficiency, safety, and innovation, solidifying the role of Industry 5.0 as a model for more collaborative and intelligent work environments.

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ANNEXES

ANNEX I – WORKSHOP DETAILS FOR PILOT 1

KUKA	SUPSI	ATB Institut für angewandte Systemtechnik Bremen GmbH	INSTITUTO PIAGET

Human Centric AI-Enabled Product Design Rapid
Motivation: In today's business landscape, companies are constantly seeking ways to improve their competitiveness, productivity, efficiency, sustainability, and resilience while keeping a human-centric approach. One motivation to adopt XR in Industry 5.0 technologies is to bridge the gap between physical and digital spaces, enabling better communication, collaboration, and decision making. Furthermore, the complexity of assembly lines and the infinite number of product variations create challenges in manufacturing, such as high levels of rejected parts and low part availability. To the rescue, XR5.0 technologies can reduce complexity, optimise operations, and create a sustainable and human-centric future.

Concept & Description: KUKA is a leading provider of systems for the assembly and testing of vehicle powertrain components, as well as the robot-automated assembly of prefabricated building elements. KUKA needs to ensure that it can minimise downtimes while also avoiding the shortage of skilled workers. Moreover, social change, such as the willingness to travel, part-time work, and work-life balance, has implications for the labour market. KUKA can leverage XR5.0's human-centric and AI-powered digital solutions to overcome these challenges. XR applications can provide immersive and interactive training experiences for workers, enabling them to learn new skills more quickly and efficiently. Additionally, XR can assist in maintenance, optimisation, and changes to the plants by reducing the complexity of the line and enabling real time feedback on production quality. Overall, by adopting XR technologies, KUKA can improve its productivity, efficiency, sustainability, and competitiveness in the market, while also providing a more human-centric approach to its operations.

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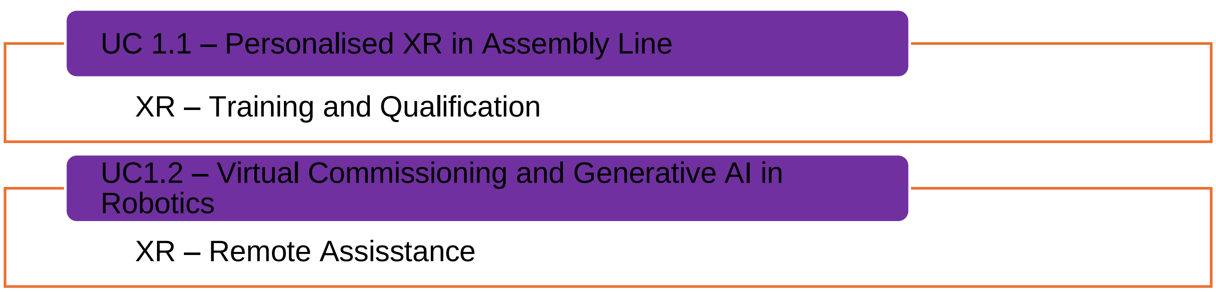
1. General Context

The workshop discusses the integration of cutting-edge technologies such as Extended Reality (XR), Virtual Commissioning, and Generative AI in industrial environments, particularly within the robotics and manufacturing sectors. The goal is to leverage these tools to enhance training, optimize processes, reduce costs, and minimize physical testing, while improving efficiency and operational accuracy. The focus is on creating a human-centric and sustainable approach to industrial automation, using both AI and XR to assist workers in real-time tasks, troubleshooting, and programming.

2. Use Cases

The booth use cases (figure 1), Personalized XR in Assembly Line and Virtual Commissioning and Generative AI in Robotin the technologies provide a more efficient and seamless operational environment, fostering collaboration and improving response times while reducing costs and physical interventions.

Figure 1: Use Cases



Use Case 1.1 – Personalized XR in Assembly Line: Training and Qualification

This use case focuses on the application of XR to provide training and qualification for assembly line workers. XR technology is used to deliver interactive, personalized training experiences, particularly important in complex manufacturing environments where not all tasks are performed daily. The training is designed to assist technicians and workers in quickly acquiring necessary skills without the need for constant retraining.

Objective: The primary goal is to ensure that assembly line workers can access quick, context-specific guidance using XR tools. This allows workers to visualize components, follow step-by-step procedures, and learn about new systems or machinery through immersive, hands-on experiences without needing direct supervision.

Benefits: XR training offers a way to reduce downtime for training while ensuring that employees stay up-to-date with the latest operational protocols. This process also helps reduce human errors by providing real-time feedback, making it easier for operators to handle maintenance or new product integration tasks efficiently.

Analysis: UC 1.1 (Personalized XR in Assembly Line) demonstrates how immersive technologies like XR can revolutionize the training of assembly line workers. This method not only enhances worker proficiency but also contributes to operational efficiency by reducing the need for repetitive training. The real-time interactive feedback improves accuracy and helps workers familiarize themselves with equipment quickly. This leads to reduced operational errors and downtime, ultimately boosting productivity and quality.

Use Case 1.2 – Virtual Commissioning and Generative AI in Robotics: Remote Assistance

This use case involves using Virtual Commissioning and Generative AI in robotic systems to facilitate XR-based remote assistance. In this scenario, technicians working on-site can use augmented reality to receive real-time support from engineers located elsewhere. The integration of AI allows for faster troubleshooting by enabling the technician to visualize the machinery's digital twin, highlighting issues like component misalignments or faults in real-time.

Objective: The key objective is to reduce the need for physical presence during complex maintenance or repair tasks. Through XR and AI, remote engineers can collaborate with on-site technicians, analyzing sensor data, checking component status, and guiding the technician through repairs.

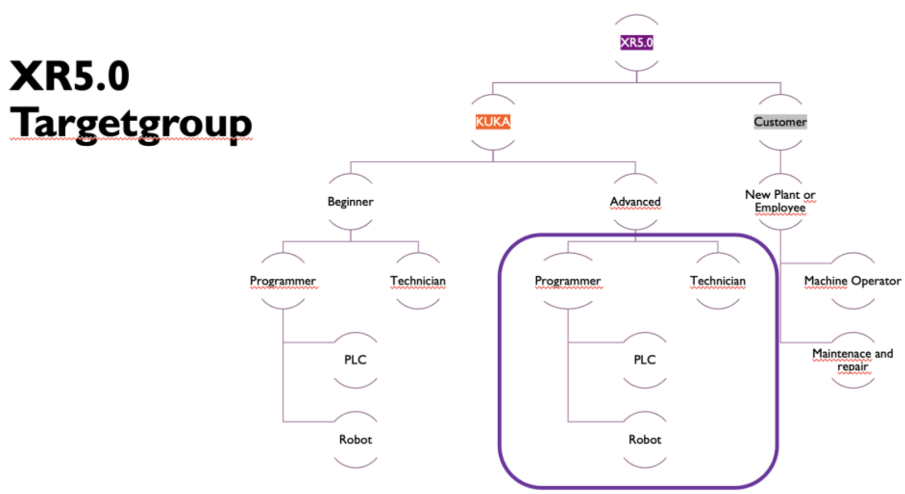
Benefits: XR-based remote assistance reduces response time and downtime by allowing experts to remotely diagnose and fix issues. This also minimizes costs associated with travel and on-site engineering support. The digital twin feature further enhances the process by providing a live model of the equipment, ensuring that remote diagnostics are accurate.

Analysis: UC 1.2 (Virtual Commissioning and Generative AI in Robotics) highlights the power of combining XR with AI to facilitate advanced troubleshooting and maintenance support. The use of a digital twin to visualize components and issues in real-time significantly enhances the ability to resolve problems without needing a physical presence. This use case underscores the value of AI-driven assistance in industrial contexts, where quick and accurate problem resolution is crucial to maintaining operational flow. The generative AI component also allows for faster programming and debugging, continuously learning from technician feedback to refine its processes.

2.1. Persona Analysis

The personas highlight distinct user groups essential for implementing and operating the project's technologies. Below is a presentation and analysis of the personas based on the data available (Figure 2).

Figure 2 – Pilot Personas



2.1.1. Personas for the Use Cases in the KUKA Project

1. Remote Expert:

- Role: Provides real-time support to on-site technicians remotely. They assist in troubleshooting, monitor system performance, and analyze data from afar using digital tools.
- Tasks: Uses XR and the digital twin to guide on-site technicians, viewing live sensor data and virtual representations of the plant. They offer solutions without being physically present, helping resolve issues quickly.
- Use Case Application: The remote assistance feature allows these experts to collaborate with on-site teams, using XR tools to visualize problems, view sensor data, and provide detailed instructions.

2. Commissioning Technician:
   - Role: Focuses on the latter stages of commissioning, ensuring that machines are fully operational after shipping and installation at customer sites.
   - Tasks: Verifies that system settings are correct, runs optimization tests (e.g., cycle times, quality checks), and ensures the machinery meets customer specifications.
   - Use Case Application: The virtual commissioning process aids these technicians by enabling remote pre-testing of system logic, reducing the need for physical troubleshooting. They utilize XR to simulate real-world operations and test parameters before on-site implementation.
3. Service Technician:
   - Role: Responsible for maintaining and repairing machinery during its operational life. They interact directly with machines on-site and ensure that issues are resolved promptly.
   - Tasks: Uses manuals, specifications, and digital tools to diagnose and repair issues. In many cases, they rely on digital twins to highlight specific components or faults within the machine.
   - Use Case Application: For maintenance and repair, the digital twin feature assists by showing real-time machine movements and component statuses. They can quickly locate faulty components or receive real-time guidance from remote experts .

Each of these personas plays a vital role in ensuring smooth operation, setup, and maintenance of industrial systems. The integration of XR, AI, and remote assistance greatly enhances their efficiency and problem-solving capabilities.

2.1.2. Analysis of the Personas:

The analysis of personas in this context highlights the various roles involved in the KUKA project and how each one interacts with the advanced technologies being implemented, such as XR, AI, and Digital Twins. The personas that utilize these technologies provide insight into the different needs and functions across the team. Here's how these personas relate to the Project will be considered (Table 1):

Persona #	Persona	Will it be considered?
1	Customer	No
2	Maintenance Engineer	Yes
3	Virtual Commissioner	Yes
4	Quality Manager	No
5	Mechanical Engineer	Yes
6	PLC Programmer	Yes
7	Robot Programmer	Yes
8	Concept Engineer	No
9	Mechanical Commissioner	Yes
10	Project Manager	No
...		

1. Customer: No
    - The customer is not directly involved in the usage of XR, AI, or Digital Twin technologies. Their role is more focused on the final product or service being delivered, relying on the technical team to manage the implementation.
2. Maintenance Engineer: Yes
    - Role: Maintenance engineers actively use XR and AI to perform repairs and maintenance. They benefit from features like real-time data access, digital twins for troubleshooting, and interactive guides for complex tasks.
    - Usage: XR is utilized to visualize internal components, guide repairs with virtual instructions, and access real-time product information. AI helps suggest parts replacements or identify issues quickly.
3. Virtual Commissioner: Yes
    - Role: Virtual commissioners are heavily involved with Digital Twin technology, using it to simulate machinery setups and test systems before physical installation.
    - Usage: They leverage XR and virtual commissioning to pre-test systems, ensuring all settings and configurations are correct, which helps to minimize errors during real-world setup.
4. Quality Manager: No
    - Quality managers focus on ensuring that final products meet standards and specifications. While they oversee the results of processes using XR and AI, they do not actively use these technologies in their role.
5. Mechanical Engineer: Yes
    - Role: Mechanical engineers use XR and Digital Twin technology to model and visualize components during design and assembly processes.
    - Usage: They utilize XR to visualize machine parts, understand how components interact, and ensure accurate assembly, often using digital twins to predict performance and solve mechanical issues early.
6. PLC Programmer: Yes
    - Role: PLC programmers interact with XR and AI to code and debug automation systems.
    - Usage: AI assists PLC programmers by generating code, debugging issues, and testing logic in a virtual environment before deploying the code to real systems, improving efficiency and reducing errors.
7. Robot Programmer: Yes
    - Role: Robot programmers rely on XR and Digital Twin technology to program and test robotic systems.

- Usage: The Digital Twin allows them to simulate robot movements and program actions in a virtual environment, reducing the need for physical testing and enabling more accurate programming.

8. Concept Engineer: No

- Concept engineers are responsible for the early-stage development of systems and do not directly interact with XR or AI technologies. Their work is more focused on design and innovation rather than the technical implementation of automation.

9. Mechanical Commissioner: Yes

- Role: Mechanical commissioners use XR and Digital Twins to validate and set up systems on-site.
- Usage: They use XR to visualize missing components, ensure proper assembly, and perform live adjustments, while Digital Twins help simulate the complete system before final handover.

10. Project Manager: No

- Project managers oversee the entire project lifecycle but are not involved in the direct use of XR, AI, or Digital Twin technologies. They rely on reports from the technical team to monitor progress and ensure project success.

Summary:

The personas that actively use XR, AI, and Digital Twins are the ones directly involved in the technical setup, maintenance, programming, and commissioning of systems. Roles like Maintenance Engineers, Virtual Commissioners, Mechanical Engineers, PLC Programmers, Robot Programmers, and Mechanical Commissioners depend on these technologies to enhance their efficiency, reduce errors, and streamline processes. On the other hand, roles such as Customers, Quality Managers, Concept Engineers, and Project Managers are more concerned with the outcomes of these processes and rely on the results, not the technologies themselves.

3. User Stories

The following user stories present the real-world applications of XR (Extended Reality), Digital Twin, and AI technologies in various industrial roles, particularly focusing on service technicians, commissioning technicians, robot programmers, and remote experts. These stories illustrate how advanced technologies are integrated into everyday tasks to improve efficiency, precision, and communication. Each story highlights a specific user's needs and the solutions provided by these technologies, enhancing the overall workflow in commissioning, maintenance, and troubleshooting processes (Table 2).

Through these scenarios, we can observe how XR headsets, real-time sensor data, interactive guides, and digital twins transform the way technicians and programmers work, making complex tasks more manageable, improving accuracy, and reducing downtime. Each user story is designed to meet the operational challenges faced by professionals in the field, ultimately streamlining industrial operations and fostering collaboration between remote experts and on-site workers.

Table 2 – User Stories

User Story #	As a …	I want to ..	So That ..
1.1	Service/ Commissioning Technician	communicate with a remote expert using my XR device	I can communicate by voice/dialogue using microphone, speakers on XR-Headset I can communicate by visual transmission in realtime, so the remote expert can see on his PC the same what I see through my XR-Headset
1.2	Robot Programmer / Technician	have a scalable overlay between the real machine and the Digital Twin, shown in my XR device	the virtual counterpart based on a 3D model and the kinematic model are displayed just the needed/desired perspective is filled out with virtual content my movement is reflected in the perspective of the digital twin the movement of the DT anticipates the reference center points of the real robot
1.3	Service Technician	have functional, selectable units and components *functional* (components shown in the virtual section are identfied and indicated by type and area: sensors, drives, supply & signal paths, network and bus systems, safety- areas) *selctable* (the user can control, which kind of units needs to be indicted: devices, paths, areas)	the virtualised section can provide an x-ray view if requested, so hidden parts are also shown I can clearly indicate/identify a single component that shall be highlighted
1.4	Remote Expert	have access to sensor data and databases	I can visualise data sheets, circuit diagramms, manuals, assambly plans (static) I can visualise realtime sensor data like pressure values, temperatures, set points, end positions (dynamic)
1.5	Commissioning Technician	use interactive features	I can see virtual HowTo's and Step by Step Instructions that support me by replacing and repairinng components I can see ToDo's and CheckLists that help me document my work during commissioning I get user support and guidenance to operate HMI and control elements
1.6	Commissioning Technician	get an impression of the finished machine, even if it is only partially built	I can see missing parts being represented by the 3D model
1.7	Service Technician	get realtime product information	I get realtime information about availability, prices and delivery conditions or suggestions about alternativ components and parts

2.2. Analysis of User Stories

2.2.1. User Story 1.1: Service/Commissioning Technician

- As a Service/Commissioning Technician,
- I want to communicate with a remote expert using my XR device,
- So that I can communicate by voice using the microphone and speakers on the XR headset, and the expert can see in real-time what I see through my XR headset.

Analysis: This story focuses on real-time collaboration between on-site technicians and remote experts. The XR device facilitates efficient communication by enabling both visual and auditory interaction, which is critical for quick troubleshooting and support. The live visual feed shared through the XR headset allows the expert to assist more accurately, reducing downtime and minimizing the risk of miscommunication.

2.2.2. User Story 1.2: Robot Programmer/Technician

- As a Robot Programmer/Technician,
- I want to have a scalable overlay between the real machine and the Digital Twin, shown in my XR device,
- So that the virtual counterpart based on a 3D model and kinematic model are displayed, only the needed perspective is filled with virtual content, and my movement is reflected in the digital twin, allowing it to anticipate the reference center points of the real robot.

Analysis: This user story emphasizes the integration of XR and Digital Twin technologies to assist robot programmers. The ability to scale and overlay the digital twin with the real machine helps in precise programming, testing, and validation. By mirroring real-world movements and adjusting the digital twin accordingly, programmers gain a better understanding of robot actions and behaviors, reducing physical testing and streamlining the commissioning process.

2.2.3. User Story 1.3: Service Technician

- As a Service Technician,
- I want to have functional, selectable units and components,
- So that functional components shown in the virtual section are identified by type and area, and I can control which units are highlighted (devices, paths, areas), with the ability to see hidden parts through an x-ray view.

Analysis: This story addresses the need for detailed component visualization during maintenance and repair. By offering an x-ray view and selective highlighting, the XR device helps technicians locate and identify specific parts, even those that are hidden or difficult to access physically. This significantly improves accuracy and speeds up repairs by ensuring the right components are targeted without guesswork or trial and error.

2.2.4. User Story 1.4: Remote Expert

- As a Remote Expert,
- I want to have access to sensor data and databases,
- So that I can visualize static data like data sheets and diagrams, as well as real-time sensor data such as pressure, temperature, and other dynamic variables.

Analysis: This user story focuses on enabling remote diagnostics and support. The remote expert can make better decisions by accessing both static documents (e.g., manuals) and live data (e.g., sensor readings). This allows for a comprehensive understanding of the system's status and enables the expert to give accurate instructions to on-site technicians, thus improving efficiency and reducing the risk of errors during troubleshooting.

2.2.5. User Story 1.5: Commissioning Technician

- As a Commissioning Technician,
- I want to use interactive features,
- So that I can see virtual How-To's, Step-by-Step instructions, and To-Do lists, helping me replace and repair components while documenting my work.

Analysis: This story highlights the importance of interactive guidance during commissioning. XR's ability to display virtual instructions in real-time helps technicians follow best practices for replacing and repairing components. The step-by-step guidance ensures that tasks are performed correctly, while the To-Do lists and checklists help in documenting progress, streamlining the commissioning process, and ensuring accountability.

2.2.6. User Story 1.6: Commissioning Technician

- As a Commissioning Technician,
- I want to get an impression of the finished machine, even if it is only partially built,
- So that I can see missing parts represented by the 3D model.

Analysis: This user story focuses on visualizing incomplete systems. By leveraging XR, the technician can see a virtual representation of the completed machine, which helps anticipate potential issues with assembly or missing parts. This feature improves planning and problem-solving, especially in complex setups where the absence of certain components could otherwise delay the process.

2.2.7. User Story 1.7: Service Technician

- As a Service Technician,
- I want to get real-time product information,
- So that I can see availability, prices, and delivery conditions, or get suggestions for alternative components and parts.

Analysis: This story addresses the need for up-to-date product information during repairs or maintenance. By accessing real-time data on parts availability and pricing, the technician can make informed decisions quickly, reducing delays in the repair process. If original parts are unavailable, suggestions for alternative components ensure that work can continue without significant interruptions.

2.3. General Analysis

These user stories illustrate a comprehensive approach to leveraging XR and Digital Twin technologies for various roles within the industrial context. The key benefits across all scenarios include:

- Enhanced Communication: Real-time collaboration between technicians and experts improves troubleshooting efficiency and reduces downtime.
- Improved Visualization: XR and digital twin overlays provide technicians and programmers with better visibility of the machine and its components, leading to more precise interventions.
- Interactive Guidance: Step-by-step instructions and interactive features help guide technicians through complex processes, ensuring accuracy and reducing errors.
- Access to Data: Real-time access to sensor data, diagrams, and product information ensures that technicians can make informed decisions during commissioning, repairs, and maintenance.
- Efficiency and Time Savings: The use of digital twins, XR, and AI reduces the need for physical interventions and manual troubleshooting, streamlining the entire workflow from commissioning to service.

These improvements contribute to more efficient, accurate, and cost-effective operations, benefiting both technicians and the overall industrial process.

3. Prioritization Of User Stories

Based on the workshop, prioritization can be established by evaluating the immediacy of need, impact on operations, and dependency on other functionalities.

3.1. User Stories Prioritization

User Story 1.2: Robot Programmer/Technician - Digital Twin Overlay

- Priority: High
- Reason: The scalable overlay between the real machine and the digital twin significantly enhances programming accuracy and efficiency, making it essential for ensuring precise control and reducing errors. This feature is critical for optimizing workflows and ensuring seamless integration between the physical and digital environments, which directly impacts overall project success.

User Story 1.4: Remote Expert - Sensor Access

- Priority: High
- Reason: The ability to access sensor data and databases in real-time is vital for remote experts to provide accurate support to on-site technicians. This directly affects the ability to diagnose and resolve issues quickly, which is crucial for maintaining operational flow.

User Story 1.5: Commissioning Technician - Interactive Features

- Priority: High
- Reason: Interactive features like step-by-step instructions and checklists are essential during the commissioning process. These help ensure tasks are done correctly the first time, minimizing errors and speeding up the commissioning process.

User Story 1.3: Service Technician - Functional Components View

- Priority: Medium
- Reason: The ability to see functional and selectable units with an x-ray view is important for complex repairs, but it builds on top of existing troubleshooting capabilities. It adds value but is not immediately critical for daily operations.

User Story 1.6: Commissioning Technician - 3D Model Visualization

- Priority: Medium
- Reason: Visualizing missing parts via the 3D model is useful for planning and identifying potential issues during commissioning. While it doesn't directly impact immediate operational success, it enhances situational awareness and helps streamline the commissioning process, making it a valuable, though not critical, tool.

User Story 1.1: Service/Commissioning Technician - Communication

- Priority: Low priority
- Reason: While real-time communication between the technician and the remote expert is beneficial for problem-solving, it is not an immediate necessity for all tasks. Other functionalities, such as programming accuracy and system integration, take higher precedence. This feature, though useful for reducing downtime, is more of an enhancement to streamline troubleshooting rather than a critical requirement.

User Story 1.7: Service Technician - Real-time Product Info

- Priority: Low priority
- Reason: Real-time product information (availability, prices, delivery) improves decision-making, but it doesn't directly impact immediate machine functionality or system operations. It's useful for long-term efficiency but not mission-critical.

3.2. Summary:

- High Priority: 1.2 (Digital Twin Overlay),1.4 (Sensor Access), 1.5 (Interactive Features)
- Medium Priority: 1.3 (Functional Components View), 1.6 (3D Model Visualization)
- Low Priority: 1.1 (Communication), 1.7 (Real-time Product Info)

This prioritization focuses on addressing critical communication and real-time data needs first, as they have the most immediate impact on maintaining operational flow and minimizing downtime.

Table 3 summarizing the prioritization of the user stories based on the analysis:

User Story	Role	Description	Priority	Reason
1.2	Robot Programmer/Technician	Have a scalable overlay between the real machine and the Digital Twin to assist in programming.	High	Significantly improves programming efficiency and accuracy, making it essential for optimizing workflows.
1.4	Remote Expert	Access to sensor data and databases to provide remote support (static documents and real-time data).	High	Essential for remote diagnosis and providing accurate support to on-site technicians, improving issue resolution speed.
1.5	Commissioning Technician	Use interactive features (How-To's, Step-by-Step guides, checklists) for commissioning tasks.	High	Ensures tasks are completed correctly, minimizes errors, and speeds up the commissioning process.
1.3	Service Technician	View functional, selectable units and components with XR, including hidden parts via x-ray view.	Medium	Useful for complex repairs and maintenance but builds on top of existing troubleshooting capabilities.
1.6	Commissioning Technician	Visualize missing parts using a 3D model during machine commissioning.	Medium	Helpful for planning and visualization, but supplementary and not essential for immediate operational success.
1.1	Service/Commissioning Technician	Communicate with a remote expert using XR headset (voice and real-time visual transmission).	Low	Beneficial for troubleshooting, but not critical for all tasks, making it more of a convenience feature.
1.7	Service Technician	Get real-time product information (availability, prices, alternative components).	Low	Helps with decision-making and part replacement, but not critical for immediate operational needs.

This table provides a clear, organized view of the user stories, their priority, and the reasoning behind each prioritization.

4. KPIs

Based on the KUKA PowerPoint (Table 4), we can identify several elements related to KPIs (Key Performance Indicators) that are referenced or implied in the user stories, though not explicitly labeled as KPIs.

Table 4: Acceptance/Success Criteria

ID	Acceptance / Success Criteria
1.1	Functionalities are implemented
1.2	Overlaying the DT with the real machine and the kinematic model
1.3	Overlaying the DT with the real machine and highlighting functionalities (e.g., x-ray view, explosive view)
1.4	Providing secure real time data on the XR device and share with a remote expert
1.5	Ready usable HowTo's for a number (tbd) of HowTo's
1.6	Overlaying the DT with the real machine
1.7	Online connectivity with ERP (e.g. SAP- or SQL database)

4.1. Acceptance / Success Criteria

4.1.1. Functionalities are implemented

- The ability for the Service/Commissioning Technician to communicate with a remote expert using an XR headset (with voice and real-time visual transmission) is clearly mentioned. The successful implementation of communication functionalities (microphone, speaker, and visual transmission) is a functional KPI implied by the story.

4.1.2. Overlaying the Digital Twin (DT) with the real machine and the kinematic model

- The Robot Programmer/Technician user story explicitly discusses the overlay of the Digital Twinwith the real machine and the use of a kinematic model, where the programmer's perspective and movement are mirrored by the DT. This matches the KPI of having accurate, real-time overlays to aid in programming and visualization tasks.

4.1.3. Overlaying the DT with the real machine and highlighting functionalities (e.g., x-ray view, explosive view)

- This KPI aligns with the Service Technician story where an x-ray view is available to display hidden parts, and the ability to selectively highlight specific components is mentioned. This is a direct reference to a core functionality that helps visualize internal machine components.

4.1.4. Providing secure real-time data on the XR device and share with a remote expert

- The Remote Expert user story discusses access to real-time sensor data (such as temperature, pressure, etc.) and the ability to visualize this data on the XR device while sharing it with an expert. The emphasis on real-time data sharing aligns with this KPI, though the security aspect is implied but not explicitly stated.

4.1.5. Ready usable HowTo's for a number (tbd) of HowTo's

- The Commissioning Technician user story refers to HowTo's and Step-by-Step Instructionsdisplayed in real-time, assisting the technician in replacing and repairing components. This matches the KPI of having ready-to-use guides to streamline technician tasks.

4.1.6. Overlaying the DT with the real machine

- In the Commissioning Technician story, the ability to visualize missing parts using the 3D modelis mentioned, which implies overlaying the DT with the real machine during commissioning, even when parts are incomplete. This reflects the KPI of DT visualization for partially completed machines.

4.1.7. Online connectivity with ERP (e.g., SAP or SQL database)

- The Service Technician user story mentions real-time access to product information (e.g., availability, prices, and delivery conditions), which would require online connectivity with systems like ERP (SAP/SQL databases). This is necessary for retrieving up-to-date information, which aligns with this KPI.

5. Human Factors

In XR environments, human factors such as fatigue, task load, digital skills, and emotional state play a crucial role in the effectiveness and user experience of the system. The integration of various biometric measures like heart rate variability, galvanic skin response, and eye-tracking metrics (e.g., attention capture, gaze behavior, and pupil dilation) allows for a more comprehensive assessment of the users' engagement and cognitive load. These metrics are increasingly used to enhance user-centered design by providing real-time feedback and adaptation mechanisms.

Table 5 outlines several user stories within an XR-driven project that applies such human factors to improve various aspects of assembly lines, remote assistance, and training systems, particularly for industrial and robotics applications.

Table 5 – XR5 Human Factors

XR5.0 Human Factors	Will it be used? (x)	In which User Story (ID)?
Questionnaires		
Fatigue	X	I.5
Task load index		
Digital Skills	X	I.5
User Experience	X	I.2
Emotion/mood		
...		
Physiological metrics		
Heart rate variability (stress, cognitive load, engagement)		
Galvanic Skin Response (stress & engagement)		
Capture & maintenance of attention (assessed by eye-tracker)	X	I.5
Pupil dilation (eye-tracker)	X	I.5
Gaze behavior (eye-tracker)	X	I.5

5.1. Analysis

Based on table 5, several human factors are applied to specific user stories within the XR system:

Fatigue (User Story ID 1.5)

Fatigue is highlighted as a significant factor in the use of XR for industrial settings. In User Story 1.5, which likely pertains to tasks related to assembly line operations or remote assistance, measuring fatigue is essential to understanding how users' performance degrades over time. Fatigue monitoring, possibly through physiological metrics like heart rate variability, is crucial for ensuring that workers do not reach unsafe levels of exhaustion, which can affect both efficiency and safety.

Task Load Index (User Story ID 1.5)

In the same User Story (1.5), task load is measured to optimize the distribution of work and prevent overloads, which could lead to stress or errors. The integration of task load metrics helps to adjust workflows dynamically, ensuring that users are operating within their optimal cognitive load levels.

Digital Skills (User Story ID 1.5)

Assessing users' digital skills is key to ensuring that the XR interfaces and tools are intuitive and appropriately challenging for workers with varying levels of technical proficiency. In User Story 1.5, these skills are likely evaluated to customize the user interface or training modules based on the individual's capabilities, making the system more accessible and reducing the learning curve for users unfamiliar with advanced digital tools.

User Experience (User Story ID 1.2)

User Experience (UX) is a core focus in User Story 1.2, which deals with virtual commissioning and AI in robotics. The system's ability to provide seamless interaction through natural gestures, intuitive control mechanisms, and real-time feedback is critical in reducing cognitive strain. Enhancing UX leads to improved worker satisfaction and efficiency, directly influencing the adoption and success of XR technologies in high-stakes environments like industrial robotics.

Attention and Engagement (User Story ID 1.5)

User Story 1.5 also explores metrics related to the capture and maintenance of attention through eye-tracking technology. Tools like gaze behavior and pupil dilation are measured to assess how well the system holds the user's focus, particularly during complex tasks such as maintenance or assembly. This data can be used to dynamically adapt the XR environment to sustain engagement and prevent lapses in attention, which are critical in environments that demand high precision.

Stress and Cognitive Load (User Story ID 1.5)

Stress levels and cognitive load are assessed using biometric signals such as heart rate variability and galvanic skin response. These measures help identify moments when users are under high cognitive strain, which could lead to errors or slower task completion. In scenarios like pre-commissioning and maintenance (referenced in User Story 1.5), this feedback enables the system to adjust difficulty levels, provide additional guidance, or schedule breaks to mitigate the impact of stress.

Pupil Dilation and Gaze Behavior (User Story ID 1.5)

In tasks requiring sustained attention, such as operating or repairing machinery, eye-tracking tools are employed to monitor both pupil dilation and gaze behavior. These metrics provide real-time insights into cognitive load and stress. For example, prolonged pupil dilation might indicate a high level of concentration or cognitive effort, signaling the system to reduce task complexity or offer assistance.

5.2. Summary

The integration of human factors such as fatigue, digital skills, task load, and user engagement into the XR project greatly enhances its usability and effectiveness. User Story 1.5, in particular, stands out as the most comprehensive in incorporating physiological and cognitive metrics like heart rate variability, pupil dilation, and task load to optimize worker performance in real time. By considering these human factors, the project ensures a more adaptive and user-friendly experience, which is crucial for the long-term success of XR technologies in industrial and training environments.

6. Technical Components

The technical components of XR5.0 focus on implementing personalized, immersive learning and problem-solving environments through advanced technologies such as digital twins, generative AI, and cloud-based repositories. These components aim to enhance user interaction, knowledge retention, and productivity in XR environments, particularly in complex industrial scenarios like robotics, commissioning, and maintenance (Table 6).

Table 6 - Technical component

Task	XR5.0 Technical Component	Will it be used?	In which User Story (ID)?
T3.3	Workers' digital twins	Yes	HDT could be used as a digital coach in E-Learnings/HowTos scenarius, e.g. **User Story 1.5**
T3.4	Personalized XR content	Yes	**All User Stories** by customised settings like langauge, resolution degree for explanations, etc... Especially **User Story 1.1** remote assitance, where highly coordinated communication is used to solve a specific problem.
T4.1	Human-centered XAI models	No	
T4.2	XR-enabled Active Learning	Yes	**User Story1.2 robot commissioning**: configuring the coordinate systems in position and orientation.Coordinate systems and dimensions are used as AR content in an MR application.
T4.2	Neurosymbolic AI models	No	
T4.3	Generative AI models	Yes	**User Story 1.2:** Providing virt. 3D-Models including kinematics as AR-Content in a MR-Application
T4.4	Visualization of XAI explanations	No	
T4.5	Visualization of AI recommendations	Yes	Interesting for all user stories which are supported by AI generated results: recommended HowTos, Step by Step guiding. This applies especially to **User Story 1.5**, Interactive features for commisioning
T5.1	Training material	Yes	Several already existing e-learning lessons could be converted from interactive web-based training into immersive XR-based trainings.
T5.2	Cloud-based repository	Yes	Used as a central platform for exchanging XR content. Needed in all **relevant User Stories,**
T5.3	Hololight Hub	Yes	The Hub should implement the repository mentioned in **T5.2**
T5.4	Training programs	Yes	Regarding Several already existing e-learning lessons could be converted from interactive web-based training into immersive XR-based trainings.

6.1. Main Discussion Points on Technical Components

This analysis will explore how each technical component is applied across different user stories, highlighting their role in improving the XR user experience.

T3.3 Workers' Digital Twins (User Story ID 1.5)

- Usage: Yes
- Application: Workers' digital twins can be used as a digital coach in User Story 1.5, where workers may engage in e-learning or how-to scenarios. This allows for real-time guidance and personalized feedback, improving the learning experience. The digital twin acts as a virtual coach, helping workers understand complex tasks in assembly or commissioning by simulating their actions and suggesting improvements.

T3.4 Personalized XR Content (User Story ID 1.1)

Usage: Yes

Application: Personalized XR content is utilized in all user stories by customizing settings like language, resolution, and the level of explanation detail. In User Story 1.1, which focuses on remote assistance, this component enhances communication between workers and remote experts. Tailoring the content ensures that workers receive instructions in their preferred language or in a simplified format, depending on their needs, leading to more efficient problem-solving.

T4.1 Human-Centered XAI Models

- Usage: No
- Application: This component is not used in any user story. Human-centered XAI (Explainable AI) models could have provided transparency in decision-making processes, but they are not implemented in this XR project.

T4.2 XR-Enabled Active Learning (User Story ID 1.2)

- Usage: Yes
- Application: In User Story 1.2, which involves robot commissioning, XR-enabled active learning is employed to configure coordinate systems in position and orientation. This component presents AR content related to coordinate systems and dimensions in a mixed reality (MR) application, allowing users to interact with and learn from real-time 3D visualizations during the robot setup.

T4.2 Neurosymbolic AI Models

- Usage: No
- Application: Neurosymbolic AI models are not utilized in this project. These models would combine neural networks and symbolic AI to handle complex reasoning, but they are not part of the current user stories.

T4.3 Generative AI Models (User Story ID 1.2)

- Usage: Yes
- Application: In User Story 1.2, generative AI models are employed to provide virtual 3D models, including kinematics, as AR content within an MR application. These models allow users to visualize robot movements and interactions in real time, facilitating tasks like commissioning by giving workers a deeper understanding of the system's behavior without needing physical prototypes.

T4.4 Visualization of XAI Explanations

- Usage: No
- Application: This component is not used. Visualization of XAI explanations could have helped users understand AI decisions visually, but it is not implemented in the described user stories.

T4.5 Visualization of AI Recommendations (User Story ID 1.5)

- Usage: Yes
- Application: AI-generated recommendations are visualized in several user stories, particularly in User Story 1.5, which focuses on interactive features for commissioning. The system offers step-by-step guides and how-to explanations, making the commissioning process easier and more intuitive. This feature is essential for enhancing worker engagement and reducing cognitive load during complex procedures.

T5.1 Training Material

- Usage: Yes
- Application: Existing e-learning lessons can be converted into immersive XR-based training programs, benefiting several user stories. This enhances the interactivity and engagement of training sessions, making it easier for workers to acquire new skills and apply them in real-world tasks.

T5.2 Cloud-Based Repository (All User Stories)

- Usage: Yes
- Application: The cloud-based repository serves as a central platform for exchanging XR content across all user stories. It enables seamless sharing of resources, updates, and AI-generated results, ensuring that all relevant user stories have access to the latest content and training material.

T5.3 Hololight Hub (All User Stories)

- Usage: Yes
- Application: The Hololight Hub implements the cloud-based repository mentioned in T5.2, allowing for the efficient distribution of XR content and ensuring that users across different scenarios can access updated and personalized content easily.

T5.4 Training Programs (All User Stories)

- Usage: Yes
- Application: Training programs are a critical part of the project, converting existing web-based training lessons into immersive XR-based experiences. This component is vital for ensuring that workers receive up-to-date, interactive training that mirrors real-world applications, enhancing their preparedness for tasks like assembly, commissioning, and maintenance.

6.2. Summary of Main Discussion Points on Technical Components

The XR5.0 project integrates a wide array of technical components to create a dynamic, personalized learning and problem-solving environment. The use of workers' digital twins, personalized XR content, and AI-driven visualizations provides users with real-time, tailored guidance across different tasks. Meanwhile, cloud-based repositories and immersive training programs ensure continuous learning and content sharing, optimizing the worker experience across all relevant user stories.

7. Software And Hardware Analysis

The XR5.0 project incorporates both software and hardware to facilitate immersive, interactive, and human-centered applications in industrial settings, particularly in the fields of assembly line production and robotic commissioning. KUKA, a key player in this project, provides two primary use cases (UC 1.1 and UC 1.2), each utilizing advanced XR technologies to enhance the user experience through augmented reality (AR), mixed reality (MR), and generative AI (Table 7).

Table 7 – Software & Hardware

Pilot #	Pilot Description (Responsible)	Software	XR Devices
1	**Rapid Human Centric AI-Enabled Product Design** **KUKA** is a leading provider of systems for the assembly and testing of vehicle powertrain components, as well as the robotautomated assembly of prefabricated building elements. For the XR5.0 project, KUKA is providing two Use Cases: **UC 1.1 – Personalised XR in Assembly Line Production** Real- an AR content are MR-based provided in XR-Devices • to enable remote assistance supported by tech. experts • to guide technicans and engineers through the machinerie • to view additional information regarding sensors, actors and other components • to provide howtos, checklists and step by step guidelines **UC 1.2 - Virt. Commissioning and gen. AI in Robotics** MR-technologie is used to provide an immersive and interactive experience in training and commissioning scenarios	The current favourites are: - Hololight Stream/Hub* - alternativ: Oculavis SHARE	The current favourites are: - Hololense 2 (Microsoft) - Magic Leap 2 (Megic Leap AR)

7.1. Analysis of Software and Hardware Components

This analysis focuses on the software and hardware elements being used in the project, detailing how they contribute to the functionalities described in the pilot use cases.

7.1.1. Software for XR Devices:

Use Case 1.1 – Personalised XR in Assembly Line Production

- Application: In this use case, AR and MR-based content is delivered through XR devices to provide various functionalities that assist technicians and engineers during assembly line production.
  - Remote Assistance: Technicians receive real-time support from technical experts via XR devices, enabling smoother communication and troubleshooting. Remote experts can view the same AR or MR content as the onsite workers, providing guidance to solve technical problems in real time.
  - Guided Navigation Through Machinery: The software guides users through complex machinery, showing relevant components such as sensors and actuators in real time. This reduces the cognitive load on users by making it easier to locate and interact with specific parts of the machinery.
  - How-Tos and Checklists: Users can access step-by-step guidelines, instructional videos, and checklists directly through the XR device. This feature is particularly useful for ensuring that assembly procedures are followed correctly, improving both efficiency and accuracy.

Use Case 1.2 – Virtual Commissioning and Generative AI in Robotics

- Application: In UC 1.2, MR technology creates an immersive and interactive experience for users in training and commissioning scenarios.

  - Immersive Training: Workers are trained in virtual environments that mimic real-life robot commissioning scenarios. This allows for hands-on practice without the need for physical components, reducing both training costs and risks associated with real-world training.
  - Interactive Commissioning: MR applications are used during robot commissioning, providing real-time visual feedback and interaction with the system's virtual components. This helps workers better understand the robotic systems they are commissioning.

- Generative AI Integration: Generative AI is used to create virtual 3D models and simulations that enhance the realism and interactivity of the training and commissioning environments.

Preferred Software Solutions:

- Hololight Stream/Hub: This software enables the streaming and management of high-quality MR content, which is critical for delivering complex interactive experiences in real time. Hololight's solutions are ideal for use cases requiring detailed visualizations, such as in remote assistance and robot commissioning.
- Alternative: Oculavis SHARE: Oculavis SHARE is another solution being considered for remote assistance. It is focused on providing collaborative solutions that allow technical experts to support onsite workers remotely, guiding them through repairs and maintenance using AR/MR content.

7.1.2. Hardware Analysis:

Hololens 2 (Microsoft)

- Application: The Hololens 2 is a mixed reality headset that offers a hands-free, immersive experience, making it highly suitable for both UC 1.1 and UC 1.2. In assembly lines, the Hololens 2 allows technicians to interact with digital content overlaid on physical components, facilitating tasks like remote assistance and step-by-step assembly guidance. In commissioning scenarios, it enables users to engage with virtual simulations of robotic systems, enhancing training and commissioning efficiency.
- Key Features:
    - High-resolution holographic content
    - Eye-tracking and hand-tracking for natural interactions
    - Comfortable design for extended use

Magic Leap 2 (Magic Leap AR)

- Application: Magic Leap 2 is another option being considered for the project. This device also provides AR and MR capabilities with a focus on enhanced field-of-view and lightweight design, making it an excellent tool for both assembly line production (UC 1.1) and robot commissioning (UC 1.2). Its ability to display high-quality AR content helps in guiding users through complex tasks while offering interactive simulations for training purposes.
- Key Features:
    - Wide field of view and high brightness for better visibility in various lighting conditions
    - Compact and lightweight, suitable for long-term wear
    - Strong AR capabilities for displaying real-time data and interactive content

7.2. Summary

The combination of advanced software and hardware in the XR5.0 project provides a robust and immersive platform for enhancing productivity and training in industrial settings. The use of software solutions like Hololight Stream/Hub and Oculavis SHARE ensures that workers have access to real-time AR and MR content, enabling remote assistance, interactive training, and detailed step-by-step guidance. Meanwhile, hardware like the Hololens 2 and Magic Leap 2 delivers a seamless mixed reality experience, allowing workers to interact with digital twins, generative AI models, and complex machinery in a hands-free, intuitive manner. Together, these technologies are driving the development of more efficient, user-centered processes in

8. Analysis of the Pilot Readiness and Support

The following analysis provides insights into the current state and future objectives of a KUKA-led pilot project that integrates XR technologies to enhance commissioning and service activities (Figure 3). The project is currently in the early stages of development, and this document outlines the necessary steps to advance to higher technology readiness levels (TRL), as well as addressing important ethical concerns and upcoming plans for demonstration events.

Figure 3 - Current state and future objectives

A) What is the current TRL level of the pilot and how is it planning to reach TRL7/8?

The TRL level achieved is currently TRL 2-4.
To reach TRL 7/8, the core functionalities should be implemented.

B) What is the concrete pilot objective and how can the consortium further support its achievement? (from KUKA side)

KUKA wants to use XR technologies to support technicians in the commissioning and service activities with augmented component related information and remote assistance. The aim is to enable efficient execution by providing information that can be used for faster trouble shooting

An important requirement is to enable the XR system to access real-time data:
- Reading and visualizing process (sensor) values from PLC
- Providing metadata (Manufacturer, order numbers, delivery time, SAP connectivity, etc.)

C) Relevant Ethical issues

The personal data collected by the XR-Device is not allowed to:
A) ... violate the personal rights of the employee
B) ... be used to evaluate the employee's work performance

D) Are you willing to host a GA at your premises to let us understand how your pilot really works?

Yes, a GA will happen from 4 to 6 February 2024 in Bremen.

A) Current TRL Level and Plan to Reach TRL 7/8

- Current TRL Level: The pilot is currently at TRL 2-4, which indicates that the technology has progressed through concept validation in a lab setting but is not yet fully mature for operational environments.
- Path to TRL 7/8: To achieve TRL 7/8, which requires system prototype demonstrations in an operational environment, the pilot needs to implement the core functionalities of the system. This includes integrating the XR technology into practical use cases where it can support technicians in service and commissioning activities with augmented reality (AR) assistance.

B) Concrete Pilot Objective and Consortium Support (KUKA's Perspective)

- Objective: KUKA aims to leverage XR technologies to assist technicians during commissioning and servicing tasks. By using augmented information that is related to components and providing remote assistance, the system will enable technicians to work more efficiently, with reduced troubleshooting times.
- Requirements:
    - The system must have the capability to access real-time data for tasks like:
        - Reading and visualizing sensor data from the PLC (Programmable Logic Controller).
        - Providing metadata about components (manufacturer details, order numbers, delivery time, SAP connectivity, etc.).

C) Relevant Ethical Issues

- Personal Data:
    - The personal data collected by XR devices must comply with ethical guidelines. Specifically:
        - A) It must not violate the personal rights of the employee.
        - B) It cannot be used for evaluating employee performance, ensuring that the XR system is strictly used for technical purposes rather than for monitoring or assessing workers.
        -

D) General Assembly (GA) Hosting

- KUKA's Readiness: KUKA has agreed to host a General Assembly (GA) from 4 to 6 February 2024 in Bremen. This event will give attendees a chance to understand how the pilot works in real-world settings.

E) Other Issus

Following the discussion between KUKA and SUPSI, a potential application for the Human Digital Twin (HDT) has been identified in the context of autonomous mobile robotics (AMR). The HDT will be utilized to predict the intentions of one or multiple workers who share a workspace with an AMR equipped with a 6-axis (+1) industrial robot.

The primary focus of the intention recognition system will be to forecast the movement paths of workers within the shared workspace. This predictive capability could serve two critical purposes:

- Support path planning for the AMR
- Facilitate timely activation of safety procedures, such as speed reduction

In this pilot, SUPSI will develop and provide the HDT for monitoring workers and predicting their movements. The specific output format for the intention recognition system will be further defined in the coming months (it could be a heatmap, a vector field representation or something similar)

The HDT model will incorporate various data points, that could include human features like current worker location, worker speed, body orientation, head orientation and contextual features, assigned tasks, workstation positions.

The system validation is expected to take place in a mixed reality scenario, where the AMR will be simulated within the actual workspace.

In conclusion, the pilot is focused on understanding the technological limits of XR and AI solutions in a real-world context, aiming for a fully operational system in field environments. The consortium's role will be crucial in providing the technical and logistical support necessary to meet these objectives while ensuring the smooth progression toward TRL 7/8.

The KUKA pilot project demonstrates significant potential for utilizing XR technologies to enhance the efficiency of technicians during commissioning and service tasks. Currently at TRL 2-4, the pilot requires the integration of core functionalities—such as real-time data visualization and augmented metadata access—to reach TRL 7/8, where it can be fully operational in real-world environments.

Key objectives include leveraging XR to provide remote assistance, sensor data visualization, and component-specific metadata, which are essential for troubleshooting and improving task performance. The consortium can support these efforts by focusing on implementing these functionalities and ensuring seamless data access between XR systems and industrial hardware (PLC systems).

ANNEX II – WORKSHOP DETAILS FOR PILOT 2

Human Centered Remote Maintenance and Asset Management

Motivation: Remote maintenance of laboratory instruments is essential for the smooth operation of industrial processes. Industrial environments use complex instruments that require regular maintenance and calibration to avoid downtime and production delays. To this end, many industrial enterprises are already using XR technologies for more efficient and cost- effective remote maintenance through virtual access to instruments in remote or hard-to-reach areas. State of the art XR technologies enable technicians to diagnose and resolve issues remotely, in ways that reduce downtime and save time and money. Nevertheless, as instruments grow in complexity, XR applications must improve in terms of the richness and specialization of information that they provide to their end-users. To this direction, XR5.0 could improve the personalization, relevance, and accuracy of the XR environments, based on its AI-driven functionalities (e.g., explanations about human maintenance processes) and their human centric DTs.

Concept & Description: SH, established in 1864, is one of the leading suppliers in its field with its polarimeters, refractometers, laboratory and online analytics, and automation solutions for optical-electronic measurement technology. The measuring instruments are used in various industries (e.g., agriculture, automotive, aviation, chemical, pharmaceuticals) in over 80 countries, making their service expensive and complex. This pilot will allow SH to optimise its service, offering personalised and rich AR solutions that enable the solution of complex problems remotely. The pilot will integrate specific maintenance workflows into OCU's SHARE software offering visual assistance. Moreover, SHARE will be extended to provide AI content produced by the human-AI collaboration (e.g., neurosymbolic learning, XAI) and by GenAI algorithms. The latter will foster increased personalisation and safety in remote maintenance applications.

Date	Name Contacts	email
July 19th	SH - Joshua Barbian OCU - Mathias Horner UPRC - George Makridis	j.barbian@schmidt-haensch.de horner@oculavis.de gmakridis@unipi.gr
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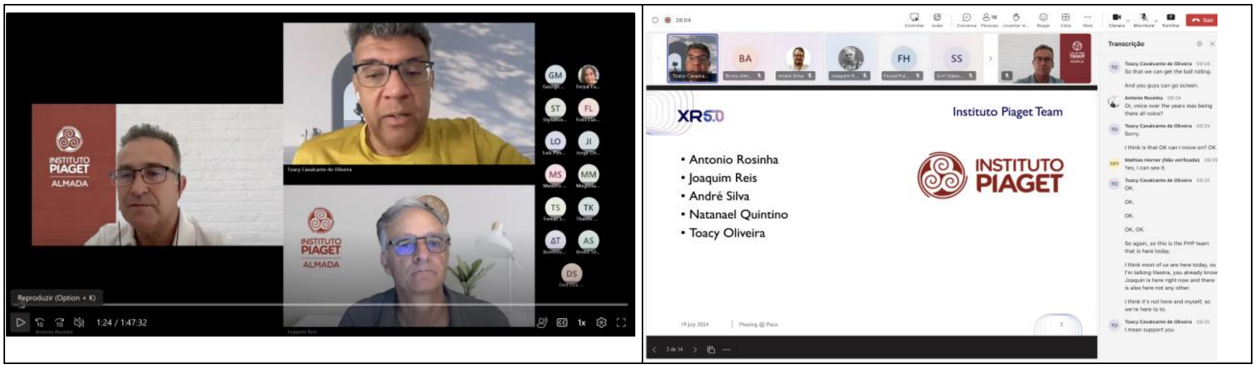


1. General Context

The Pilot 2 SH project seeks to leverage AI to capture service technicians' expertise, reducing reliance on in-person work. This addresses challenges like a skilled labor shortage in Germany and upcoming retirements of experienced staff. The AI copilot enhances communication between experts and field technicians, optimizing maintenance through devices like smartphones, laptops, and smart glasses. Hosted locally, the AI ensures secure handling of sensitive data without cloud reliance.

1.1.Project Objectives:

1. Efficient Utilization of Technician Knowledge: The main objective is to maximize the knowledge of experienced technicians while minimizing the need for extensive documentation in PDF files.
2. Reduction of On-Site Service Work: The goal is to decrease on-site service work by more than 50%, enhancing the efficiency of remote operations.
3. AI Empowerment: AI will be trained to learn from each technician interaction, including emails and service tests, aiming to develop a knowledge base equivalent to that of the most experienced technicians over the years.
4. Remote Support: Experienced technicians will work from headquarters, assisting less experienced field technicians through virtual assistance solutions.

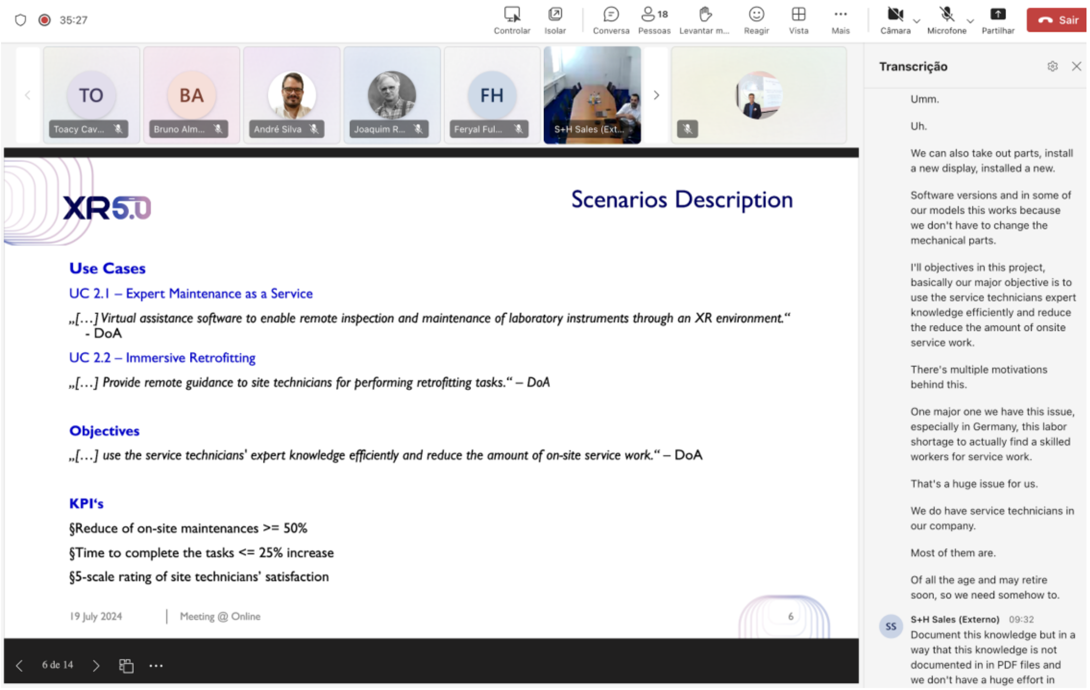
1.2.Challenges and Motivations

1. Skilled Labor Shortage: Finding qualified workers for service roles is a major challenge, exacerbated by the advanced age of many current technicians who are nearing retirement.
2. Knowledge Documentation: Traditional documentation methods are seen as inefficient, and there is an effort to develop alternative methods for knowledge transfer.
3. Support for Less Experienced Technicians: Remote assistance aims to provide effective support to field technicians, reducing the need for frequent travel by more experienced technicians.

1.3.Priorities and User Stories

The project aims for a significant transformation in how technical knowledge is managed and applied, using AI to maximize efficiency and reduce the reliance on on-site services. This not only addresses the skilled labor shortage but also prepares the company for a future where technical knowledge can be accessed and utilized more efficiently and integratively.

2. Use Case



UC 2.1 – Expert Maintenance as a Service

Description: "Virtual assistance software to enable remote inspection and maintenance of laboratory instruments through an XR environment." - DoA

Objective: The primary goal is to leverage virtual assistance software within an extended reality (XR) environment to facilitate remote inspection and maintenance of laboratory instruments. This approach aims to utilize the expertise of seasoned technicians efficiently while reducing the need for on-site service work.

Key Features:

1. Virtual Assistance Software:
   - Employs XR technology to create an immersive environment that simulates physical presence for maintenance tasks.
   - Allows experts to guide on-site technicians remotely, providing visual and interactive support.
2. Remote Inspection:
   - Enables experts to inspect instruments in real-time, identifying issues and providing immediate solutions without being physically present.
   - Uses high-resolution visuals and XR tools to conduct thorough inspections.
3. Maintenance Guidance:
   - Provides step-by-step instructions to on-site technicians, enhancing the quality and consistency of maintenance procedures.
   - Experts can demonstrate techniques using virtual tools within the XR environment.
4. Collaboration Tools:

- o Integrates real-time communication tools (video, voice, text) to facilitate effective collaboration between remote experts and on-site technicians.
- o Ensures seamless interaction and immediate feedback during maintenance tasks.

Challenges Addressed:

- Expertise Accessibility:
  - o Solves the problem of limited access to expert knowledge, particularly in remote or underserved locations.
  - o Ensures high-level expertise is available regardless of geographic constraints.
- Efficiency and Downtime Reduction:
  - o Decreases the need for travel, allowing experts to manage and support multiple sites more efficiently.
  - o Minimizes instrument downtime by providing prompt maintenance and troubleshooting.

Benefits:

- Cost Savings:
  - o Reduces travel expenses and the need for frequent on-site visits by experts.
  - o Optimizes resource allocation, enabling experts to handle more tasks remotely.
- Enhanced Maintenance Quality:
  - o Improves the accuracy and thoroughness of inspections through detailed XR visualizations.
  - o Provides consistent and standardized maintenance procedures across various locations.

UC 2.2 – Immersive Retrofitting

Description: "Provide remote guidance to site technicians for performing retrofitting tasks." - DoA

Objective: The goal is to offer remote guidance to site technicians for retrofitting tasks using immersive technology, such as augmented reality (AR) and virtual reality (VR). This approach aims to bridge the skill gap and optimize the use of expert resources.

Key Features:

1. Immersive Guidance:
   - o Utilizes AR/VR technology to overlay virtual instructions and markers onto the physical environment.
   - o Enables experts to guide technicians through retrofitting tasks in real-time.
2. Real-Time Support:
   - o Allows experts to see what the technicians see, providing immediate feedback and corrections.
   - o Ensures accurate execution of retrofitting tasks through live, interactive support.
3. Detailed Instructions:
   - o Offers comprehensive, visual instructions for complex retrofitting procedures.
   - o Includes interactive elements for technicians to follow step-by-step.
4. Enhanced Training:
   - o Acts as a training tool, helping technicians learn retrofitting procedures without extensive in-person training sessions.
   - o Facilitates knowledge transfer from experienced experts to less experienced technicians.

Challenges Addressed:

- Skill Gaps and Training:
  - o Addresses the skill gap by providing hands-on guidance and training remotely.
  - o Reduces the learning curve for technicians performing retrofitting tasks for the first time.
- Resource Optimization:

- o Optimizes the use of expert resources by enabling them to assist with multiple retrofitting projects simultaneously.
- o Reduces the need for experts to be physically present at each site.

Benefits:

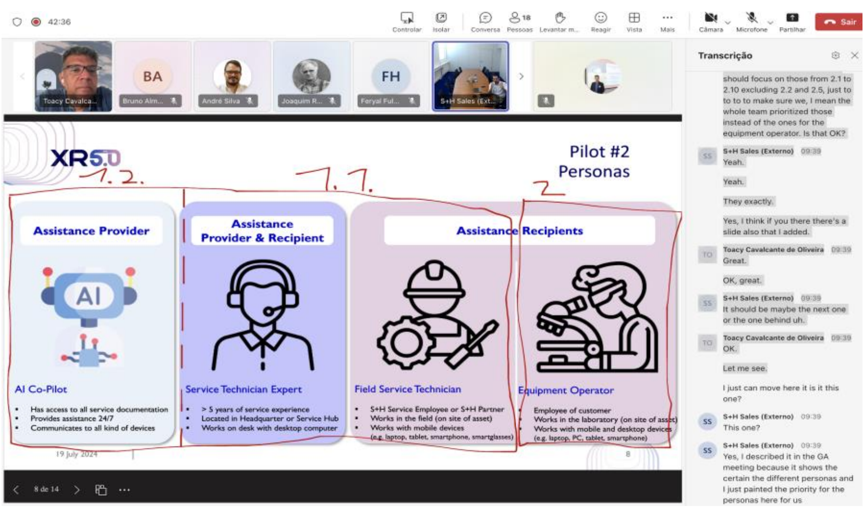
- Increased Efficiency:
  - o Accelerates retrofitting tasks by providing precise and immediate guidance.
  - o Reduces errors and rework, ensuring retrofitting is done correctly the first time.
- Cost-Effective Solutions:
  - o Lowers the costs associated with retrofitting by reducing the need for expert travel and on-site presence.
  - o Maximizes the utilization of expert knowledge and experience.
- Scalable Training and Support:
  - o Allows for scalable training programs that can reach multiple technicians across different locations.
  - o Ensures a consistent level of expertise and quality in retrofitting tasks.

Both use cases focus on leveraging immersive technologies to enhance the efficiency and quality of maintenance and retrofitting tasks. By using XR and AR/VR environments, the solutions aim to provide expert guidance and support remotely, addressing challenges related to expertise accessibility, training, and resource optimization. These approaches not only reduce costs and downtime but also ensure consistent and high-quality outcomes across various sites.

3. Persona Analysis

In the following sections, we will delve into the key personas and essential aspects of our project. These personas play pivotal roles in achieving the project's objectives and ensuring efficient maintenance operations. For a comprehensive understanding, please refer to Figure 1, which visually represents the various personas and their interactions within the scenario.

Figure 1 - Personas within the scenario



3.1. Personas

1. **Service Technician Expert**
   - o Role: Highly experienced technician working primarily from the headquarters. This persona is responsible for creating comprehensive training modules, developing a centralized knowledge base, and providing remote assistance using AR technology. The

expert may also receive support from the AI copilot for enhanced troubleshooting and decision-making.
- Primary Focus: Provides remote assistance and expert guidance to field technicians.
- Objective: Utilize expertise to solve complex issues without needing to travel, ensuring efficiency and leveraging their knowledge across multiple sites.
- Tools: Virtual assistance software, AR visualizations, centralized knowledge base.
- Attributes:
  - More than five years of service experience within the company.
  - Located at the headquarters or a service hub.
  - Works at a desk with a desktop computer.
  - Provides and receives assistance.

2. **Field Service Technician**
   - Role: Technicians working on-site, less experienced compared to the Service Technician Expert. This persona is engaged in performing maintenance and repairs on-site. They rely on AR content, real-time communication with experts, and step-by-step instructions to carry out their tasks efficiently.
   - Primary Focus: Conduct on-site maintenance and repairs with the support of remote experts.
   - Objective: Quickly and effectively address issues on-site, using AR aids and real-time communication with experts.
   - Tools: AR content, step-by-step instructions, real-time communication devices.
   - Attributes:
     - Typically an employee or partner of Schmitt and Henge.
     - Works on-site, directly at the location of the equipment.
     - Utilizes mobile devices such as laptops, tablets, smartphones, and potentially smart glasses.
     - Receives assistance

3. **Equipment Operator**
   - Role: End-users of the equipment, responsible for basic operations and minor troubleshooting. This persona is involved in the day-to-day operation of the equipment. They may eventually benefit from the AI copilot and AR instructions, but this will only be implemented after thorough validation with company employees and partners.
   - Primary Focus: Operate the equipment efficiently and perform simple maintenance tasks.
   - Objective: Resolve minor issues independently before escalating to technical support, enhancing self-sufficiency.
   - Tools: User-friendly AR guided instructions, quick communication links to experts, accessible knowledge base.
   - Attributes:
     - An employee of the customer.
     - Works in a laboratory setting with access to mobile and desktop devices.
     - Not a current priority for smart glasses integration due to cost considerations.
     - Receives assistance.

4. **AI Copilot**
   - Role: A digital persona providing augmented assistance through AI. he AI copilot aids both the service technician expert and the field service technician by offering troubleshooting solutions, training support, and other assistance. It is crucial for improving operational efficiency and reducing the need for on-site maintenance.

- Primary Focus: Enhance the capabilities of both service technicians and field technicians by offering predictive maintenance suggestions, troubleshooting support, and real-time data analysis.
- Objective: Improve the efficiency and accuracy of maintenance tasks, reducing dependency on human experts.
- Attributes:
  - Provides assistance 24/7.
  - Can communicate with various devices (desktop computers, smartphones, laptops, smart glasses).
  - Learns from both structured and unstructured data.

3.2. Key Aspects

- Priority Personas: The focus is primarily on the Service Technician Expert and Field Service Technician, with the Equipment Operator being a lower priority for now.
- Integration of AI: The AI Copilot acts as a digital assistant, enhancing the capabilities of human technicians by providing additional support and predictive insights.
- Scenarios and Prioritization: The main scenarios involve remote guidance and AR-based support to optimize maintenance operations. User stories are prioritized based on their impact and feasibility, with an emphasis on scenarios that enhance remote assistance and AR integration.
- Objective Alignment: The primary goals are to reduce on-site service work by at least 50%, limit the increase in task completion time to 25%, and ensure high satisfaction among field technicians through effective training and support.

These personas are critical for understanding the different user roles and their specific requirements in the context of our project. Their interactions and dependencies are essential for designing effective solutions that meet their needs and enhance overall operational efficiency.

4. User Stories X Scenarios

4.1. Introduction to the User Stories

The following figure and table (Figure 2, Table 1) outlines the user stories for the virtual assistance project, detailing the roles, their needs, the expected outcomes, and the prioritization of each story. This structured approach ensures that the development focuses on the most critical aspects first, aligning with the project's objectives to efficiently utilize expert knowledge and reduce on-site service work.

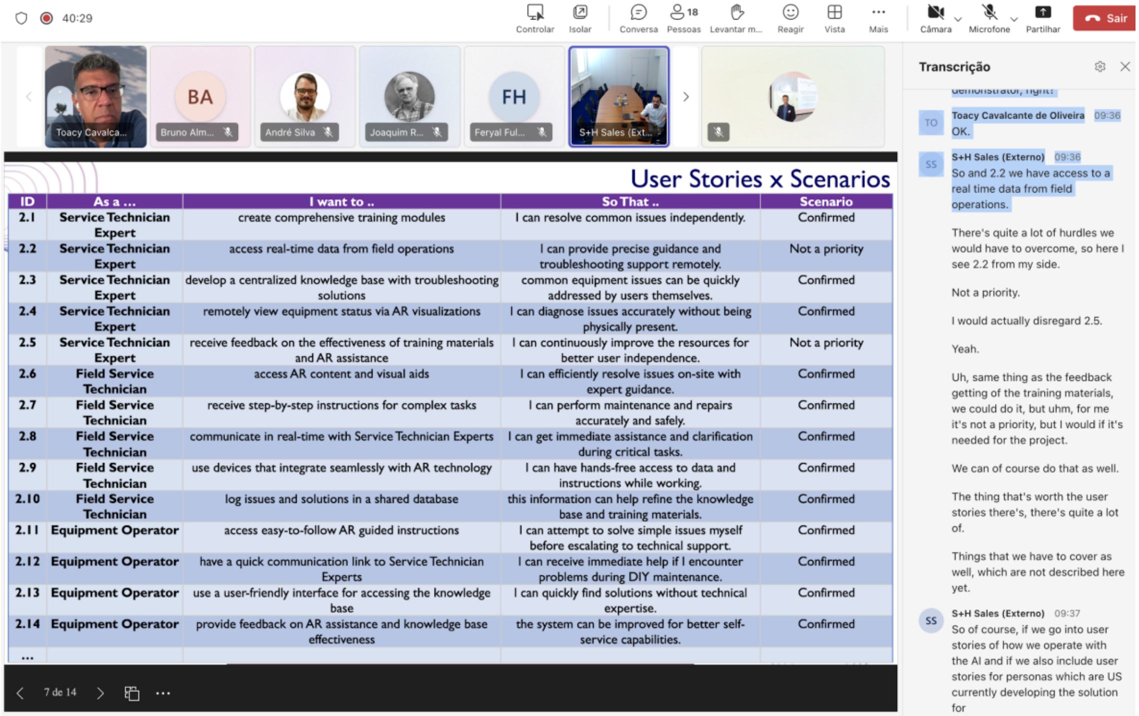


Table 1 - User Stories ID

ID	As a ...	I want to ...	So That ...	Scenario	Priority
2.1	Service Technician Expert	create comprehensive training modules	I can resolve common issues independently.	Confirmed	High
2.2	Service Technician Expert	access real-time data from field operations	I can provide precise guidance and troubleshooting support remotely.	Not a priority	Low
2.3	Service Technician Expert	develop a centralized knowledge base with troubleshooting solutions	common equipment issues can be quickly addressed by users themselves.	Confirmed	High
2.4	Service Technician Expert	remotely view equipment status via AR visualizations	I can diagnose issues accurately without being physically present.	Confirmed	Very Highest
2.5	Service Technician Expert	receive feedback on the effectiveness of training materials and AR assistance	I can continuously improve the resources for better user independence.	Not a priority	Low
2.6	Field Service Technician	access AR content and visual aids	I can efficiently resolve issues on-site with expert guidance.	Confirmed	High
2.7	Field Service Technician	receive step-by-step instructions for complex tasks	I can perform maintenance and repairs accurately and safely.	Confirmed	High
2.8	Field Service Technician	communicate in real-time with Service Technician Experts	I can get immediate assistance and clarification during critical tasks.	Confirmed	Very Highest
2.9	Field Service Technician	use devices that integrate seamlessly with AR technology	I can have hands-free access to data and instructions while working.	Confirmed	High

ID	As a …	I want to …	So That …	Scenario	Priority
2.10	Field Service Technician	log issues and solutions in a shared database	this information can help refine the knowledge base and training materials.	Confirmed	High
2.11	Equipment Operator	access easy-to-follow AR guided instructions	I can attempt to solve simple issues myself before escalating to technical support.	Confirmed	Medium
2.12	Equipment Operator	have a quick communication link to Service Technician Experts	I can receive immediate help if I encounter problems during DIY maintenance.	Confirmed	Medium
2.13	Equipment Operator	use a user-friendly interface for accessing the knowledge base	I can quickly find solutions without technical expertise.	Confirmed	Medium
2.14	Equipment Operator	provide feedback on AR assistance and knowledge base effectiveness	the system can be improved for better self-service capabilities.	Confirmed	Medium

Highest Priority

- 2.8: Field Service Technician
  - As a: Field Service Technician
  - I want to: communicate in real-time with Service Technician Experts
  - So That: I can get immediate assistance and clarification during critical tasks.
  - Explanation: This user story directly impacts the efficiency and effectiveness of field operations, reducing downtime and ensuring issues are resolved quickly with expert input.

High Priority

- 2.4: Service Technician Expert
  - As a: Service Technician Expert
  - I want to: remotely view equipment status via AR visualizations
  - So That: I can diagnose issues accurately without being physically present.
  - Explanation: This enables experts to diagnose and troubleshoot issues without the need to travel, saving time and resources.

4.2. Summary of Key Decisions

- The highest priority user stories involve the roles of Field Service Technicians (2.8) and Service Technician Experts (2.4), ensuring efficient resolution of issues through remote assistance and comprehensive training.
- The implementation of the virtual assistance software (UC 2.1) and the development of centralized knowledge bases are critical.
- User stories related to feedback on training materials and real-time data access from field operations (UC 2.2 and UC 2.5) are of lower priority.
- The KPIs established aim to significantly reduce on-site maintenance, control the increase in task completion time, and ensure high satisfaction among field service technicians.

5. KPIs

Below is figure 3 and table 2 highlighting some of the most important KPIs, including their descriptions and concrete examples of statements related to each KPI.

Figure 3 – Acceptance/Success Criteria

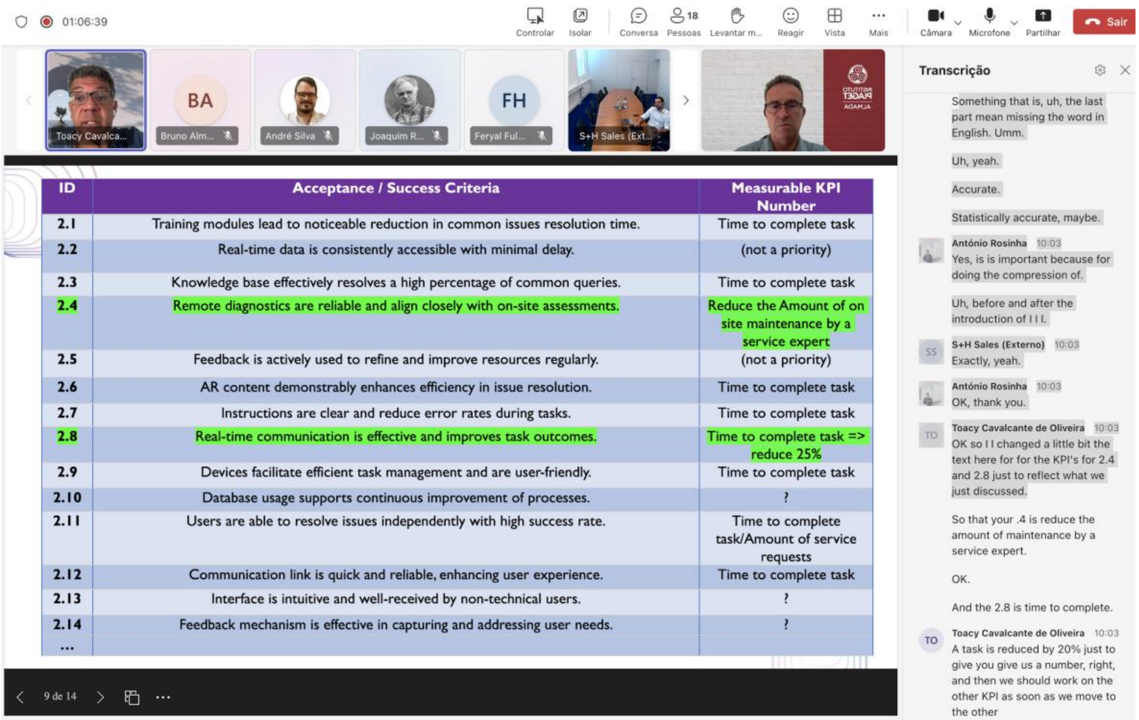


Table 2 - Key Performance Indicators

KPI	Description	Concrete Example of Statement
Time to Complete Task	Measures the duration taken to finish a specific task.	"Our main KPI is to reduce on-site maintenance time by 50%."
Reduce On-Site Maintenance	Decreases the need for on-site service expert interventions.	"We aim to reduce on-site maintenance by a service expert by 30%."
Amount of Service Requests	Tracks the number of service requests submitted by users.	"We monitor the number of service requests to ensure efficient problem resolution."
User Satisfaction	Assesses the level of user satisfaction with a product or service.	"Customer satisfaction score is a key KPI to ensure quality service."
Efficiency Improvement	Measures the improvement in process efficiency.	"Our KPI is to enhance efficiency by 25% in the next quarter."

Key Performance Indicators (KPIs) were selected to measure and evaluate the success of the project in achieving its strategic and operational goals. The most important KPIs identified include:

1. Time to Complete Task: This KPI measures the duration taken to finish specific tasks. It is crucial for evaluating the efficiency and effectiveness of training modules, knowledge base

usage, and real-time communication. Reducing task completion time is a high priority across multiple user stories.
2. Reduce On-Site Maintenance: This KPI aims to decrease the need for on-site service expert interventions. It is particularly relevant for assessing the reliability of remote diagnostics and the effectiveness of AR content in resolving issues, both of which are high priority.
3. Amount of Service Requests: Tracking the number of service requests helps monitor the ability of users to resolve issues independently. This KPI is essential for ensuring that the support system and resources provided are effective.
4. User Satisfaction: Although not explicitly listed in the user stories, this KPI is implied in the overall objective of improving user experience and ensuring that solutions are well-received by users, including non-technical ones.
5. Efficiency Improvement: This KPI measures improvements in process efficiency, which is a core goal of implementing training modules, a knowledge base, and AR content.

The prioritization of these KPIs ensures that the project focuses on areas with the greatest impact on efficiency, user satisfaction, and the reduction of on-site interventions, thereby aligning resources effectively to achieve strategic objectives.

5.1.Classification of User Stories by Priority Level

The following table classifies user stories by their priority level, including additional information such as analysis and the related KPI.

Table 3 – Classification of user stories by priority level

User Story ID	Description	Related KPI	Priority
2.1	Training modules lead to noticeable reduction in common issues resolution time.	Time to Complete Task	High
2.2	Real-time data is consistently accessible with minimal delay.	(Not a priority)	Low
2.3	Knowledge base effectively resolves a high percentage of common queries.	Time to Complete Task	High
2.4	Remote diagnostics are reliable and align closely with on-site assessments.	Reduce On-Site Maintenance	High
2.5	Feedback is actively used to refine and improve resources regularly.	(Not a priority)	Low
2.6	AR content demonstrably enhances efficiency in issue resolution.	Time to Complete Task	High
2.7	Instructions are clear and reduce error rates during tasks.	Time to Complete Task	High
2.8	Real-time communication is effective and improves task outcomes.	Time to Complete Task => Reduce 25%	High
2.9	Devices facilitate efficient task management and are user-friendly.	Time to Complete Task	High
2.10	Database usage supports continuous improvement of processes.	?	Medium
2.11	Users are able to resolve issues independently with high success rate.	Time to Complete Task/Amount of Service Requests	High
2.12	Communication link is quick and reliable, enhancing user experience.	Time to Complete Task	High
2.13	Interface is intuitive and well-received by non-technical users.	?	Medium

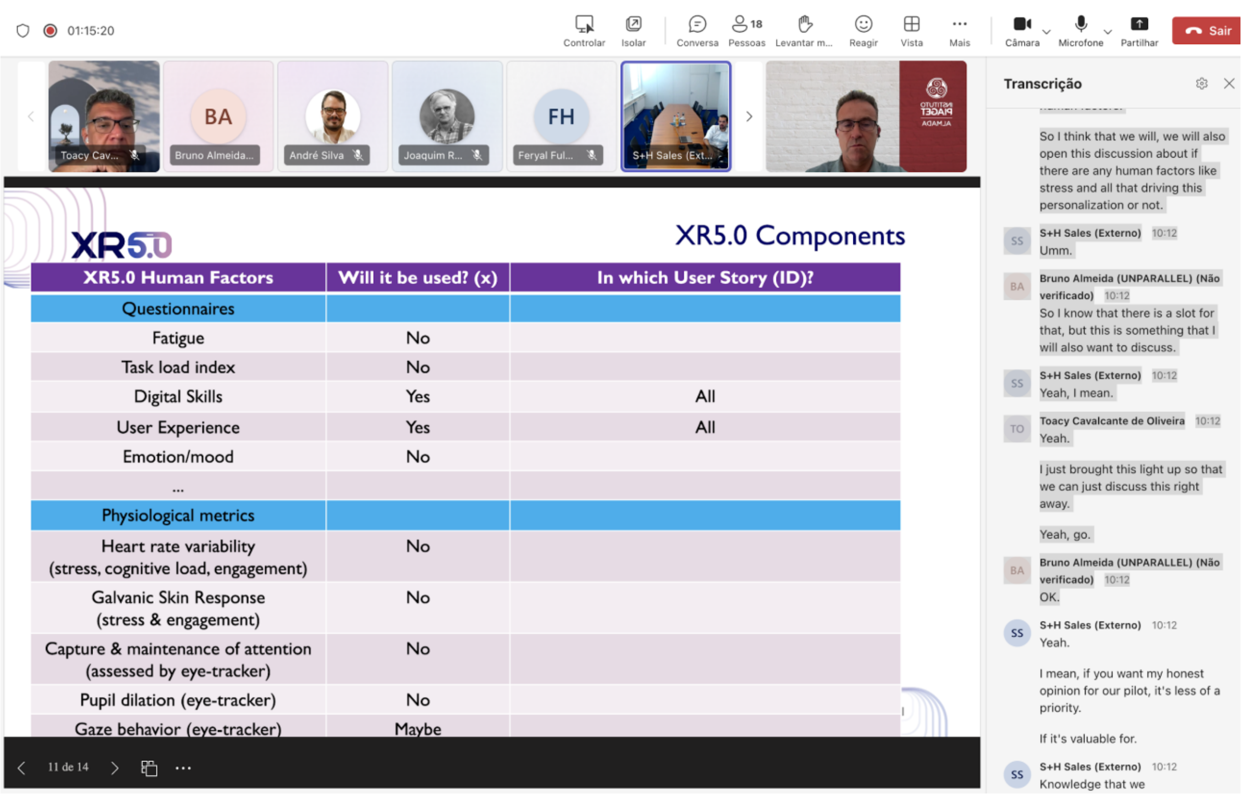
User Story ID	Description	Related KPI	Priority
2.14	Feedback mechanism is effective in capturing and addressing user needs.	?	Medium

This classification helps prioritize areas of greatest impact and ensures that resources are allocated efficiently to achieve the strategic objectives of the project.

6. Human Factors

Human factors are critical in designing effective systems that users can interact with efficiently and comfortably. In the context of the XR5.0 project, prioritizing human factors ensures that the technological components are not only functional but also user-friendly and capable of enhancing the overall user experience. The figure 4 and table 4 below details the human factors that will be used, their applicability to specific user stories, and a brief description of each factor.

Figure 4 – XR5 Human Factors



6.1. Prioritization of human factors

The prioritization of human factors in the XR5.0 project highlights the commitment to creating a user-centered system (Tabel 4). By focusing on user experience, digital skills, and collecting feedback through questionnaires, the project aims to enhance usability and ensure that the technology is accessible to all users.

Table 4 - Prioritization of Human Factors

Human Factor	Will Be Used?	In Which User Story (ID)?	Description
Questionnaires	Yes	All	Used to gather subjective user feedback on various aspects of the system.
Fatigue	No	-	Not considered critical for current project scope.
Task Load Index	No	-	Not considered critical for current project scope.
Digital Skills	Yes	All	Assessing users' digital literacy to tailor training and support materials.
User Experience	Yes	All	Evaluating overall satisfaction and usability of the system.
Emotion/Mood	No	-	Not prioritized for current implementation.
Physiological Metrics	No	-	Not prioritized for current implementation.
Heart Rate Variability	No	-	Measures stress, cognitive load, and engagement but not used in this phase.
Galvanic Skin Response	No	-	Measures stress and engagement but not used in this phase.
Capture & Maintenance of Attention	No	-	Assessed by eye-tracker but not used in this phase.
Pupil Dilation (eye-tracker)	No	-	Not prioritized for current implementation.
Gaze Behavior (eye-tracker)	Maybe	-	Potentially useful for understanding user interaction but not decided yet.

Questionnaires and User Feedback:

- Implementation: Regularly administered questionnaires will gather valuable feedback from users, helping to identify pain points and areas for improvement. This data will guide iterative design changes and ensure continuous improvement.
- Impact: Direct feedback mechanisms empower users to contribute to the development process, fostering a sense of ownership and engagement.

Digital Skills Assessment:

- Implementation: Evaluating users’ digital skills will help customize training materials and support resources, ensuring that all users can effectively interact with the system regardless of their technical background.
- Impact: This targeted approach will reduce frustration and increase the efficiency of learning new tools, ultimately leading to higher productivity and satisfaction.

User Experience Evaluation:

- Implementation: Ongoing user experience assessments will ensure the interface remains intuitive and user-friendly. This includes usability testing and regular updates based on user feedback.
- Impact: A focus on user experience will result in a more seamless interaction with the system, reducing errors and enhancing overall satisfaction.

6.2. Analysis of Human Factors in User Stories

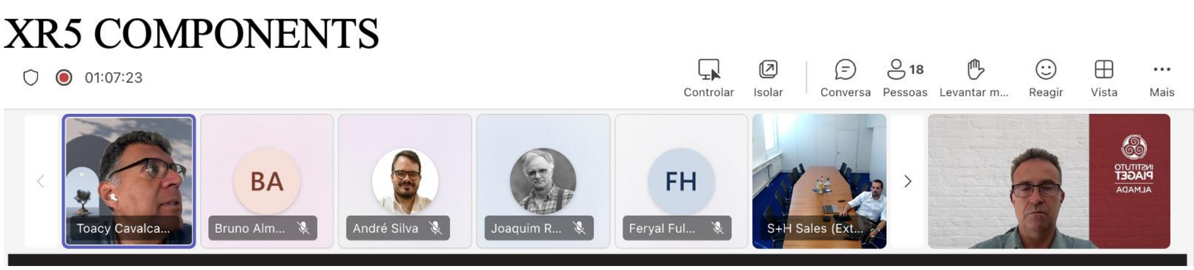
1. Questionnaires: These will be used across all user stories to collect qualitative data on user satisfaction, perceived ease of use, and overall experience with the system. They provide direct insights into user opinions and areas needing improvement.
2. Digital Skills: Assessing digital literacy is crucial for tailoring the training modules and support resources to match the varying levels of user expertise. This ensures that all users, regardless of their initial skill level, can effectively utilize the system.
3. User Experience: Continuously evaluating the user experience helps in identifying usability issues and improving the interface to make it more intuitive. This factor is essential across all user stories to ensure the system meets user needs and preferences.

By strategically prioritizing these human factors, the XR5.0 project aims to create a more effective, user-friendly system that meets the needs of its diverse user base. This approach will not only improve current implementation but also provide a robust foundation for future enhancements.

7. Technical Components

The use of different technical components of XR5.0 was discussed across various user stories. The discussion addressed the applicability of each technical component and how they contribute to achieving the objectives of the respective tasks (Figure 5).

Figura 5 – Technical component



Task	XR5.0 Technical Component	Will it be used?	In which User Story (ID)?
T3.3	Workers' digital twins	No	Use DT for the machine not for the Worker
T3.4	Personalized XR content	Yes	2.1, 2.3, 2.4, 2.6, 2.7, 2.8, 2.9, 2.11, 2.13
T4.1	Human-centered XAI models	No	
T4.2	XR-enabled Active Learning	(?)	
T4.2	Neurosymbolic AI models	(?)	
T4.3	Generative AI models	Yes	2.1, 2.3, 2.7, 2.11, 2.13
T4.4	Visualization of XAI explanations	Yes	2.1, 2.3, 2.4, 2.6, 2.7, 2.8, 2.9, 2.11, 2.13
T4.5	Visualization of AI recommendations	Yes	2.1, 2.3, 2.4, 2.6, 2.7, 2.8, 2.9, 2.11, 2.13
T5.1	Training material	Yes	2.1, 2.3, 2.7, 2.11, 2.13
T5.2	Cloud-based repository	Yes	
T5.3	Hololight Hub	No	
T5.4	Training programs	Yes	

7.1.Synthesis of Decisions on Technical Components

During the discussion, several key decisions were made regarding the use and implementation of various technical components in the project. The focus was on ensuring that all stakeholders (test leader, tech provider, and pilot) agree on the usage and integration of these components. Special attention was given to components like the digital twin and personalized content based on worker qualifications.

The following table summarizes the technical components discussed, whether they will be used, their related user stories, and additional details (Table 5).

Table 5 – XR5.0 Technical Components

Task	XR5.0 Technical Component	Will it be used?	In which User Story (ID)?	Details
3.3	Digital Twin	Yes	Multiple	Digital twin of equipment to document and maintain current status of the machine.
3.4	Personalized Exact Content	Yes	2.4, 2.8, etc.	Content tailored based on worker qualifications and experience, including language and specific skills.

These decisions ensure that the most relevant technical components are effectively integrated into the project, enhancing both the efficiency of the system and the user experience.

7.2.Discussion of Technical Components

The primary focus was to align the components with the project goals and ensure seamless integration among the stakeholders: the test leader, tech provider, and pilot. Here is a detailed discussion of the technical components:

7.2.1. Digital Twin

The digital twin is a critical component that was discussed in detail. It involves creating a digital replica of the equipment used in the field, which helps in documenting and maintaining the current status of the machine.

Usage and Implementation:

- Agreement on Use: It was confirmed that the digital twin will be used, but not for simulating workers. Instead, it will focus on the equipment itself.
- User Story Relevance: This component is relevant to user stories that require detailed, real-time data about equipment status, such as in tasks involving remote diagnostics and asset management.
- Details: The digital twin will document all activities related to the equipment, including repairs and status changes, ensuring a comprehensive digital representation of the machine.

Benefits:

- Efficiency: By having a real-time digital image, maintenance and troubleshooting can be conducted more efficiently without the need for physical presence.
- Documentation: Ensures all modifications and repairs are tracked, providing a clear history of the machine’s performance and issues.

7.2.2. Personalized Exact Content

The personalization of content based on worker qualifications and experience was another significant component discussed. This involves tailoring the training modules and informational content to match the individual needs of different workers.

Usage and Implementation:

- Agreement on Use: It was agreed that personalized content is essential and will be implemented based on worker qualifications and experience.
- User Story Relevance: This component supports user stories that focus on training and information dissemination, such as improving task outcomes and reducing error rates.
- Details: The content will be personalized based on qualifications (mechanical, electrical, etc.) and experience levels. Language customization is also a priority to cater to diverse user needs.

Benefits:

- Relevance: Ensures that workers receive the most pertinent information, enhancing their ability to perform tasks effectively.
- User Engagement: Tailored content increases user engagement and reduces confusion, leading to better performance and fewer errors.

7.2.3. Integration and Coordination

The discussion emphasized the need for coordination among the test leader, tech provider, and pilot to ensure these components are effectively integrated into the project.

Key Points:

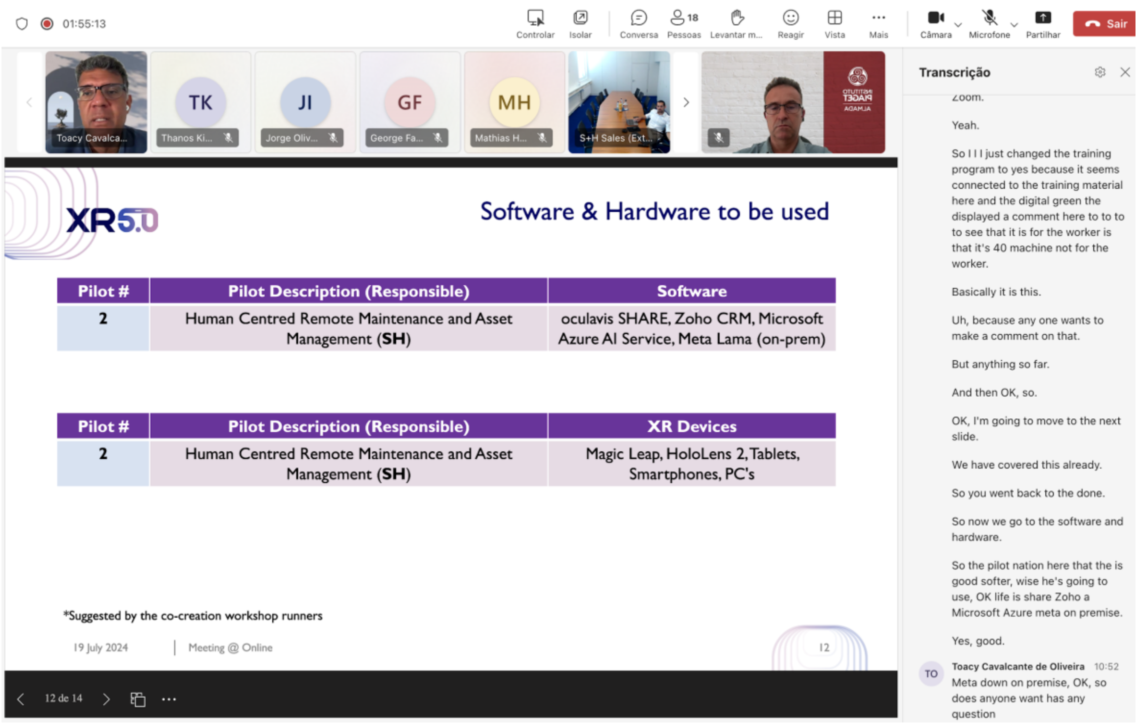
- Collaboration: All parties must agree on the implementation details and work together to troubleshoot and refine the components.
- Focus Areas: Special attention should be given to high-priority user stories (e.g., 2.4 and 2.8) to ensure they meet the project's strategic objectives.
- Future Discussions: Some aspects, like human factors (e.g., stress), will be discussed further to see how they can influence the personalization of content.

By focusing on these key technical components and ensuring a collaborative approach, the project aims to enhance efficiency, reduce on-site maintenance needs, and provide tailored, effective training to workers. This strategic integration of technology will drive the project's success and meet its operational goals.

8. Software Analysis

The software landscape utilized by the company and how it can be leveraged for the XR5.0 project was extensively discussed. The company aims to maintain a cohesive and efficient software environment, minimizing the diversity of systems in use (Figure 6). The analysis includes a summary of the software platforms and applications, as well as the hardware devices that will be used. This combination of technologies was selected to meet the operational and functional needs of the project, allowing for effective integration and support for the various activities involved.

Figure 6 – Software



8.1. Software

1. LifeShare
   - o Description: Likely a platform for managing or sharing information, though specifics aren't provided.
   - o Role: May handle data sharing or collaboration aspects of the project.
2. Zoho
   - o Description: A suite of cloud applications for business, including CRM, project management, and more.
   - o Role: Used for project management, customer relationship management, or other business processes.
3. Microsoft
   - o Description: A cloud computing service offering from Microsoft for building, testing, and managing applications and services through Microsoft-managed data centers.
   - o Role: Provides cloud-based infrastructure, services, and applications. It might be used for hosting applications, storing data, or running analytics.
4. Meta (On-Premise)
   - o Description: This could refer to a system or platform provided by Meta (formerly Facebook), used locally within an organization.
   - o Role: Likely used for internal applications or data that need to be kept on-premise rather than in the cloud.

8.2. Hardware

1. HoloLens
    - Description: Microsoft's mixed reality headset.
    - Role: Used for augmented reality applications, potentially for interactive training or visualization within the project.
2. Tablets
    - Description: Portable touchscreen devices.
    - Role: Likely used for accessing project materials, applications, or collaboration tools.
3. Smartphones
    - Description: Mobile phones with advanced computing capabilities.
    - Role: Used for communication, accessing project apps, or performing on-the-go tasks.
4. PCs
    - Description: Personal computers.
    - Role: General-purpose computing, data processing, and software use within the project.

8.3. General Observations

- Integration: The software tools mentioned (LifeShare, Zoho, Microsoft Azure) are integrated into the project, possibly serving different functions such as data management, cloud services, and business processes.
- Hardware Variety: The mix of HoloLens, tablets, smartphones, and PCs suggests a need for diverse technology to accommodate various project needs, including augmented reality, mobile access, and standard computing.
- On-Premise vs. Cloud: The use of both on-premise solutions (Meta) and cloud services (Microsoft Azure) indicates a hybrid approach to data management and application deployment.

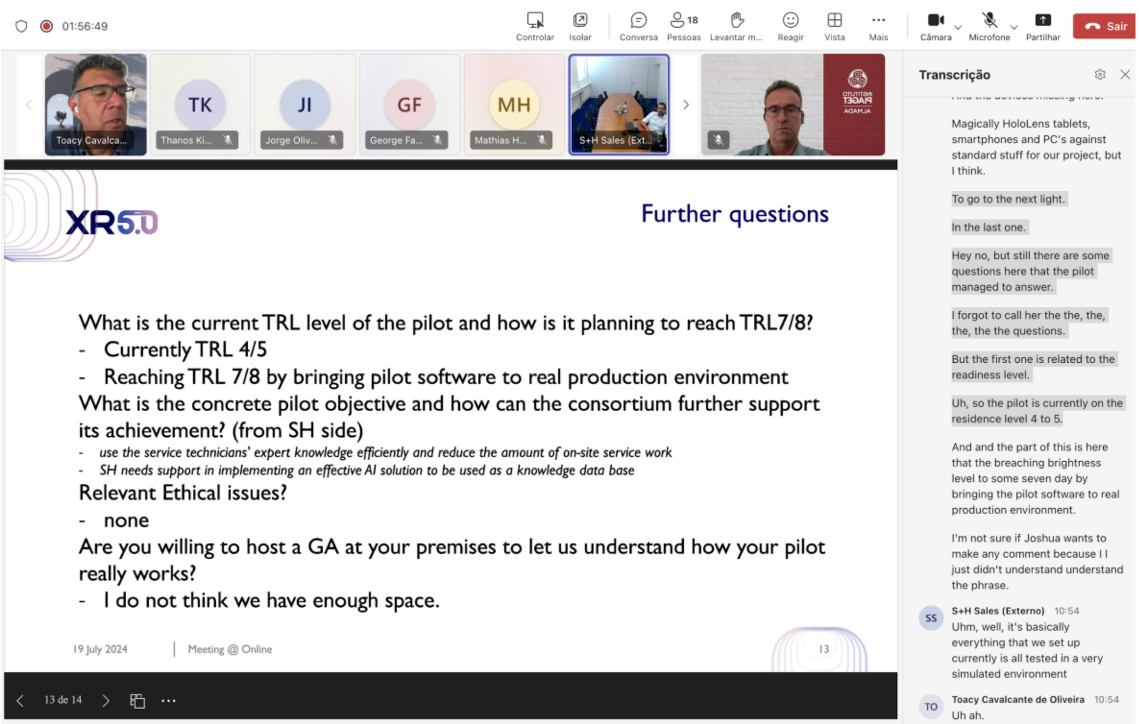
8.4. Questions to Consider

- Compatibility: How well do these software solutions integrate with each other?
- Scalability: Is the chosen hardware and software scalable to future project needs?
- Security: How will data security be managed across cloud and on-premise solutions?
- User Training: What kind of training will be required for users to effectively utilize these tools?

9. Further Analysis

We will explore the key aspects discussed regarding the project pilot, focusing on four main categories: the pilot's readiness level, the concrete objectives of the pilot and the support required, technical and ethical issues, and collaboration with partners (Figure 7). Each of these categories is analyzed to provide a clear understanding of the project's progress and the challenges faced.

Figure 7 – Further questions



9.1. Readiness Level

Question: What is the current readiness level of the pilot, and what does it mean for transitioning to a real production environment?

Analysis:

- Current Readiness Level: The pilot is at readiness levels 4 to 5.
  - Readiness Level 4: This typically means that the technology is in the prototype stage and tested in a controlled, simulated environment.
  - Readiness Level 5: This indicates that the technology has been validated in a relevant environment, but it might not yet be fully operational in a production setting.
- Transition to Production: Moving from readiness level 4-5 to level 7 involves deploying the solution in a real production environment. This means the technology will be used in actual operational settings, beyond controlled tests.

Clarification: The goal is to test the technology in a real production environment to confirm its effectiveness and functionality outside of a simulated setup.

9.2. Concrete Pilot Objectives

Question: What are the concrete objectives of the pilot, and how can the consortium support achieving these goals?

Analysis:

- Pilot Objectives:
  - Efficient Use of Technician Expertise: The pilot aims to leverage the expert knowledge of service technicians to improve operational efficiency.
  - Reduction of On-Site Service Work: The objective is to minimize the need for on-site service interventions, potentially through advanced technology or AI solutions.
- Support Needed:
  - Implementation of AI Solutions: The consortium needs to support the integration of effective AI solutions to serve as a knowledge database, which is a key aspect of the pilot.

9.3. Technical and Ethical Issues

Question: Are there any technical or ethical issues associated with the project?

Analysis:

- Technical Issues:
  - Current Setup: There is no indication of significant technical issues at this stage. The pilot appears to be focused on integrating and testing technologies as planned.
- Ethical Issues:
  - Ethics Statement: The project has no current ethical issues listed, mainly because it involves on-site hosting without measuring sensitive personal data (e.g., heart rates).
  - Future Considerations: If the project evolves to include personal data collection, it may raise ethical concerns that would need to be addressed.

9.4. Partnership and Collaboration

Question: How is the collaboration with partners like UPRC being handled, and what issues have arisen?

Analysis:

- Current Status: There are issues with communication and collaboration with UPRC, particularly regarding the API and development side

ANNEX III – WORKSHOP DETAILS FOR PILOT 3

Operator 5.0 Training for Smart Water Pipes based on XR Streaming

Motivation: Water networks require regular maintenance to provide safe and reliable water to communities. Therefore, the maintenance of water network can greatly benefit from Condition-Based Maintenance (CBM) practices such as Predictive Maintenance. To benefits from such maintenance models and practices, maintenance workers (e.g., technicians) need to acquire new skills that would allow them to access and interpret analytical outcomes (e.g., ML-based Remaining Useful Life (RUL) calculations, AI-driven detection of defects). XR environments provide perfect playgrounds for training workers on such new skills in cost-effective, yet realistic and safe ways. To exploit the full potential of data-driven maintenance practices, such trainings should be tailored to the varying levels of the workers' digital literacy and skills.

Concept & Description: EKSO has invested in digitally transforming its smart pipes manufacturing processes for trenchless pipe rehabilitation, utilizing embedded detection and measurement devices. Various distributed sensors (electric, fiber optic, accelerometers) are used to monitor pipe operativity, continuity, and integrity by combining signals from sensors along the pipes. This data enables intelligent Condition-Based Monitoring (CBM) and predictive maintenance, developed in the company's R&D lab through projects like HORIZON Even flow and H2020 AI4PublicPolicy. EKSO plans to offer personalized training for maintenance technicians using the XR5.0 training platform. This pilot will leverage XR streaming from HOLO's platform for hands-on training without physical equipment or access to confined spaces, reducing costs and risks associated with traditional methods. The training program will feature AI-based XR content tailored to operators' skills, aiming to demonstrate the capabilities of Operator 5.0, who utilizes technology and creativity to inspect and service advanced pipes.

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1. General Context

In the current industrial landscape, digitization and automation are essential for optimizing processes, increasing efficiency, and ensuring safety in operations. EKSO, in partnership with HOLO, is seeking to transform critical operations through advanced technological solutions. The main goal is to enhance operator training, conduct predictive maintenance, and automate inspections using technologies such as augmented reality (AR), artificial intelligence (AI), and smart sensors. These advancements enable companies to operate more safely, efficiently, and at lower costs, while minimizing failures and reducing downtime.

This digital transformation is crucial for empowering workers, automating critical tasks, and improving real-time decision-making.

2. Use Cases

2.1. Description

UC 1 - XR-Based Training on Visual Inspection and Anomaly Detection

Objective:
The objective of this use case is to leverage extended reality (XR) to provide immersive and interactive training experiences for EKSO workers and its customer network, focused on smart pipes. Through AR glasses (e.g., HoloLens 2), users will be able to visualize the overall network and sensor structure, as well as detect malfunctions or anomaly locations in real-time. The training will emphasize visual inspection of pipes, aiding in the identification of issues such as leaks, cracks, or corrosion by overlaying real-time data and visual guidance within the XR environment.

Context and Justification:
This use case aims to improve the accuracy and efficiency of visual inspections by integrating real-time and offline sensor data into an XR-based platform. Workers from EKSO and its customer network will perform visual inspections in an augmented reality environment using AR devices. By overlaying sensor data onto the physical equipment, the system will help users identify areas that need closer examination, streamlining the detection of malfunctions or anomalies within the pipe system.

Key Components:

- Hololight Hub (XR Platform): The centralized XR platform that will host the training application, enabling access to real-time and offline data overlays.
- Hololight Space (Training Application): An XR-based tool allowing users to visualize and interact with smart pipe data in real time, highlighting areas of potential concern.
- Hololight Stream (Streaming Technology): XR content will be streamed from a server to the client device (e.g., HoloLens 2), providing seamless access to the training environment.
- AI-Powered Anomaly Detection (INNOV): INNOV's AI-driven computer vision system will analyze live video feeds to detect issues such as corrosion, leaks, or cracks. Alerts will be provided through the Hololight Space application, enhancing the ability of workers to identify potential problems during training.

This use case enhances the training process for pipe operators using XR technologies, ensuring workers can conduct precise visual inspections and quickly detect anomalies in smart pipes.

UC 2 - XR-Based Training on Condition-Based Maintenance (CBM)

Objective:

This use case aims to utilize extended reality (XR) streaming technology to conduct live training sessions for Condition-Based Maintenance (CBM), allowing trainers to remotely guide trainees through real-time simulated scenarios. The goal is to provide an interactive training experience that teaches CBM and predictive maintenance processes using advanced XR tools, enhancing the learning of complex maintenance tasks in a controlled and safe environment.

Context and Justification:

The XR-based training for CBM will enable trainers to offer real-time guidance to trainees, who will experience simulated maintenance scenarios through mobile XR devices, such as AR glasses. By using Hololight Space, the training will offer high-quality 3D content streamed to these devices, enabling efficient delivery of training content through cloud or edge-based workflows. The addition of AI-powered insights from INNOV's models will enrich the training with realistic, data-driven scenarios, improving the trainee's ability to respond to predictive maintenance needs effectively.

Key Components:

- Hololight Space (Training Application): This application provides an immersive XR environment where trainees can interact with real-time simulated CBM scenarios. The application will guide users through predictive maintenance tasks, enriching the learning process with visual overlays and data from AI models.
- Hololight Stream (Streaming Technology): The high-quality 3D content for the training will be streamed from the cloud or edge servers to the trainees' mobile AR devices (e.g., HoloLens 2), ensuring computational efficiency and smooth delivery of XR content.
- AI Models from INNOV: INNOV's AI models will integrate into the XR platform, providing real-time insights during the training sessions. These models will enhance the simulations with predictive maintenance data, allowing trainees to engage with realistic, data-driven scenarios.
- AR Remote Assistance: Trainers can provide real-time, remote assistance to trainees during the XR training sessions, using augmented reality features to guide and correct trainees as they navigate through the CBM scenarios. This feature ensures that learning is dynamic, with immediate feedback and support available during the session.

This use case extends the application of XR streaming technology to the field of CBM and predictive maintenance, providing a powerful tool for remote, real-time training with enriched, AI-driven content. Through this approach, trainees will gain practical experience in handling advanced maintenance technologies and tools in a simulated, risk-free environment.

UC 3 - XR-AI Based CCTV Inspection and Anomaly Detection

Objective:

This use case aims to develop an AI-driven process to digitally examine CCTV images and videos of pipes using extended reality (XR) technology. The goal is to automate the detection of anomalies (e.g., leaks, cracks, corrosion) by analyzing video feeds from CCTV inspections and displaying the results in an immersive XR environment. Workers from EKSO and its customer network will use XR glasses (e.g., HoloLens 2) to conduct virtual inspections, improving the efficiency and accuracy of anomaly detection.

Context and Justification:

Currently, inspections of pipes are performed manually by analyzing CCTV footage, which is time-consuming and prone to human error. This use case seeks to enhance the inspection process by integrating AI and XR technologies. AI will automatically detect anomalies in the video footage, while XR glasses will provide an immersive environment where workers can visualize the inspection results in real-time, allowing for faster, more accurate maintenance decisions.

Key Components:

- AI-Powered Anomaly Detection (INNOV): INNOV's AI models will analyze CCTV video feeds in real-time to detect anomalies such as leaks, cracks, or corrosion. This automated process will significantly reduce the time required for manual video review and increase accuracy.
- Hololight Space (Training and Inspection Application): This XR-based application will enable workers to view real-time inspection results within an immersive environment. The AI-generated insights from the CCTV footage will be overlaid onto the virtual pipe model, allowing workers to interact with and examine the detected anomalies.
- Hololight Stream (Streaming Technology): The high-quality 3D content and inspection data will be streamed from cloud or edge servers to the workers' XR glasses, ensuring real-time interaction and visualization of the pipe inspections.
- XR Glasses (e.g., HoloLens 2): Workers will use XR glasses to carry out virtual inspections, allowing them to visualize the internal condition of the pipe and the AI-detected anomalies within the XR environment.

This use case combines the power of AI for automated anomaly detection with the immersive capabilities of XR technology, enabling workers to perform more efficient and accurate pipe inspections in a virtual environment. This approach will improve both the speed and reliability of identifying issues in the pipeline infrastructure.

Conclusion:

These three use cases demonstrate EKSO's commitment to modernizing and digitizing operational processes, whether in training, maintenance, or pipeline inspection. Implementing these solutions not only improves efficiency and safety but also optimizes resources and reduces operational risks.

2.2. Persona analysis

The personas highlight distinct user groups essential for implementing and operating the project's technologies. Below is a presentation and analysis of the personas based on the data available (Figure 1).

Figure 1 – Pilot Personas

Persona #	Persona	Will it be considered?
1	Equipment Maintenance Operator	Yes, indirectly
2	Pipe Maintenance Operator/Trainee	Yes, indirectly
3	CCTV Operator	Yes, indirectly
...		

Persona 1: Equipment Maintenance Operator

Description*:*

The Equipment Maintenance Operator is responsible for ensuring the proper functioning of the machinery and tools used in the maintenance and repair of the smart pipe infrastructure. Their role involves both preventative and reactive maintenance to keep all equipment operational.

Key Functions*:*

- Conduct routine maintenance and repairs on inspection and maintenance equipment.
- Troubleshoot mechanical or technical issues with devices.
- Use XR tools to monitor equipment health and receive real-time performance updates.
- Collaborate with the Pipe Maintenance Operator to ensure equipment readiness during inspections.

Challenges*:*

- Handling complex mechanical or technical issues with limited information.
- Adapting to new XR technologies for equipment monitoring.
- Managing unexpected equipment breakdowns during critical maintenance operations.

Analysis*:*

The Equipment Maintenance Operator plays a crucial role in ensuring that tools and machinery work effectively, which directly impacts the efficiency of pipe inspections and repairs. The integration of XR technology allows for more proactive maintenance, improving response times and reducing equipment downtime.

Persona 2: Pipe Maintenance Operator/Trainee

Description:

The Pipe Maintenance Operator or Trainee is tasked with inspecting and maintaining the smart pipe infrastructure. Through XR-based training, they learn how to detect and respond to anomalies in real time, using advanced tools to improve maintenance processes.

Key Functions:

Conduct visual pipe inspections, both in real-world scenarios and virtual simulations using XR glasses.

Utilize real-time data overlays and AI-detected insights to identify issues like leaks and corrosion.

Perform maintenance and repairs based on the identified anomalies.

Participate in XR-based training focused on Condition-Based Maintenance (CBM) and predictive maintenance.

Challenges:

Learning to interpret real-time data and AI-generated insights during inspections.

Adapting to the use of XR glasses and other advanced tools for maintenance operations.

- Developing expertise in predictive maintenance techniques through immersive training sessions.

Analysis:

The Pipe Maintenance Operator/Trainee benefits from the immersive training environment provided by XR technology, allowing them to safely practice and refine their skills. This role is critical for ensuring the smart pipe infrastructure remains operational, and the use of XR accelerates learning and response times.

Persona 3: CCTV Operator

Description*:*

The CCTV Operator is responsible for operating robotic systems that inspect the interior of pipelines, capturing video footage for anomaly detection. They work closely with AI systems to analyze video feeds and identify issues like leaks or cracks.

Key Functions*:*

- Operate CCTV and robotic systems to inspect the internal condition of pipes.
- Capture and analyze video footage, looking for signs of damage or malfunction.
- Collaborate with AI-powered tools to detect anomalies in real-time.
- Use XR glasses to visualize video data and anomalies in an immersive environment.

Challenges:

- Interpreting video data in real-time, especially when anomalies are subtle or unclear.
- Learning to collaborate with AI systems for automated anomaly detection.
- Using XR glasses effectively to overlay data and make quick, accurate decisions.

Analysis:

The CCTV Operator's role is enhanced by AI and XR technologies, which streamline the inspection process and improve accuracy in detecting anomalies. The shift from manual video analysis to AI-assisted and XR-visualized inspections significantly reduces human error and speeds up the identification of issues.

Will it be considered? - Justification for Personas Used Indirectly

In the initial stages of the use cases, the personas are involved indirectly for several reasons:

1. Preliminary Phase of Design and Development: The operators and workers who represent these personas have not been directly involved yet because the project is in a preliminary phase. Factors such as language barriers and the fact that these workers are focused on execution tasks have contributed to this decision.
2. Future Training Involvement: These personas will be considered more directly in a second phase, where they will participate in experimental activities, practical training, and direct operations.
3. Support for Future Validation: While these operators are an important part of the process, the current focus is on testing and validating the technological concepts and solutions before formally involving these personas.

This ensures that, once the technology and solutions are refined, the operators can be fully integrated into the training and operational processes in a more efficient manner.

3. User Stories

The user stories presented across UC I, UC II, and UC III emphasize improving operational efficiency, safety, and accuracy through advanced technologies like sensor networks, real-time data visualization, AI-based anomaly detection, and animated simulations. The overall goal is to equip operators with the tools and insights necessary for quick and effective decision-making in both maintenance and inspection tasks. Figure 2 represents the distribution of personas across scenarios.

Figure 2 – User Stories

P	ID	As a …	I want to ..	So That ..	Scenario
I	3.1	UC I - Equipment Maintenance Operator	see the overall network/sensors structure (technology/connections/etc...)	I can understand the generated scheme	
I	3.2	UC I - Equipment Maintenance Operator	see the malfunction indication located in space	I can understand where to intervene	
	3.3	UC II Pipe Maintenance Operator	see the detailed simulated scheme of the selected phase/equipment	I can understand the single component potential defects	
	3.4	UC II -Pipe Maintenance Operator	see the over all simulated scheme of the process/Phases	I can understand where the sensors have been installed on the infrastructure	
	3.5	UC II - Pipe Maintenance Operator	See any simulated animation of the operations to be carried out.	I can intervene on the infrastructure with the highest precision directly on the problem	
©	3.6	UC III - CCTV Operator	Receive support during CCTV inspection	I can understand where the damages/anomalyties are located	
	3.7	UC III - CCTV Operator	Receive immediate preliminary automatic anomaly evaluation and localization	I can seed up and increase precision in inspecting the pipe	
	...				

3.1. Analysis of User Stories

3.1.1. User Story 3.1 - UC I - Equipment Maintenance Operator

Description:
The Equipment Maintenance Operator needs to visualize the overall network and sensor structure (technology/connections/etc.) to understand the generated scheme.

Analysis:
In this story, the operator focuses on visualizing the network and sensor structure to gain a better understanding of how the system is connected. This helps in operational training by allowing the operator to interact with the data that represents the real-time layout of sensors and technology in the infrastructure. The available sensor data, such as CSV files with measurements, can be used to support this visualization and enhance the operator's ability to understand the system.

3.1.2. User Story 3.2 - UC I - Equipment Maintenance Operator

Description:
The operator needs to see the malfunction indication located in space and understand where to intervene.

Analysis:
This story highlights the need for the operator to visualize malfunction locations in the system. Through real-time sensor data and visual overlays, the operator can quickly identify the exact point of failure and determine where to intervene. The combination of network structure visualization and real-time anomaly detection ensures that the operator can take swift action in critical situations.

3.1.3. User Story 3.3 - UC II - Pipe Maintenance Operator

Description:
The Pipe Maintenance Operator needs to see the detailed scheme of the selected phase/equipment and understand the potential defects in individual components.

Analysis:
In this context, the operator works directly with the equipment on-site. The visualization provides a detailed view of the real system in the field, allowing the operator to identify potential defects in individual components. This on-site approach helps the operator understand specific maintenance requirements, without the need for remote simulations or animations. The data used comes directly from real-time field observations and equipment checklists.

3.1.4. User Story 3.4 - UC II - Pipe Maintenance Operator

Description:
The operator needs to see the overall scheme of the process and phases to understand where the sensors have been installed on the infrastructure.

Analysis:
In this case, the operator is provided with a complete view of the process and infrastructure. This allows the operator to easily identify the locations of the sensors installed throughout the system. The on-site nature of the operations means that the operator can visualize real-time sensor data and understand their placement in relation to the physical infrastructure.

3.1.5. User Story 3.5 - UC II - Pipe Maintenance Operator

Description:
The operator needs to see any animation of the operations to be carried out and intervene on the infrastructure with the highest precision directly at the problem.

Analysis:
The operator interacts with visualizations that guide them through the operation step-by-step. The data for these animations comes from on-site observations and recorded procedures. Instead of a simulated animation, the operator uses real-time guidance or video content to ensure precise interventions on the infrastructure. This enhances the ability to perform maintenance accurately and efficiently.

3.1.6. User Story 3.6 - UC III - CCTV Operator

Description:
The CCTV Operator needs to receive support during the CCTV inspection to understand where damages or anomalies are located.

Analysis:
In this story, the operator receives support through AI analysis of CCTV footage. The system helps to automatically detect and highlight anomalies, providing visual cues for the operator to focus on during the inspection. The combination of AI for detection and visual feedback through the system ensures that the operator can identify and address issues effectively.

3.1.7. User Story 3.7 - UC III - CCTV Operator

Description:
The operator needs to receive immediate preliminary automatic anomaly evaluation and localization to speed up and increase precision during pipe inspection.

Analysis:
The AI system automatically evaluates CCTV footage, providing immediate feedback on the location and type of anomalies detected. This allows the operator to act swiftly, focusing directly on the identified areas of concern. This real-time analysis increases the efficiency and precision of the inspection process.

Final Considerations:
These user stories outline the practical application of real-time data, visualizations, and AI technologies in on-site inspections and maintenance. The operator interacts with data directly from the field, using tools that enhance both the accuracy and efficiency of their work.

4. Prioritization of User Stories

To prioritize the user stories effectively, it is essential to understand their relevance and impact on the system's implementation and the overall goals of the project. Each user story focuses on different aspects of operation, training, and maintenance. The prioritization is based on the complexity, potential benefits, and immediate impact on operational efficiency.

4.1. Prioritization Context

1. Operational Efficiency: The ability to quickly locate and resolve malfunctions is crucial to minimize downtime and improve system performance. This is key for user stories related to maintenance (e.g., User Stories 3.2 and 3.5).
2. Training and Knowledge Transfer: Effective training using simulated environments can greatly enhance the operators' understanding and preparedness, making training-based user stories (e.g., 3.1 and 3.3) important.
3. Innovation and Automation: The integration of AI and automated anomaly detection (User Stories 3.6 and 3.7) offers high potential for improving accuracy and reducing human error, but may involve more complexity.

4.2. Priority Levels

- High Priority: User stories that focus on critical operational aspects like real-time malfunction detection and essential training.
- Medium Priority: Those that improve process precision and provide enhanced visualizations, but may not be immediately necessary.
- Low Priority: Stories that add advanced functionalities like automation and AI-based anomaly detection, which can be implemented in later phases.

4.3. User Stories Prioritization

The User Stories Prioritization table 1outlines the most important user stories for the successful implementation of the EKSO-HOLO-INNOV project. The goal is to ensure that essential operational features and training components are addressed first, followed by more advanced functionalities (Table 1).

Table 1 - User Story Prioritization

User Story ID	Priority	Explanation
3.1 - UC I - Equipment Maintenance Operator - See the overall network/sensors structure	High	Essential for understanding the system architecture, leading to better operational efficiency. It provides foundational knowledge for maintenance.
3.2 - UC I - Equipment Maintenance Operator - See malfunction indication in space	High	Critical for quick and precise interventions. This story directly improves maintenance speed and accuracy by enabling operators to identify problems faster.
3.3 - UC II - Pipe Maintenance Operator - See detailed simulated scheme of selected equipment/phase	Medium	Helps operators understand potential defects in specific components, improving defect detection, but it’s not as immediately critical as direct malfunction detection.
3.4 - UC II - Pipe Maintenance Operator - See overall simulated scheme of process/phases	Medium	Provides a broader understanding of sensor placement and process phases. Useful for monitoring but not as immediately impactful as fault detection.
3.5 - UC II - Pipe Maintenance Operator - Simulated animation of operations	High	Ensures operators can execute tasks with precision. Directly improves the accuracy of interventions, especially in complex systems.
3.6 - UC III - CCTV Operator - Receive support during CCTV inspection	Medium	Improves inspection efficiency by assisting operators with real-time data, but may involve higher technological complexity.
3.7 - UC III - CCTV Operator - Immediate automatic anomaly evaluation and localization	Low	High potential but involves complex AI integration. This can be implemented in later phases, after other systems are fully functional.

4.4. Summary

User stories 3.1, 3.2, and 3.5 are given high priority because they are directly related to improving operational efficiency and task execution. User stories like 3.3, 3.4, and 3.6, while important for enhancing process understanding and monitoring, have medium priority due to their less immediate impact on operations. Finally, advanced automation and AI features in 3.7 have low priority, as they involve more complex development and can be phased in after core functionalities are stable.

5. KPIs

The KPIs discussed align with the user stories and operational goals of the EKSO-HOLO -INNOV project. The following analysis evaluates how each KPI corresponds to specific operational tasks and training processes, using the user stories 3.1, 3.2, 3.3, and 3.4 as the framework. (Figure 3).

Figure 3- Key Performance Indicators

ID	Acceptance / Success Criteria	UC - I	UC - II	UC - III
3.1	General purpose of understanding	x	xxx	xxx
3.2	Facilitate speed of intervention	x	xx	xx
3.3	Facilitate problem solving	xx	xxx	xx
3.4	General purpose of understanding	xxx	xxx	xxx
3.5				
3.6				
3.7				
...				

5.1. General Discussion on KPIs

The main concern regarding KPIs was the difficulty in defining them clearly, given that some functionalities and developments are still in the early stages. Despite this, the KPIs specified in the Grant Agreement were seen as an essential starting point for measuring progress. However, there was a need to adapt them to the operational reality of the project as the use cases develop.

5.2. Predefined KPIs from the Grant Agreement

The predefined KPIs in the Grant Agreement (GA) include:

1. Industrial Processes to be supported in terms of training: >= 3 processes
2. Latency of XR streaming objects: < 1 second
3. Average reduction of training time and costs: > 30%
4. 5-point scale rating of site technicians' satisfaction from the training.

These KPIs provide a clear baseline of expectations regarding project performance, especially in relation to using XR for training and operational improvement.

5.3. Need to Adapt and Prioritize KPIs

It was discussed that while it is necessary to follow the KPIs set in the Grant Agreement, it may be important to adapt them to ensure that the results reflect the actual needs of the pilot. It was emphasized that while the KPIs provide measurable goals, their impact and applicability may vary depending on the specific pilot conditions and the technology involved. This adaptation would help prioritize KPIs that are more aligned with the specific conditions of the project and could be realistically implemented.

5.4. Efficiency-Related KPI

It was emphasized that KPIs should be practical and measurable, such as the time required to complete an operation. For example, the >30% reduction in training time stipulated in the Grant Agreement was highlighted as a relevant performance metric. However, it was noted that this target was initially based on a superficial estimate and needs to be validated as the project progresses. Additionally, it was pointed out that the impact of these training sessions could vary depending on the scope and depth of the content provided.

5.5. XR Latency and Technician Satisfaction

Another highlighted KPI was the XR object streaming latency, which must be less than 1 second. This KPI represents a specific technical challenge that is crucial to delivering a seamless, immersive training experience. Furthermore, the technician satisfaction measured on a 5-point scale was identified as an important qualitative metric to assess the social and practical impact of the training, ensuring that the training is well-received and effective from the perspective of the end users.

5.6. Challenges in Early KPI Definition

It was also mentioned that while KPIs are necessary, it is too early to define them precisely, especially since the full scope of training activities has not yet been detailed. The definition of precise KPIs will depend on having a clearer understanding of which operations will be simulated and how the training will impact operator performance. It was emphasized that in addition to latency and satisfaction, KPIs like the number of industrial processes supported by training (goal of >= 3 processes) would also be a key indicator of the project's success.

5.7. Initial Focus Proposal

It was suggested that the initial focus should be on simpler KPIs that are directly related to the goals described in the Grant Agreement. By following these KPIs initially, the project could stay on track, with the possibility to expand or adapt the metrics as needed. This approach would help keep efforts aligned with the expectations of the Grant Agreement while allowing adjustments as technological challenges arise.

5.8. Conclusion

The discussion on KPIs made it clear that while it is important to have well-defined metrics, the project is still at a stage where many variables need to be adjusted before committing to specific figures. The KPIs from the Grant Agreement provide a solid foundation, particularly with goals like XR latency, supported processes, and training time/cost reductions, along with technician satisfaction. However, there is a consensus that the KPIs may need to be adapted to reflect the reality of the project. Operational efficiency and time reduction are clear examples of KPIs that could be implemented, but their final definition will depend on the progress of the project

6. Human Factors

In the EKSO-HOLO-INNOV project, various human factors will be assessed to optimize both the system and user experience. Below is a detailed evaluation of each human factor and whether it will be implemented in the project (Figure 4).

Figure 4 – XR5 Human Factors

XR5.0 Human Factors	Will it be used? (x)	In which User Story (ID)?
Questionnaires		
Fatigue	x	UC – II
Task load index	xx	UC – II
Digital Skills	xxx	UC – I – II and III
User Experience	xxx	UC – I – II and III
Emotion/mood	x	TBD
...		
Physiological metrics		
Heart rate variability (stress, cognitive load, engagement)	x	UC – II
Galvanic Skin Response (stress & engagement)	xx	UC – II
Capture & maintenance of attention (assessed by eye-tracker)	xx	UC – I and II
Pupil dilation (eye-tracker)	x	TBD
Gaze behavior (eye-tracker)	x	TBD

The discussion on key human factors focused on the integration of XR (Extended Reality) and AI technologies while ensuring they align with the abilities and limitations of the operators. Below is an analysis of the main human factors discussed, based on the provided document and table.

6.1. Description:

Fatigue

- Will it be used?: Yes (x)
- User Story: UC – II
- Analysis: Fatigue was acknowledged as a significant factor, especially in extended XR sessions where operators need to wear headsets for long durations. The concern here is to minimize physical strain while ensuring the operators remain engaged. The user story UC – II involves tasks that require monitoring fatigue to prevent any negative impact on performance during training.

Task Load Index

- Will it be used?: Yes (xx)
- User Story: UC – II
- Analysis: Task load refers to the cognitive and physical demands placed on workers. By assessing the task load, the training can be optimized to balance the complexity of tasks and

prevent overwhelming the operators. This is crucial for user story UC – II, where the focus is on training efficiency and maintaining manageable workloads.

Digital Skills

- Will it be used?: Yes (xxx)
- User Story: UC – I, II, and III
- Analysis: The varying levels of digital skills among operators were discussed as a key challenge. As the XR content and AI models become more integrated, it's essential to assess and improve the digital literacy of operators across all user stories. This ensures that both novice and experienced users can navigate the digital tools effectively, thereby enhancing the training outcomes.

User Experience (UX)

- Will it be used?: Yes (xxx)
- User Story: UC – I, II, and III
- Analysis: User experience was emphasized as a critical factor to ensure that the interface of XR and AI tools is intuitive. The ease of use, interaction with virtual environments, and responsiveness of the systems are vital to ensure that the operators are comfortable and can focus on their tasks without being hindered by the technology.

Emotion/Mood

- Will it be used?: Yes (to be determined)
- User Story: TBD
- Analysis: Monitoring the emotional state of workers (such as stress or frustration) could provide insights into how training environments are affecting their well-being. Although this factor is yet to be fully integrated into a specific user story, it was noted as an important element for future consideration, especially in scenarios involving intensive or repetitive tasks.

Physiological Metrics

Heart Rate Variability (HRV)

- Will it be used?: Yes (x)
- User Story: UC – II
- Analysis: HRV is used to measure stress and cognitive load, ensuring that operators are not overexerting themselves during training. Monitoring HRV during XR training can provide feedback on how mentally demanding the tasks are and help tailor the training intensity in real time.

Galvanic Skin Response (GSR)

- Will it be used?: Yes (xx)
- User Story: UC – II
- Analysis: GSR is linked to stress and engagement, making it a useful metric to monitor during critical operations in UC – II. By tracking skin response, trainers can assess how engaged or stressed operators are, allowing for real-time adjustments to the training.

Capture and Maintenance of Attention (Eye-Tracker)

- Will it be used?: Yes (xx)
- User Story: UC – I and II
- Analysis: Attention capture, monitored via eye-tracking, is key to ensuring operators remain focused during XR training. This tool helps in identifying moments where attention wanes, enabling improvements to be made in the training material to hold the users' attention more effectively.

Pupil Dilation (Eye-Tracker)

- Will it be used?: Yes (to be determined)
- User Story: TBD
- Analysis: Pupil dilation can indicate cognitive load, though this metric has not yet been assigned to a specific user story. It may play a future role in analyzing the stress and cognitive challenges faced by operators during complex tasks.

Gaze Behavior (Eye-Tracker)

- Will it be used?: Yes (to be determined)
- User Story: TBD
- Analysis: Gaze behavior provides insight into how operators interact with the XR environment, where they focus their attention, and how they react to different stimuli. This could be used in future scenarios to optimize the layout and design of virtual training environments.

6.2. Summary Table of Human Factors

Table 2 - User Story Prioritization

Human Factor	Will it be Used?	User Story (ID)	Priority
Fatigue	Yes	UC – II	High
Task Load Index	Yes (double usage)	UC – II	High
Digital Skills	Yes (triple usage)	UC – I, II, and III	High
User Experience (UX)	Yes (triple usage)	UC – I, II, and III	High
Emotion/Mood	Yes (TBD)	TBD	Medium
Heart Rate Variability (HRV)	Yes	UC – II	Medium
Galvanic Skin Response (GSR)	Yes (double usage)	UC – II	Medium
Capture & Maintenance of Attention	Yes (double usage)	UC – I and II	Medium
Pupil Dilation	Yes (TBD)	TBD	Low
Gaze Behavior	Yes (TBD)	TBD	Low

Prioritization Summary:

- High Priority: Fatigue, Task Load, Digital Skills, and UX, as these factors directly impact the operators' ability to perform effectively and engage with the XR systems.
- Medium Priority: Emotion/Mood and physiological metrics like HRV and GSR, which can provide insights into stress and cognitive load but may require more advanced technology and integration.

- Low Priority: Pupil dilation and gaze behavior, which are still under consideration and may not be as critical in the early stages of the project.

7. Technical Components

The technical components listed in the EKSO-HOLO project are designed to enhance the integration of extended reality (XR), artificial intelligence (AI), and data-driven systems into training and operational processes. (Figure 5).

Figure 5 - Technical component

Task	XR5.0 Technical Component	Will it be used?	In which User Story?
T3.2	Information Gathering	yes	
T3.3	Workers' digital twins		**UC – I and II**
T3.4	Personalized XR content	yes	**UC – I – II and III**
T4.1	Human-centered XAI models	Yes?	**UC – I – II (minor) and III (yes)**
T4.2	XR-enabled Active Learning	Yes?	**UC – I – II (minor) and III (yes)**
T4.2	Neurosymbolic AI models	**no**	
T4.3	Generative AI models	**yes**	**UC – I** **UC - II**
T4.4	Visualization of XAI explanations	**Yes?**	**UC – I – II (minor) and III (yes)**
T4.5	Visualization of AI recommendations	**yes**	**UC – I – II and III**
T5.1	Training material	**yes**	**UC – II and III**
T5.2	Cloud-based repository	**yes**	
T5.3	Hololight Hub	**yes**	
T5.4	Training programs	yes	**UC – II and UC III**

7.1. Main Discussion Points on Technical Components

Based on the available information and the specific use cases outlined in the project, an analysis of whether each technical component will be utilized in the EKSO-HOLO project follows (Table 2):

Table 2 - Technical Components

Technical Component	Will It Be Used?	Explanation
T3.2 - Information Gathering	Yes	Essential for gathering real-time data from sensors and operational environments.
T3.3 - Workers' Digital Twins	Not specified	Unclear if digital twins will be implemented, but they could enhance operational performance.
T3.4 - Personalized XR Content	Yes	Key for providing tailored training experiences to operators.
T4.1 - Human-Centered XAI Models	Yes	Used to provide transparent AI-driven decision-making to operators, enhancing trust and usability.
T4.2 - XR-Enabled Active Learning	Yes	Critical for interactive learning and training modules within XR environments.
T4.2 - Neurosymbolic AI Models	No	Will not be implemented, possibly due to complexity or limited applicability in the current scope.
T4.3 - Generative AI Models	Yes	To generate scenarios or data for improving training and operational simulations.
T4.4 - Visualization of XAI Explanations	Yes	Provides visual aids to help operators understand AI decisions.

Technical Component	Will It Be Used?	Explanation
T4.5 - Visualization of AI Recommendations	Yes	Will be used to deliver AI recommendations to operators in a clear, actionable format.
T5.1 - Training Material	Yes	Digital training materials will be developed for operators to use in XR environments.
T5.2 - Cloud-Based Repository	Yes	Will be used to store and manage all digital resources, ensuring accessibility and version control.
T5.3 - Hololight Hub	Yes	Central platform for delivering and managing XR content, crucial for the project.
T5.4 - Training Programs	Yes	Core to guiding operators through training in an immersive, interactive environment.

7.2. Summary of Main Discussion Points on Technical Components

The EKSO-HOLO project will implement a broad range of technical components, with a strong focus on XR-enabled training, personalized learning content, and AI-driven decision support. These components are aimed at enhancing both the efficiency and effectiveness of training and operational processes, ensuring that operators can quickly adapt to new technologies and perform their tasks with greater precision and safety.

8. Software and Hardware Analysis

In the context of the discussed pilot, focused on "Operator 5.0 Training for Smart Water Pipes based on XR Streaming," the integration of advanced software and hardware solutions plays a pivotal role in enhancing both training and operational efficiency. The following analysis explores the software and hardware mentioned, illustrating how these elements contribute to the overall goals of the project, such as real-time collaboration, anomaly detection, and immersive training experiences. (Figure 6).

Figure 6 – Software & Hardware

Pilot #	Pilot Description (Responsible)	Software
3	Operator 5.0 Training for Smart Water Pipes based on	Hololight Stream/HUB*/Hololight Space

Pilot #	Pilot Description (Responsible)	XR Devices
3	Operator 5.0 Training for Smart Water Pipes based on XR Streaming (**EKSO**)	HoloLens 2, Quest 2, Quest 3, Quest Pro, Magic Leap, tablet, phone, iOS, eye-tracker equipped device*

8.1. Software Analysis:

- Hololight Stream/HUB: These software components are central to enabling XR (Extended Reality) streaming and real-time collaboration. From the discussions, it is clear that Hololight Stream plays a crucial role in allowing complex XR applications to be streamed from powerful remote servers to devices with lower processing capabilities. This setup is essential for enabling immersive experiences on devices like HoloLens 2, mobile phones, or tablets without overloading their hardware. The Hololight HUB seems to be the platform where these XR experiences are hosted and managed, facilitating access to users across different environments and devices.

- Hololight Space: Although not deeply elaborated on, this software likely enables collaborative workspaces in XR, where users can interact with shared virtual environments. This could be important for training scenarios, remote support, or collaborative maintenance tasks, as suggested in the discussions around smart pipe monitoring and training applications.

- GenAI: The application of Generative AI was mentioned in the context of video inspection and anomaly detection, particularly within pilot scenarios involving AI-powered image analysis during CCTV inspections. The AI component here could help analyze video feeds in real time, identify anomalies such as cracks or damages in pipes, and provide instant feedback to operators. This would streamline the training and operational processes by assisting workers in recognizing problems faster and more accurately.

8.2. Hardware Analysis:

- HoloLens 2: This mixed reality headset by Microsoft is widely used in scenarios that require both virtual and physical interactions. In the document, it appears to be a preferred device for real-time collaboration and training, where holograms or 3D models of infrastructure, such as pipes, are overlaid in the real world to guide users during maintenance or inspection tasks.
- Quest 2, Quest 3, Quest Pro: These VR headsets from Meta (formerly Oculus) were discussed as part of the overall XR solution. While primarily used for virtual reality, their integration with the Hololight streaming software suggests that they could be used for both immersive simulations and possibly remote collaboration in training or field operations.
- Magic Leap: Another headset specializing in augmented and mixed reality, the Magic Leap appears to be considered for its ability to enhance real-world operations by overlaying virtual data. The use of this headset might be aligned with tasks requiring in-situ visualizations, such as viewing the status of smart pipes during field operations.
- Mobile Devices (Tablets, Phones, iOS): These devices are key for accessing XR solutions in a more portable form. The ability to stream high-quality XR experiences to tablets and smartphones, likely through Hololight Stream, enables flexibility for users who may not have access to advanced headsets but still need to engage with XR content, especially for simpler tasks or remote assistance.
- Eye-tracking Devices: Devices equipped with eye-tracking technology were mentioned as potentially useful for gathering user data during XR experiences. Eye-tracking can be used to measure user engagement, attention, or even assist in training by providing real-time feedback on what the operator is focusing on, thus improving the overall training process.

8.3. Summary:

The combination of XR software like Hololight Stream, HUB, alongside GenAI for real-time analysis and anomaly detection, creates a powerful platform for industrial applications, particularly in training and maintenance. The wide range of hardware devices—from high-end headsets like HoloLens 2 and Magic Leap to more accessible platforms like smartphones—ensures flexibility for users across different environments and technical capabilities.

This setup allows companies to leverage advanced XR tools for both in-field operations (smart pipe monitoring, maintenance) and remote training. The ability to stream high-quality XR experiences also reduces the need for expensive, high-performance devices, as much of the processing power is handled on external servers. This enhances the scalability and accessibility of the solution across different user groups and operational contexts.

9. Analysis of the Pilot Readiness and Support

In the context of advancing the pilot project for XR-based training and smart water pipe maintenance, several key questions arise concerning the current status, objectives, and future steps of the initiative. This section provides an analysis of the pilot's readiness level, its core goals, the ethical considerations involved, and preparations for the upcoming workshop (Figure 7). By addressing these aspects, we aim to outline the path forward, focusing on the technical challenges, collaborative support from the consortium, and the necessary actions to reach higher levels of technological maturity.

Figure 7 – Furter Questions

What is the current TRL level of the pilot and how is it planning to reach TRL7/8?
TBD

What is the concrete pilot objective and how can the consortium further support its achievement? (from EKSO side) UNDERSTANDING THE REAL TECH LIMITS AND DELIVER THE BEST SOLUTION

Relevant Ethical issues? NONE

Is there anything you need to point out in view of the Workshop that we will have in October? NONE FOR THE MOMENT

What is the current TRL level of the pilot and how is it planning to reach TRL7/8?

- Answer: TBD (To Be Determined)

What is the concrete pilot objective and how can the consortium further support its achievement?

- Answer: The objective from EKSO's side is to understand the real technical limits and deliver the best solution.

Relevant Ethical issues?

- Answer: None

Is there anything you need to point out in view of the Workshop that we will have in October?

- Answer: None for the moment.

Annex IV – Workshop Details for Pilot 4

Worker Centric Aircraft Maintenance Training

Motivation: Proper maintenance of airplanes is critical to ensure the safety of passengers and crew members. One of the essential components that must be in working order is the Wing Anti-Ice Valve (WAIV), which is a part of the Minimum Equipment List (MEL). If this component fails, the aircraft cannot take off, and maintenance technicians must quickly repair it to minimize the grounding time. The process of repairing the WAIV is not only time-sensitive but also subject to maloperation, which can lead to costly consequences. All certified Aircraft Maintenance Technicians (AMTs) are required to perform this maintenance procedure, and they face harsh stress conditions during the process. XR5.0 technologies can be used to improve the efficiency and safety of such training processes.

Concept & Description: The pilot will improve the efficiency and accuracy of the WAIV maintenance procedure while reducing the risk of maloperation. This will be achieved through the development of AI tools and XR environments that will train and support TAP's junior engineers in performing this critical maintenance procedure. To this end, the pilot will expand IML's VR platform with the project's AI and human DTs solutions providing immersive simulations based on the most skilled AMTs. The successful implementation of the pilot will allow the integration of various human-centric XR applications in the aviation industry, enhancing the safety and reliability of the aircraft fleet and benefiting both passengers and airlines.

Date	Name Contacts	email
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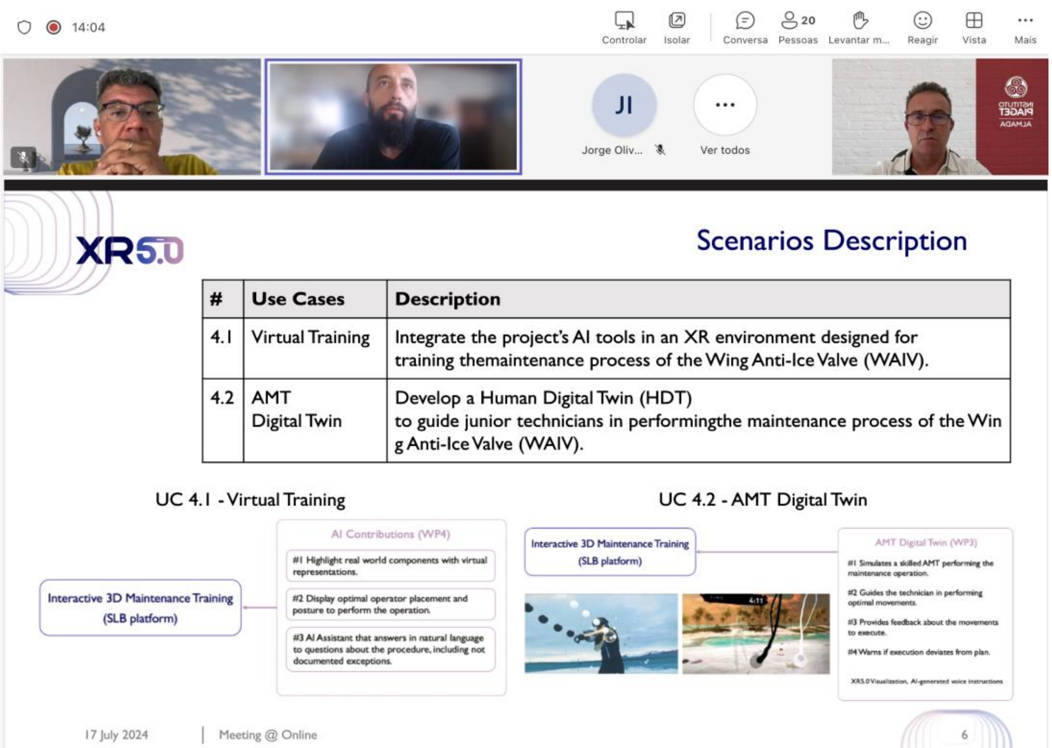
1. General Context

The general context describes two use cases developed within the project to enhance training and guidance for maintenance technicians using advanced technologies. The use cases focus on integrating Artificial Intelligence (AI) tools into Extended Reality (XR) environments and developing a Human Digital Twin (HDT). These use cases aim to improve the efficiency and accuracy of maintenance procedures for the Wing Anti-Ice Valve (WAIV).

The details of the use cases, along with specific examples provided during a detailed discussion among project members, are presented below (Figure 1 and Table 1).

Figure 1 – Scenarios Description



2. Use Cases

2.1. Virtual Training

Integrate the project's AI tools in an XR environment designed for training the maintenance process of the Wing Anti-Ice Valve (WAIV).

Detailed Description:

The Virtual Training use case involves enhancing an existing virtual reality (VR) training tool with advanced AI capabilities. The primary objectives are:

1. Highlighting Real World Components: The current VR tool is a fully virtual simulation. The integration aims to incorporate augmented reality (AR) or mixed reality (MR) elements to highlight real-world components within the virtual environment. This would help operators better understand where specific components are located and how they interact with them.
2. Displaying Optimal Operator Placement and Posture: The tool will assist operators in determining the best positions and postures to adopt when accessing equipment in difficult locations. This ensures that operations are performed efficiently and safely.

3. AI Assistant for Natural Language Queries: An AI assistant will be integrated to provide real-time answers to questions about the maintenance procedure. This assistant will not only reference the documented procedure but also include undocumented exceptions and insights from experienced operators.

2.2. AMT Digital Twin

Develop a Human Digital Twin (HDT) to guide junior technicians in performing the maintenance process of the Wing Anti-Ice Valve (WAIV).

Detailed Description:

The AMT Digital Twin use case focuses on creating a digital replica of an experienced Aircraft Maintenance Technician (AMT) to assist junior technicians. The key features include:

1. Guidance on Optimal Movements: The HDT will demonstrate the exact movements and procedures required for the maintenance tasks. This includes showing the optimal stance, hand placements, and the correct sequences of actions.
2. Feedback on Execution: The system will provide feedback on the junior technician's actions, warning them if they deviate from the optimal procedures or make errors in their movements.
3. Simulating Real-World Scenarios: The HDT will simulate realistic maintenance scenarios, helping junior technicians gain practical experience in a controlled, virtual environment before performing actual maintenance tasks.

Table 1 - Summary of Use Cases

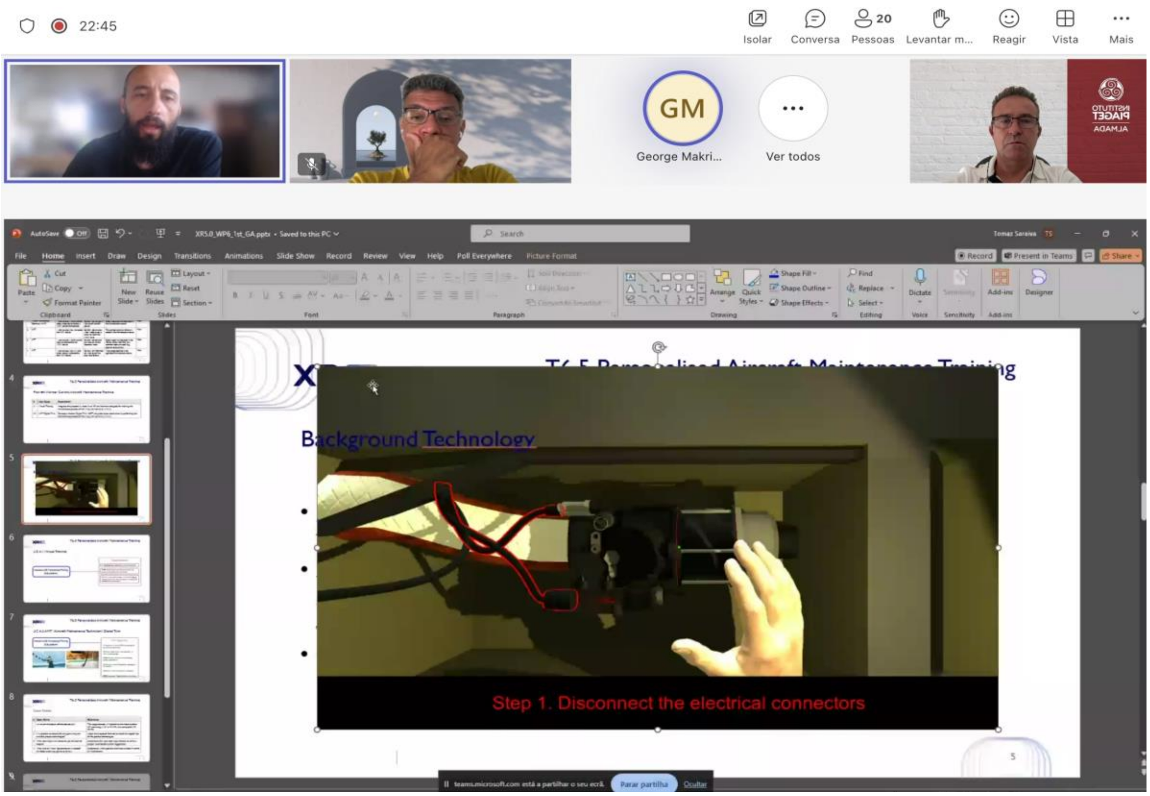
Use Case	Significant Details	Exact Examples from the Discourse
4.1 Virtual Training	- Integration of AI tools into an XR environment for training the maintenance process of the WAIV.	"Integrate the project's AI tools in an XR environment designed for training the maintenance process of the Wing Anti-Ice Valve (WAIV)."
	- Highlighting real-world components with virtual representations.	"To highlight real world components with virtual representations."
	- Displaying the optimal operator placement and posture.	"Display the optimal operator placement and posture to perform the operation."
	- AI assistant that answers questions about the procedure in natural language.	"An AI assistant that answers in natural language to questions about the procedure."
4.2 AMT Digital Twin	- Development of a Human Digital Twin to guide junior technicians in performing the maintenance process of the WAIV.	"Develop a Human Digital Twin (HDT) to guide junior technicians in performing the maintenance process of the Wing Anti-Ice Valve (WAIV)."
	- Guidance on optimal movements, posture, and operator position.	"This is where you need to stand. This is the movement that you need to make. This is where you need to place your hand."
	- Providing feedback on the execution of movements and warnings in case of errors.	"Would provide feedback about the movements we execute and warn the technician if it's not doing the movement exactly like it is supposed to."
	- Simulation of real-world maintenance scenarios for practical experience in a controlled environment.	"Simulating realistic maintenance scenarios, helping junior technicians gain practical experience in a controlled, virtual environment."

2.3. VR tool used for maintenance training

The focus is on explaining the current capabilities of the VR tool, its limitations, and the potential integration of AI for enhancing the training process. The discourse also covers the importance of adhering to predefined maintenance steps and the regulatory guidelines, alongside exploring the feasibility and implications of integrating AI in these scenarios.

The discussion begins with an overview of the current VR tool used for maintenance training (Figure 2). This tool is a VR simulation that allows operators to interact with a fully simulated 3D environment, specifically designed for the maintenance process of the valve that needs to be replaced. The operator uses a VR headset to follow step-by-step instructions provided by the tool, ensuring that the maintenance procedure is performed correctly.

Figure 2 - VR tool used for maintenance training



The steps provided in the VR tool are derived from the official maintenance manual and are fixed, meaning they are not generated by AI. This adherence to predefined steps is crucial for regulatory compliance, ensuring that the maintenance process follows the formal aircraft maintenance manual strictly. The team emphasizes the importance of not letting AI generate steps autonomously, as this could lead to deviations from the approved procedures.

The conversation then shifts to the potential integration of AI into the VR training tool. One suggestion is to implement a feedback mechanism where the operator can provide feedback on whether the steps were followed correctly. This feedback could potentially lead to updates in the procedure, ensuring that any deviations or improvements are documented and approved by the manufacturer.

However, some contributions initially considered for the first use case, such as modeling optimal operator placement and posture, might be more appropriate for the digital twin use case rather than the VR use case. The digital twin use case involves creating a Human Digital Twin (HDT) to guide junior technicians in performing maintenance tasks. This HDT would provide real-time guidance on optimal movements, posture, and operator position, ensuring that the junior technician performs the task correctly.

The integration of AI into the VR tool and the digital twin use case remains a topic of discussion. While the AI assistant and the visualization aspects of the VR use case are deemed feasible, modeling optimal operator placement and posture might require more data and could be more relevant for the digital twin use case (Table 2).

Table 2 - Key Discussion Points on VR Tool and AI Integration

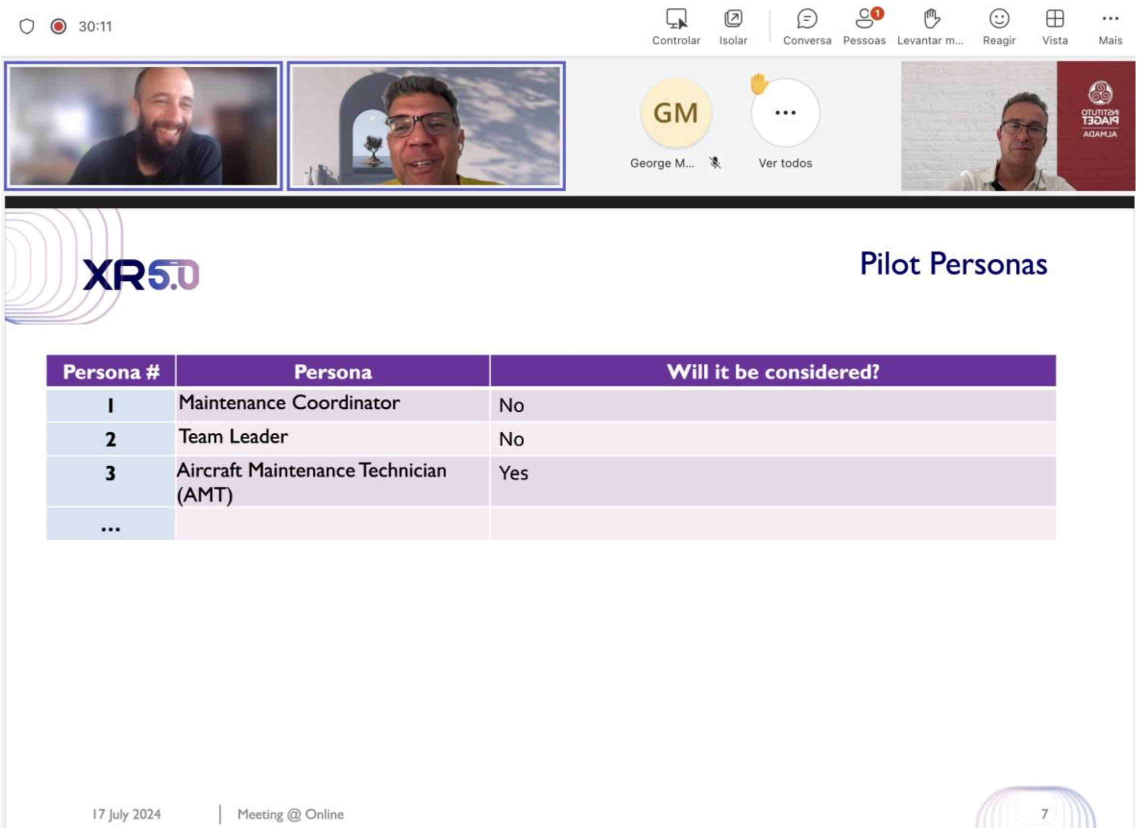
Theme	Sub-Theme	Explanation	Examples from the Discourse
VR Tool	Current Capabilities	VR simulation of maintenance procedure using a VR headset.	"So we have the 3D model of the valve that we, the operator needs to replace and the operator can see this using the VR headset."
	Source of Steps	Steps are derived from the official maintenance manual, not generated by AI.	"So they were taken from the documentation, but they are fixed in this case for the procedure here."
	Regulatory Compliance	Importance of following formal aircraft maintenance manual strictly.	"We could not let AI generate steps by itself when we already have the steps predefined and we have to follow them strictly."
AI Integration	Feedback Mechanism	Implementing a feedback loop where operators can provide feedback on the procedure steps.	"If the user gives feedback if each step was followed correctly or not... should we possibly notify the manufacturer."
	Applicability to VR and Digital Twin Use Cases	AI features like operator placement and posture modeling may be more suitable for the digital twin use case.	"Maybe this feature is not important for this first use case... it's more important for the digital twin."
Digital Twin Use Case	Human Digital Twin (HDT)	Developing an HDT to guide junior technicians in performing maintenance tasks.	"Develop a Human Digital Twin (HDT) to guide junior technicians in performing the maintenance process of the Wing Anti-Ice Valve (WAIV)."
	Real-Time Guidance	HDT provides real-time guidance on optimal movements, posture, and operator position.	"This is where you need to stand. This is the movement that you need to make. This is where you need to place your hand."
	Feedback and Improvement	HDT gives feedback on the execution of movements and warns of errors.	"Would provide feedback about the movements we execute and warn the technician if it's not doing the movement exactly like it is supposed to."

This summary captures the key points of the discussion, outlining the capabilities and limitations of the current VR tool, the potential for AI integration, and the distinction between the VR and digital twin use cases. The discussion concluded with agreement on the relevance of AI assistants and visualization tools for enhancing virtual training while recognizing the challenges in data collection and the limitations of current AI applications in predicting optimal procedures.

3. Persona Analysis

The focus is on the personas involved in the maintenance process of the aircraft, specifically on how they interact with the VR tool and AI integrations. The conversation touches on the stages of detailing user stories, key performance indicators (KPIs), and the personas themselves (Figure 3).

Figure 3 – Pilot Personas



3.1. Analysis of Personas

In the discussion, various personas are being evaluated to ensure that the project aligns with the needs and expectations of different user types. Here's a breakdown of the relevant personas and their roles as discussed:

3.1.1. Maintenance Coordinator/Team Lead

Role: Oversees and manages the maintenance process and team.

Discussion Context: It was mentioned that the maintenance coordinator or team lead is not going to be a primary user of the VR tool in this instance.

Implication: The focus is not on this persona for the current phase, which might be due to the specific nature of the tool's use or the current stage of the project.

3.1.2. Aircraft Maintenance Technician (AMT)

Role: Performs the actual maintenance tasks on the aircraft.

Discussion Context: The primary user for the current project phase is the Aircraft Maintenance Technician.

Implication: The VR tool and AI integrations are designed with this persona in mind, focusing on their direct interaction with the tool during the maintenance procedures.

The conversation reflects a stage in the project where the team is detailing user stories and KPIs related to these personas. The emphasis is on ensuring that the VR tool and AI integrations cater to the needs of the Aircraft Maintenance Technician, while other roles, such as the Maintenance Coordinator, are not the primary focus at this time (Table 3).

Table 3 - Analysis of Personas

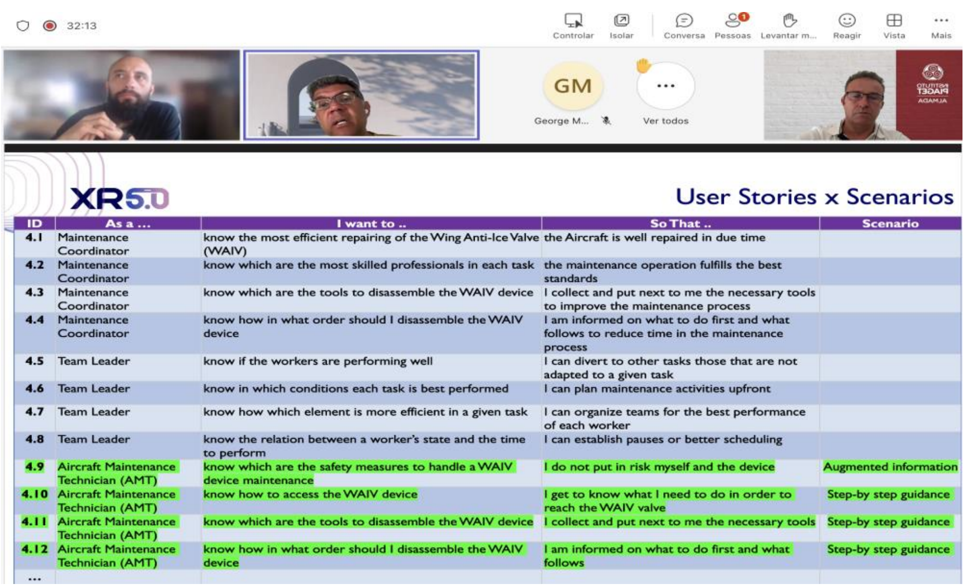
Persona	Role	Discussion Context	Implication
Maintenance Coordinator/Team Lead	Oversees and manages the maintenance process and team	Not a primary user for the current project phase.	The project is currently focusing on the Aircraft Maintenance Technician, not on management roles.
Aircraft Maintenance Technician (AMT)	Executes maintenance tasks on the aircraft	Main user for the VR tool and AI integrations.	The design and features of the VR tool and AI are tailored to the needs and interactions of this persona.

This analysis helps clarify the focus of the project, emphasizing the importance of aligning tools and technologies with the needs of the Aircraft Maintenance Technician while acknowledging that other roles are not the focus at this stage.

4. User Stories

In the ongoing project, user stories are essential for defining the needs and expectations of various personas involved. The focus here is on analyzing and prioritizing user stories related to the Aircraft Maintenance Technician (AMT), as other personas' user stories are currently considered out of scope. This analysis aims to clarify which user stories should be prioritized and why, providing a structured approach to ensure that the most critical requirements are addressed. Figure 4 represents the distribution of personas across scenarios.

Figure 4 – User Stories



4.1. Analysis of User Stories

The discussion has led to the identification of specific user stories related to the AMT, with some user stories for other roles being deemed irrelevant for the current phase. The key user stories are related to step-by-step guidance for maintenance tasks. The following table provides an organized view of these user stories, including their dimensions, sub-dimensions, and examples (Table 4).

Table 4 -User Stories Dimensions and Examples

Dimension	Sub-Dimension	Explanation	Concrete Examples of Statements
User Role	AMT	The role of the Aircraft Maintenance Technician in the context of the VR tool and AI integration.	"As an AMT, I want to know which are the safety measures to handle the valve device maintenance..."
Task	Step-by-Step Guidance	The need for detailed, sequential instructions to perform maintenance tasks accurately.	"As an AMT, I want to know how to access the valve device so that I know what I need to reach it."
Safety	Safety Measures	Ensuring that safety protocols are followed during maintenance tasks.	"As an AMT, I want to know the safety measures for handling the valve device so that I do not put myself or the device at risk."
Tools Required	Tool Identification	Identifying and organizing tools needed for specific maintenance tasks.	"As an AMT, I want to know which tools are needed to disassemble the valve device so that I can collect them before starting the task."
Procedure Order	Assembly Instructions	Understanding the correct order for assembling components to ensure proper functioning.	"As an AMT, I want to know the order for assembling the valve device so that I am informed on what to do first and what follows next."

4.2. Prioritization of User Stories

Based on the discussion, the user stories have been categorized and prioritized. The focus is on those that directly impact the Aircraft Maintenance Technician (AMT's) ability to perform maintenance tasks effectively, ensuring that the most critical aspects of training and procedure are addressed.

Table 5 - User Stories Prioritization

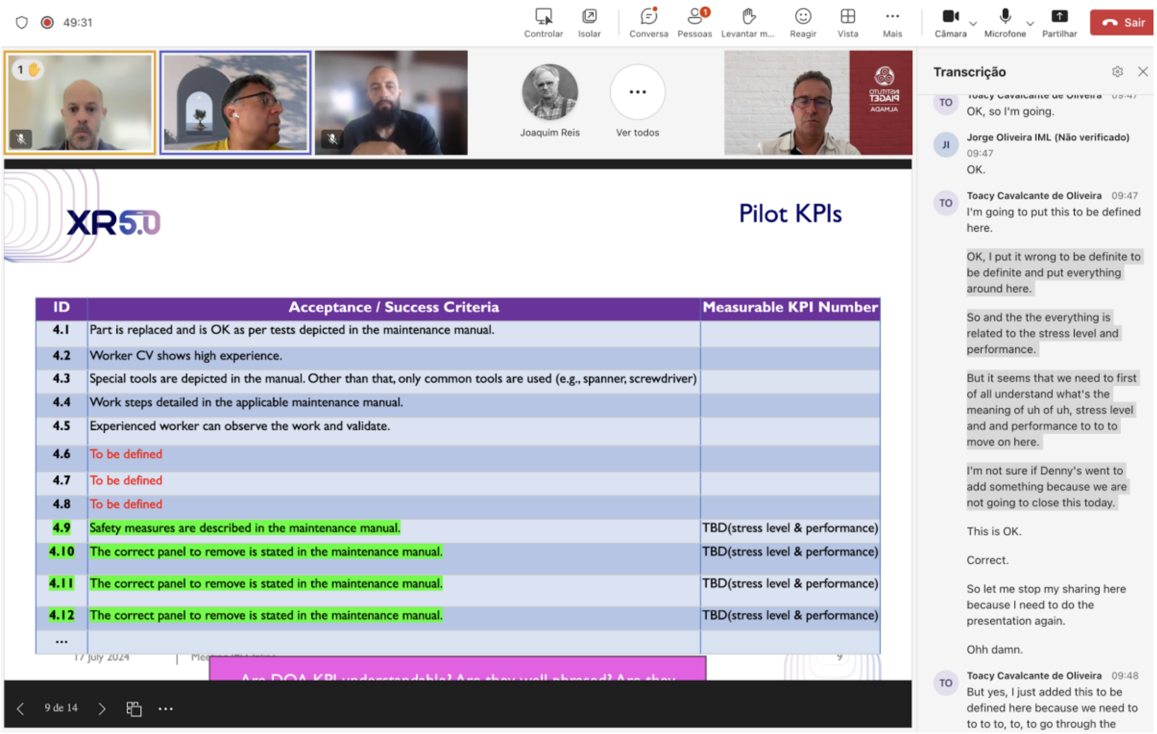
User Story	Role	Description and Analysis	Prioritization
4.9	AMT	Ensures that safety measures are clear, preventing risks during maintenance. Critical for protecting both the technician and the equipment.	High
4.10	AMT	Provides guidance on accessing the valve device, essential for effective maintenance and training.	High
4.11	AMT	Focuses on identifying the tools required for disassembly, helping in preparation and ensuring all necessary tools are on hand.	Medium
4.12	AMT	Details the assembly order of the valve device, crucial for ensuring the correct assembly process and functionality of the device.	Medium

The discussion clarified the importance of focusing on user stories related to the Aircraft Maintenance Technician, prioritizing those that enhance step-by-step guidance and safety measures. By concentrating on these prioritized user stories, the project aims to deliver effective training and maintenance tools tailored to the needs of AMTs.

5. KPIs

The discussion centers around defining and refining Key Performance Indicators (KPIs) relevant to the project, particularly focusing on stress levels and performance metrics for the Aircraft Maintenance Technician (AMT). Below is a detailed analysis of the conversation, organized for clarity and understanding (Figure 5).

Figure 5 - Key Performance Indicators



5.1. Analysis of the Discussion on KPIs

1. Absence of Initial KPIs:
    - o The team noted the lack of provided KPIs and referred to the grant agreement for some predefined KPIs.
    - o Stress index and performance metrics were highlighted as crucial KPIs mentioned in the agreement.
2. Stress Index and Performance Metrics:
    - o The stress index is proposed to be measured using physiological sensors, such as heart rate variability.
    - o There is a need to establish a baseline for stress levels by comparing a resting state with a skilled worker's performance under stress.
3. Measurement Methods:
    - o Different methods were proposed for measuring stress, including computer vision techniques and wearable sensors.
    - o The importance of correlating sensor data with self-reported questionnaires was emphasized to accurately gauge individual stress levels.
4. Constructing a Model:
    - o A model to determine stress thresholds for individual workers was suggested. This model would use pre-task measurements to establish personalized stress baselines.
    - o It was proposed to use training sessions to gather initial data for creating this model.
5. Combining Stress and Performance:

- There was a suggestion to create a combined index of stress and performance to provide a more comprehensive KPI.
- Performance metrics should also be included, as the ultimate goal is to measure both stress reduction and operational efficiency.

6. Scenario Comparison:
   - It was suggested to compare current scenarios using the SLB platform with future scenarios integrating AI and XR technologies.
   - This comparison would help validate the effectiveness of new solutions in reducing stress and enhancing performance.

5.2. KPI Development

The discussion emphasized the need for concrete and achievable KPIs (Table 6). The following table outlines the main dimensions, sub-dimensions, and examples discussed:

Table 6 - KPI Dimensions and Examples

Dimension	Sub-Dimension	Explanation	Concrete Examples of Statements
Stress Measurement	Baseline Comparison	Comparing stress levels at rest with those during task performance.	"The baseline will be a resting person, compared with the skilled worker's performance during tasks."
Physiological Metrics	Heart Rate Variability	Using heart rate variability to measure stress.	"Heart rate variability may be used to index the stress level."
Performance Metrics	Task Efficiency	Measuring how effectively tasks are performed under different stress levels.	"We can combine stress levels with performance levels to create a unique index."
Scenario Comparison	Current vs. Future	Comparing existing SLB platform scenarios with new AI and XR-based scenarios to measure improvements.	"Compare the operator using the SLB platform without AI to the scenario with AI assistance to see the performance improvement."

5.3. Prioritization of User Stories and KPIs

Based on the discussion, the following user stories were identified as high priority, focusing on enhancing the training and performance of AMTs. The KPIs for these user stories are essential for tracking improvements and ensuring the effectiveness of the training program (Table 7).

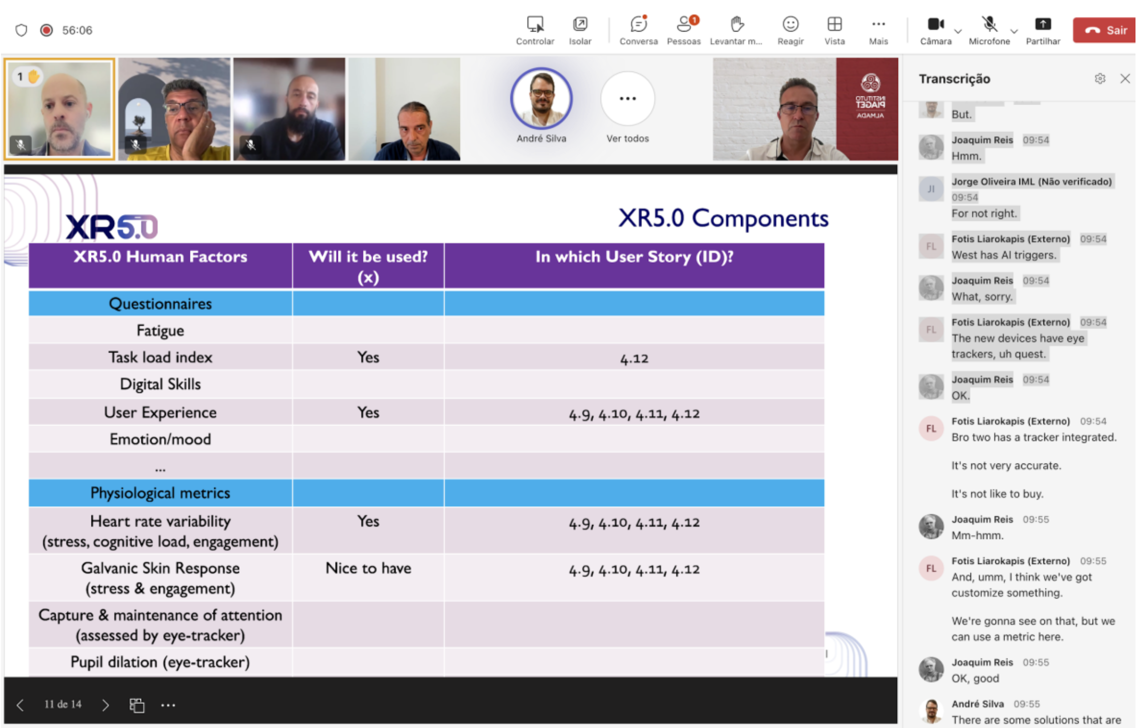
Table 7 - User Stories Prioritization

User Story	Role	Description and Analysis	Prioritization
4.9	AMT	Ensures that safety measures are clear, preventing risks during maintenance. Critical for protecting both the technician and the equipment.	High
4.10	AMT	Provides guidance on accessing the valve device, essential for effective maintenance and training.	High
4.11	AMT	Focuses on identifying the tools required for disassembly, helping in preparation and ensuring all necessary tools are on hand.	Medium
4.12	AMT	Details the assembly order of the valve device, crucial for ensuring the correct assembly process and functionality of the device.	Medium

The discussion highlighted the importance of establishing clear, measurable KPIs to track the success of the VR training program for AMTs. By focusing on stress reduction and performance improvement, and using physiological metrics alongside task performance data, the team can ensure that the training tools developed are effective and beneficial for the technicians. Further refinement of these KPIs and user stories will be essential as the project progresses.

6. Human Factors

The discussion covered data collection to measure user experience and the physiological and psychological impacts of using these technologies, highlighting the following points (Figure 6)
Figure 6 – XR5 Human Factors



6.1. Main Discussion Points

Health and Comfort Issues:

- Motion Sickness: Motion sickness from VR/AR exposure is a concern, with standard questionnaires like NASA TLX suggested for measuring symptoms.
- User Stress: Stress may stem from the novelty of using VR rather than the task itself, prompting the inclusion of questions about the experience, including motion sickness.

Data Collection Tools and Methods:

- Skin Conductance and Heart Rate Variability: The accuracy of skin conductance measurements and challenges with movement were noted, with alternatives like smartwatches suggested.
- EEG and Eye Tracking: The use of EEG for data collection and the importance of eye tracking were discussed, including the feasibility and cost of integrating these technologies into VR glasses.

Practicality of Monitoring Devices:

- Usability in Technical Tasks: The practicality of using devices like rings and watches during technical tasks was discussed, with feasibility depending on the task and device design.

User Experience Questionnaires:

- Questionnaire Scope: A combined questionnaire was proposed to measure various dimensions of user experience, including presence, engagement, immersion, and usability.

The integration of human factors and the respective user story, along with some notes derived from previous analyses, is presented in Table 8.

Table 8 - XR5.0 Human Factors integration

Factor	Will it be used? (x)	In which User Story (ID)?	Description/Notes
Questionnaires			
Fatigue			
Task load index	Yes	4.12	
Digital Skills			
User Experience	Yes	4.9, 4.10, 4.11, 4.12	Includes various dimensions like presence, engagement, immersion, usability. Fotis Liarokapis suggests a comprehensive questionnaire.
Emotion/mood			
Motion Sickness/Presence	Yes	4.9, 4.10, 4.11, 4.12	Include questions about the VR experience, especially for new users, to address motion sickness concerns.
Physiological metrics			
Heart rate variability (stress, cognitive load, engagement)	Yes	4.9, 4.10, 4.11, 4.12	Accurate but may face practical challenges in technical tasks.
Galvanic Skin Response (stress & engagement)	Nice to have	4.9, 4.10, 4.11, 4.12	Alternatives like smartwatches are discussed, though accuracy can be an issue.
Capture & maintenance of attention (assessed by eye-tracker)	Nice to have		Eye tracking is crucial but may increase costs. Various solutions, including those from Magic Leap and Pupil Labs, are considered.
Pupil dilation (eye-tracker)	Nice to have		Can be integrated into VR glasses, though it might require additional costs.
Gaze behavior (eye-tracker)	Nice to have		Important for capturing user attention and engagement.

6.2. Considerations and Recommendations

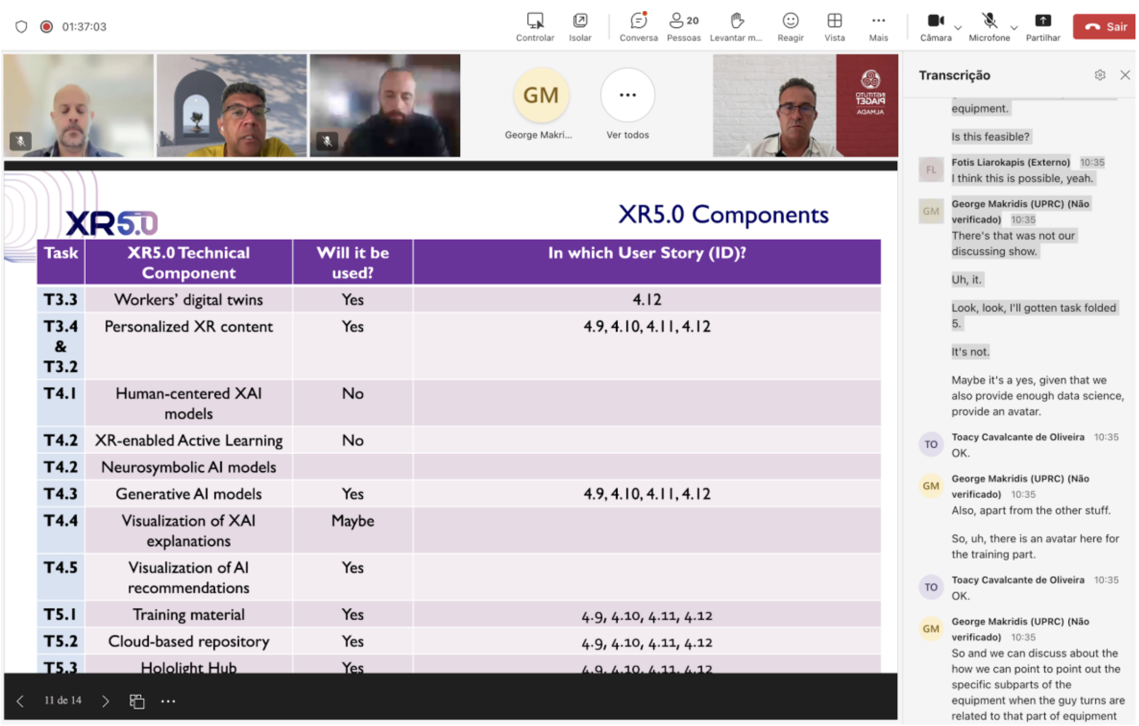
- Inclusion of Specific Questions: Specific questions about the VR experience, especially for new users, and symptoms of motion sickness should be included.
- Selection of Monitoring Devices: Choose devices that do not interfere with users' tasks, considering less intrusive alternatives like integrated eye tracking or lighter devices.
- Customization of Solutions: Evaluate existing market solutions and consider customizations to meet the project's specific needs, particularly in terms of cost and usability.
- Practical Tests: Conduct practical tests with the chosen devices to ensure they do not hinder the execution of technical tasks.

The discussion reflects a multidimensional concern for user experience in VR/AR environments, focusing on health, comfort, practicality, and accuracy of data collection. The approach is collaborative and detailed, indicating a joint effort to find effective and viable solutions.

7. Technical Components

The use of different technical components of XR5.0 was discussed across various user stories. The discussion addressed the applicability of each technical component and how they contribute to achieving the objectives of the respective tasks (Figure 7).

Figura 7 - Technical component



Task	XR5.0 Technical Component	Will it be used?	In which User Story (ID)?
T3.3	Workers' digital twins	Yes	4.12
T3.4 & T3.2	Personalized XR content	Yes	4.9, 4.10, 4.11, 4.12
T4.1	Human-centered XAI models	No	
T4.2	XR-enabled Active Learning	No	
T4.2	Neurosymbolic AI models		
T4.3	Generative AI models	Yes	4.9, 4.10, 4.11, 4.12
T4.4	Visualization of XAI explanations	Maybe	
T4.5	Visualization of AI recommendations	Yes	
T5.1	Training material	Yes	4.9, 4.10, 4.11, 4.12
T5.2	Cloud-based repository	Yes	4.9, 4.10, 4.11, 4.12
T5.3	Hololight Hub	Yes	4.9, 4.10, 4.11, 4.12

7.1. Discussion of Technical Components

During the meeting, there was a detailed discussion about the application of technical components across various tasks and user stories, with emphasis on the following points:

Digital Twin of Workers (Task 3.3)

- Objective: To create a digital twin for workers, which serves as an information repository and supports the customization of AR interfaces.
- Challenges: The need to define a new data model to represent relevant worker information. Dependence on instructions from specialized AR and user interface partners for full integration.
- Potential: The possibility of adding functional modules that estimate new states of workers based on stored data.

2. XR Content Personalization (Task 3.4)

- Relation to Task 3.3: XR content personalization is seen as a natural extension of the workers' digital twin.
- Required Information: Physical characteristics of workers, level of expertise, skills.
- Challenges and Considerations: The importance of collecting personal and analytical data through devices such as smartwatches to support content personalization.

3. Explainable AI Models for Human Monitoring (Tasks 4.1 and 4.2)

- Proposal: Utilization of generative AI to provide step-by-step guidance to workers.
- Considerations: The need for specific data to implement AI models that can provide real-time recommendations. The importance of integrating proprietary knowledge from technical equipment documents.

4. Visual Guides and AR Integration (Tasks 4.3, 4.4, and 4.5)

- Technical Challenges: Implementation of visual guides that can provide clear and precise instructions to workers in real time.
- Possible Solutions: Use of pre-recorded videos as a visual response instead of automatically generated videos. Consideration of visual elements in the work environment to highlight specific components during instructions.

5. Integration Discussion and Technical Feasibility

- Participant Feedback: Discussion on the feasibility of simulating workers' behavior using the digital twin. Issues raised about the integration of virtual components and the need for accurate visualization.
- Suggestions for Improvements: Proposal to highlight predefined equipment components during instructions, and incorporate training videos to provide a clear visualization of tasks.

In this analysis, we present a table summarizing which technical components will be used, in which user stories, and a brief explanation of their use (Table 9).

Table 9 – XR5.0 Technical Components

Task	XR5.0 Technical Component	Will it be used?	In which User Story (ID)?	Description
T3.3	Workers’ digital twins	Yes	4.12	Digital representations of workers for simulation and training purposes.
T3.4 & T3.2	Personalized XR content	Yes	4.9, 4.10, 4.11, 4.12	Customized extended reality content tailored to individual user needs.
T4.1	Human-centered XAI models	No		Explainable AI models focused on human interpretability.

Task	XR5.0 Technical Component	Will it be used?	In which User Story (ID)?	Description
T4.2	XR-enabled Active Learning	No		Active learning methodologies enhanced with XR technology.
T4.2	Neurosymbolic AI models	Yes	4.9, 4.10, 4.11, 4.12	AI models combining neural networks and symbolic reasoning.
T4.3	Generative AI models	Yes	4.9, 4.10, 4.11, 4.12	AI models capable of generating new content or data.
T4.4	Visualization of XAI explanations	Maybe		Tools for visualizing explanations from explainable AI models.
T4.5	Visualization of AI recommendations	Yes		Visualization tools for AI-generated recommendations.
T5.1	Training material	Yes	4.9, 4.10, 4.11, 4.12	Educational resources for training users on various tasks.
T5.2	Cloud-based repository	Yes	4.9, 4.10, 4.11, 4.12	Online storage for collaborative access to training and simulation data.
T5.3	Hololight Hub	Yes	4.9, 4.10, 4.11, 4.12	Centralized platform for managing XR content and applications.
T5.4	Training programs	Yes	4.9, 4.10, 4.11, 4.12	Structured programs designed to train users on various skills and tools.

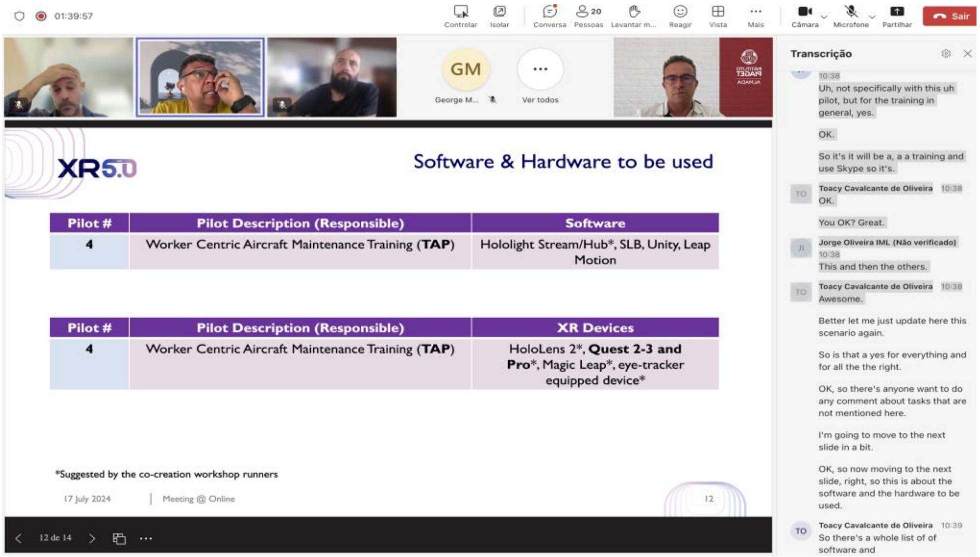
7.2. Summary

The meeting highlights the technical complexity and the need for multidisciplinary collaboration to achieve successful integration of various systems and components. Key points include the creation and personalization of workers' digital twins, the use of AI to provide guidance, and the implementation of visual guides in AR. Effective communication and continuous feedback among different team members are crucial to resolving technical challenges and ensuring the project's success.

8. Software And Hardware Analysis

A detailed evaluation of the necessary software and hardware components was conducted. This assessment aimed to determine the optimal tools and devices required to support the development and implementation of XR (Extended Reality) applications. The focus was on selecting appropriate software for XR content management and development, as well as identifying suitable hardware for various functionalities, including gesture recognition and eye tracking. Key points of discussion included the use of HoloLight Stream and HoloLight Hub for streaming and resource management, Unity for application development, and various XR devices such as Meta Quest and Magic Leap. This introduction provides an overview of the considerations and decisions made regarding the software and hardware to be employed in the project.

Figure 8 – Software and Hardware



8.1. Analysis of Software

HoloLight Stream and HoloLight Hub

- Usage: These software tools are essential for the project, providing streaming capabilities and a centralized hub for XR content.
- Functionality: HoloLight Stream enables efficient data streaming, while HoloLight Hub serves as a repository for managing XR applications and resources.

Unity

- Usage: Used for developing XR applications.
- Functionality: Unity provides a versatile platform for creating interactive and immersive experiences.

Leap Motion

- Usage: Potential use for gesture recognition.
- Functionality: Leap Motion provides precise hand tracking capabilities, which can be leveraged to enhance user interactions within XR environments.

8.2. Hardware

XR Devices (Meta Quest 2/3, Meta Quest Pro, Magic Leap):

- Usage: Core for XR applications.
- Functionality: Varying capabilities, including high-resolution displays, hand tracking, and optional eye tracking.
- Comments: Preference was noted for Meta Quest 2/3 based on features, though additional purchases may be needed for eye tracking. Magic Leap offers comprehensive functionality but at a higher cost.

Eye Tracking Solutions (Magic Leap, Meta Quest Pro):

- Usage: Crucial for applications requiring detailed user attention data.
- Functionality: Enables precise data on gaze direction, enhancing interaction for training and monitoring tasks.
- Comments: Cost and functionality comparisons highlighted integrated eye tracking in devices like Magic Leap.

The importance of selecting the right combination of software and hardware to align with project requirements was emphasized.

8.3. The Key considerations include:

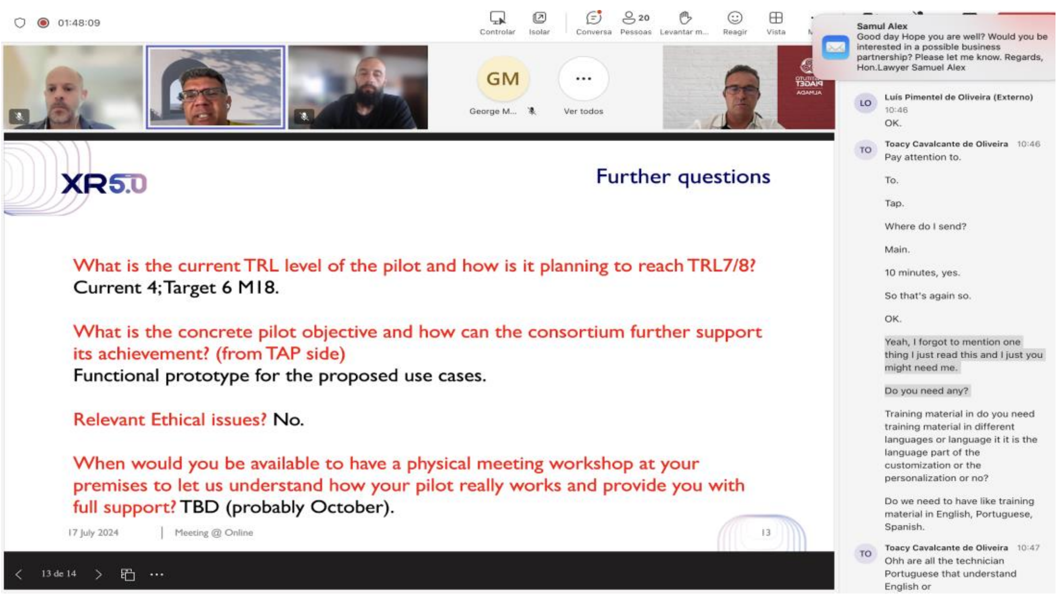
- The integration of HoloLight Stream and HoloLight Hub for effective data streaming and resource management.
- The use of Unity for developing versatile and interactive XR applications.
- The potential use of Leap Motion for gesture recognition, enhancing user interaction.
- The selection of XR devices based on the required features, with a preference for Meta Quest 2 or 3, but also considering the Meta Quest Pro and Magic Leap for their eye tracking capabilities.

Overall, the analysis highlights the need for careful selection and integration of both software and hardware to ensure the project's success, considering both technical capabilities and cost implications.

9. Analysis of the Pilot Readiness and Support

The final discussion of the meeting focused on evaluating the current status and future objectives related to the pilot projects, as well as the associated support requirements (Figure 9).

Figure 9 – Furter Questions



Here's a breakdown of the key points:

1. Current Readiness Level:
   - o Status: The pilot's current readiness level is reported as 4, with a target of reaching level 6 by Milestone 18. Clarification was sought on whether Milestone 18 refers to a specific deadline or period, indicating some uncertainty around this point.
   - o Comment: It was important to confirm and understand the milestone timelines to align development efforts and expectations.
2. Pilot Objectives:

  - Objective: The goal is to create a functional prototype that is integrated with the proposed use case. This includes ensuring compatibility with both hardware and software components.
  - Comment: The emphasis is on achieving integration and functionality, ensuring the prototype meets the project requirements.

3. Ethical and Regulatory Considerations:
   - Issues Raised: There was a discussion about relevant ethical issues, particularly around regulations and compliance. Concerns were raised about the potential for technology providers to deviate from regulated procedures, which could impact ethical considerations.
   - Comment: It was suggested to explicitly include regulatory compliance in the discussion to ensure all tech providers adhere to required standards and practices. This includes considering guidelines from TAP (presumably a regulatory body).
4. Training Material:
   - Language Considerations: A query was raised about the need for training material in multiple languages. It was clarified that all technicians are proficient in English, so multilingual training materials may not be necessary.
   - Comment: Confirming language needs is crucial for ensuring effective training and support. It was decided that English would suffice, given the team's language proficiency.
5. Physical Meeting and Workshop:
   - Scheduling: A physical meeting or workshop was proposed to better understand the pilot and provide comprehensive support. October was suggested as a potential time for this meeting.
   - Comment: Scheduling a workshop will facilitate deeper engagement with the pilot's operational aspects and enable tailored support.

The meeting highlighted the need for clarity on milestones, regulatory compliance, and training material requirements. It also emphasized the importance of scheduling a workshop to support the pilot project effectively. These actions will help address current readiness levels, align objectives, and ensure all regulatory and support needs are met.

ANNEX V – WORKSHOP DETAILS FOR PILOT 5

Increased Effectiveness and Safety of Product Assembly and Repair Processes

Motivation: SPACE customizes and configures edge devices with sensors and actuators focused on physical security. These devices include an LTE modem, analog and digital I/O, and a compute node for IoT edge logic. SPACE also develops a custom agent for connecting these devices to the Guardian™ 2.0 PSIM platform for integrated incident response (e.g., alarms, door locking, lighting control). These devices are used by SPACE's enterprise customers, such as in the banking sector. However, the complex assembly and support process is challenging. XR solutions, including VR/AR, could improve engineer training and provide remote support for maintenance and repair. SYN offers such solutions to industry but lacks personalization to workers' skills.

Concept & Description: This pilot will implement and demonstrate XR solutions for training and support of SPACE's workers in the edge devices assembly, deployment, and repair processes. Most importantly, it will prove the importance and effectiveness of personalized instructions during assembly and repairs of edge devices, notably instructions that address two different skills levels (i.e., beginner, intermediate). To this end, the pilot will develop personalized content and workflows as part of two UCs.

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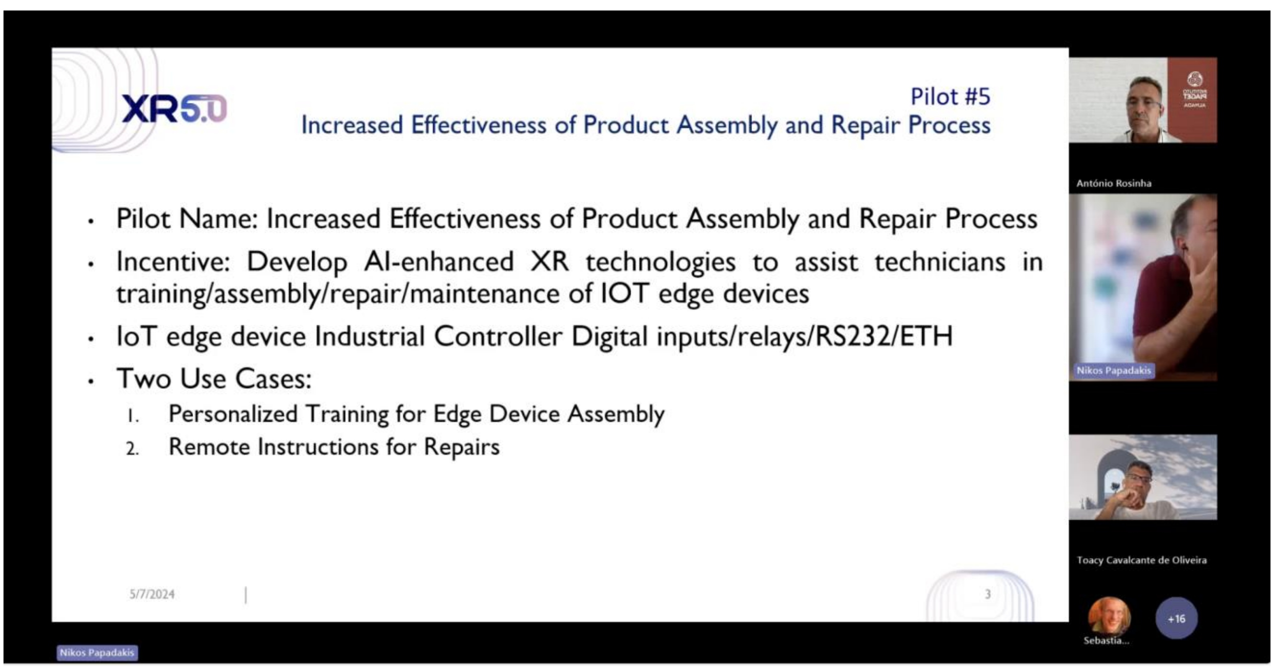
1. General Context

This pilot is centered on developing and integrating XR (Extended Reality) solutions for training and supporting the assembly, deployment, and repair of edge devices at SPACE. The document details discussions about customer support environments, the importance of training technical staff, and the development of personalized content to enhance the effectiveness of these training programs. The initial discussion focused on establishing a clear strategy for training and supporting SPACE’s technicians through innovative XR solutions, with a strong emphasis on personalization, technical support, and efficient task prioritization.
The introduction of the use cases, along with specific examples provided during a detailed discussion among project members, are presented below (Figure 1). These use cases aim to enhance the efficiency and effectiveness of SPACE's technical operations through the integration of XR (Extended Reality) solutions. Below are detailed descriptions of the two use cases.

Figure 1 – Scenarios Description



2. Use Cases

2.1. Description

2.1.1. Use Case 1: Personalized Training for Edge Device Assembly

Objective:

To develop and implement personalized XR-based training programs that assist SPACE's technical staff in efficiently assembling and configuring edge devices, accommodating varying skill levels ranging from beginners to intermediate technicians (Figure 2).

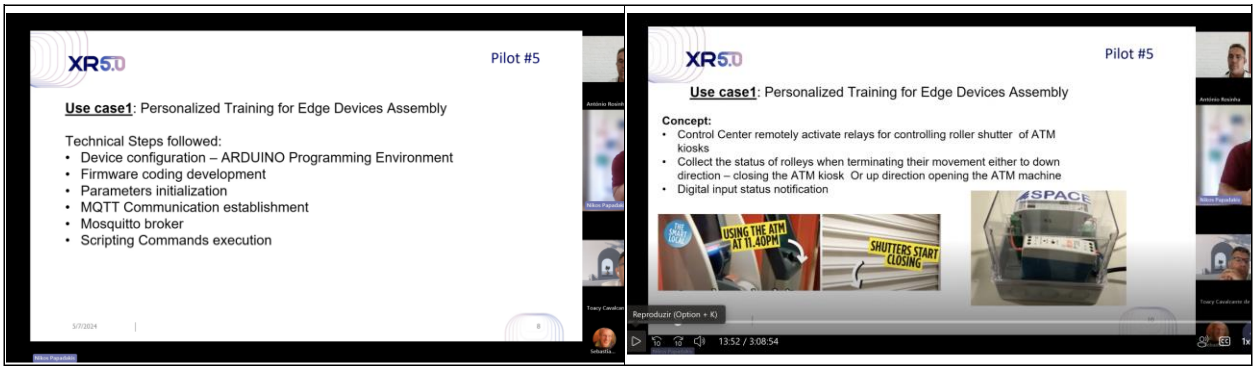
Context and Rationale:

- Diverse Skill Levels: SPACE employs technicians with varying degrees of experience. Some lack prior experience in assembling and configuring complex edge devices, necessitating tailored training solutions.
- Complex Assembly Processes: Edge devices comprise multiple components, including replaceable parts, requiring precise assembly procedures to ensure optimal functionality.
- Resource Optimization: Efficient training reduces the time and resources spent on onboarding and upskilling technicians, leading to improved operational productivity and reduced errors during assembly.

Key Components:

1. Development of Guided XR Training Content:
   - Interactive Modules: Creation of immersive, step-by-step instructional modules utilizing AR and MR technologies to guide technicians through the assembly process.
   - Skill-Level Adaptation: Training content is tailored to the technician's experience level, providing more detailed guidance for beginners and advanced scenarios for intermediate users.
   - Multimedia Integration: Incorporation of 3D models, animations, and interactive simulations to enhance understanding and retention of assembly procedures.
2. Implementation of AI-Driven Training Workflows:
   - Adaptive Learning Paths: Use of AI algorithms to adjust training complexity based on real-time performance assessments, ensuring personalized learning experiences.
   - Performance Tracking: Continuous monitoring of trainee progress through biometric feedback (e.g., heart rate variability) and task completion times to inform and adjust training content.
   - Feedback Mechanisms: Provision of immediate, context-specific feedback within the XR environment to correct mistakes and reinforce correct procedures.
3. Cloud-Based Repository for Training Materials:
   - Centralized Access: Development of a secure, cloud-based repository where all training materials and resources are stored and easily accessible to technicians across various locations.
   - Version Control: Ensuring that all training content is up-to-date, with seamless updates and maintenance of training modules.
   - Analytics and Reporting: Collection and analysis of usage data to evaluate training effectiveness and identify areas for improvement.

Figure 2 – Use case 1



Expected Outcomes:

- Enhanced Competency: Technicians achieve a higher level of proficiency in assembling edge devices accurately and efficiently.
- Reduced Training Time: Streamlined training processes lead to quicker onboarding and skill development.
- Improved Quality and Safety: Reduction in assembly errors and adherence to safety protocols through comprehensive and engaging training.
- Increased Engagement: Interactive and immersive training experiences boost engagement and motivation among technical staff.

2.1.2. Use Case 2: Remote Instruction for Edge Device Repairs

Objective:

To establish an XR-enabled remote support system that provides real-time, personalized assistance to technicians performing repairs on edge devices, enhancing problem-solving efficiency and reducing device downtime (Figure 3).

Context and Rationale:

- Low Frequency but High Impact Repairs: Although defective units are infrequent, timely and effective repairs are critical to maintaining operational continuity and client satisfaction.
- Complex Troubleshooting Processes: Identifying and resolving issues can be challenging, particularly for less experienced technicians or in cases involving complex faults.
- Resource Efficiency: Remote support minimizes the need for on-site expert interventions, saving time and reducing operational costs.

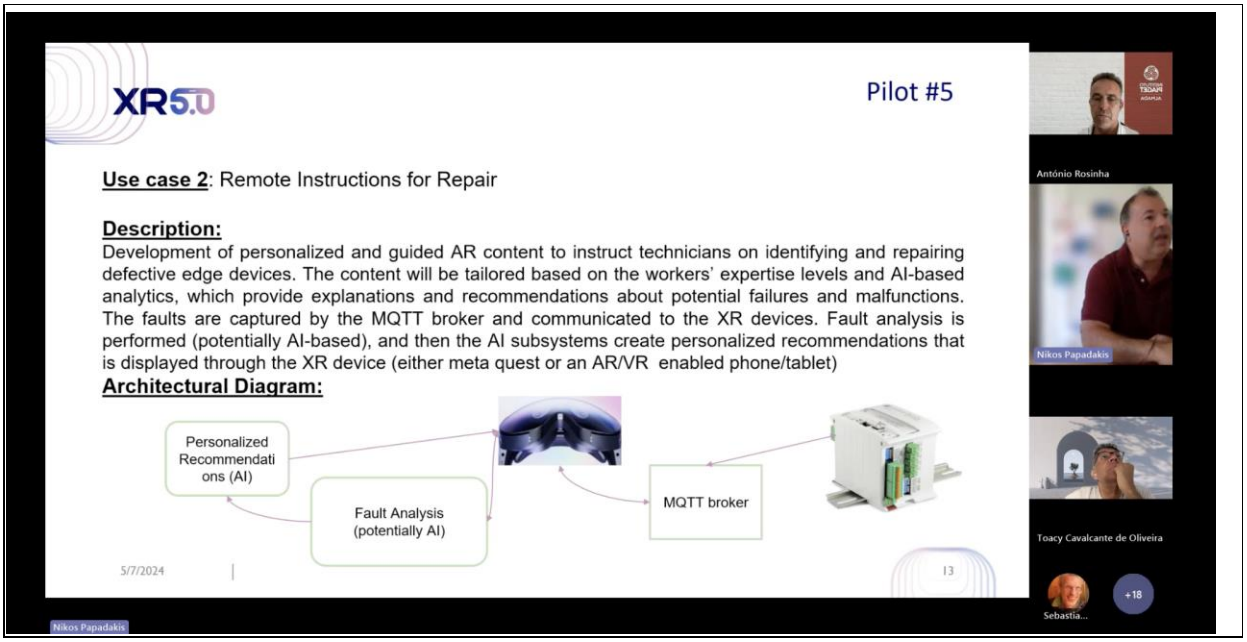
Key Components:

1. Real-Time AR-Based Remote Assistance:
    - Live Support Sessions: Technicians can connect with remote experts through AR interfaces, receiving step-by-step guidance during repair tasks.
    - Visual Annotations: Experts can overlay visual cues and instructions directly onto the technician’s field of view, facilitating precise and clear guidance.
    - Bidirectional Communication: Seamless audio and video communication channels enable effective collaboration and immediate problem resolution.
2. Diagnostic and Troubleshooting Tools:
    - Integrated Sensor Data Access: Real-time access to device diagnostics and sensor data within the XR environment assists in quick identification of issues.

- Interactive Troubleshooting Guides: Access to comprehensive, interactive repair manuals and decision trees tailored to specific fault scenarios.
- AI-Powered Fault Detection: Utilization of AI models to predict and identify common issues, providing proactive recommendations to technicians.

3. Personalization Based on Skill Levels:
   - Adaptive Support Intensity: The level of guidance and detail provided adjusts according to the technician's experience and familiarity with the repair process.
   - Skill Development Tracking: Monitoring and recording repair tasks to inform future training needs and support personalization.
   - Feedback and Assessment: Post-repair evaluations to assess performance and provide constructive feedback for continuous improvement.

Figure 3 – Use case 2



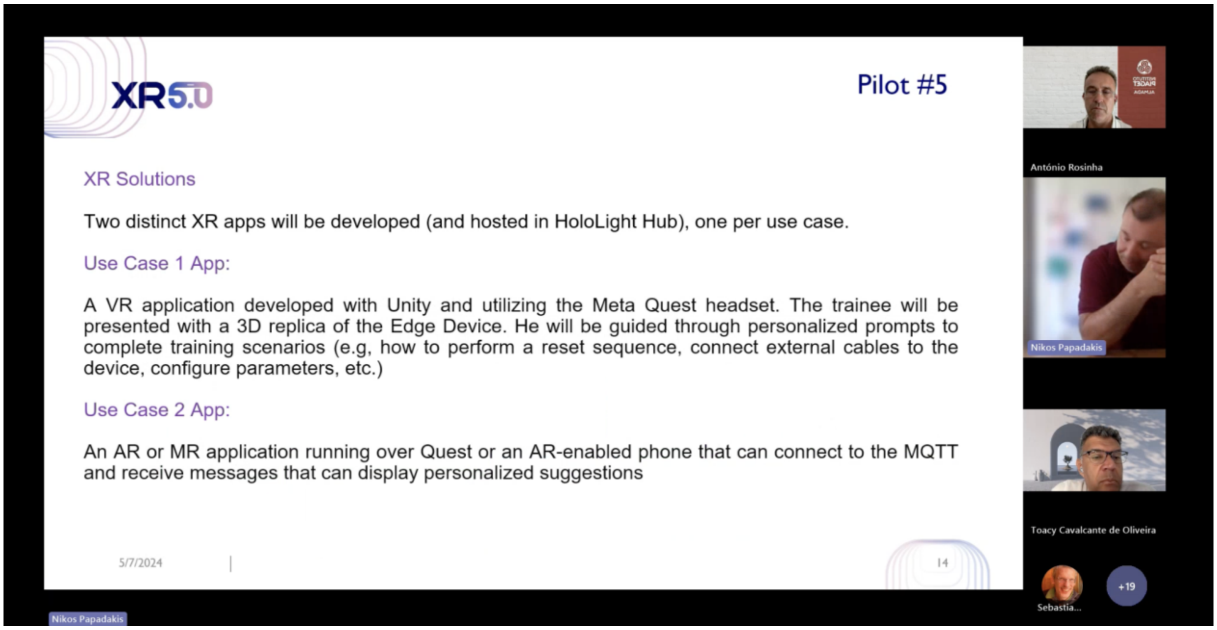
Expected Outcomes:

- Faster Repair Times: Enhanced support leads to quicker identification and resolution of device issues.
- Reduced Operational Downtime: Prompt repairs ensure minimal disruption to services and operations.
- Knowledge Transfer: Facilitates the sharing of expertise and best practices across the technical team, elevating overall competency.
- Cost Savings: Decreases the necessity for on-site expert visits and associated costs through effective remote support mechanisms.

2.1.3. XR Applications:

During the meeting, it was discussed that two distinct XR applications (Figure 4) would be developed for the use cases, both hosted in the Hub. The first application is a VR app built using Unity and designed for the Meta Quest headset. This application will guide training through personalized prompts to complete the training scenarios. The second application is an MR/AR app running on a wearable device, capable of receiving and sending messages to display personalized suggestions in real-time. These applications are key to enhancing the training and support processes as outlined in the respective use cases.

Figure 4 – XR Applications



2.2. Key Points about Personalization:

The discussion on personalization primarily focused on tailoring training and support content to the varying skill levels and needs of SPACE's technical staff.

1. Personalized Training Content:
   - There was a strong emphasis on the need to develop training modules that adapt to the experience level of the technicians, ensuring that both beginners and more advanced users receive appropriate guidance. This approach was considered crucial for improving the efficiency and effectiveness of training sessions, particularly in the assembly and configuration of edge devices.
2. Skill Level Adaptation:
   - The training content would be designed to offer more detailed and basic instructions for beginners, while providing more complex and less guided scenarios for intermediate technicians. This ensures that all technicians, regardless of their starting point, can progress and perform their tasks competently.
3. XR Solutions for Personalized Guidance:
   - XR technologies, including VR and AR, were discussed as tools to deliver personalized instructions. These technologies would allow for real-time adjustments based on the technician's performance, providing prompts and feedback that cater specifically to the user's skill level and current task requirements.
4. Remote Support Personalization:
   - For repair processes, the personalization extends to the level of support provided remotely. The MR/AR application, for example, would deliver personalized suggestions and instructions to technicians based on the specific issues they are addressing and their previous experience with similar tasks.

Overall, personalization was seen as a critical factor in both training and operational support, aimed at enhancing learning outcomes, reducing errors, and increasing the overall efficiency of SPACE's technical staff.

Conclusion:

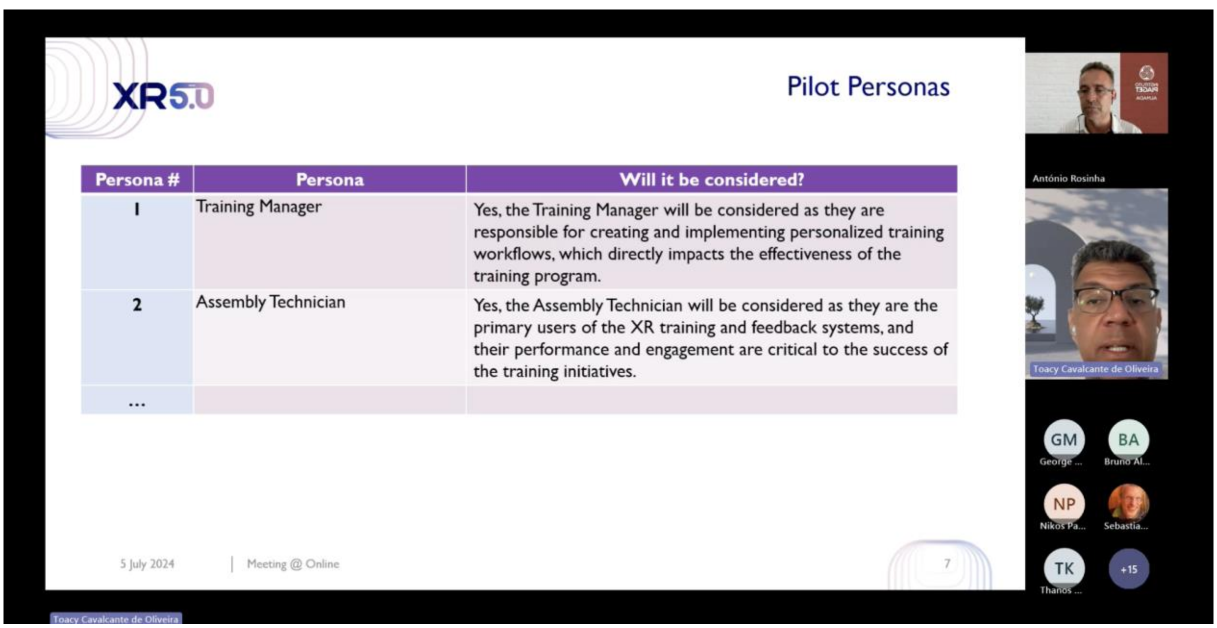
Both use cases underscore the strategic implementation of XR technologies to revolutionize training and support processes within SPACE. By focusing on personalization and leveraging advanced technologies such as AI and cloud computing, these initiatives aim to significantly improve operational efficiency, technician proficiency, and service quality in the assembly and maintenance of edge devices.

3. Persona Analysis

In the context of SPACE's efforts to enhance the assembly and configuration of edge devices through innovative training and support systems, two key personas emerge: the Training Manager and the Assembly Technician (Figure 5). These personas represent the critical roles involved in ensuring the successful deployment and maintenance of complex technologies within the organization.

The Training Manager is the architect of the learning journey, responsible for designing and implementing personalized training programs that equip the technical staff with the skills they need. On the other hand, the Assembly Technician is the hands-on expert who brings these devices to life, relying on tailored training and real-time support to perform their tasks with precision and efficiency. Together, these personas highlight the importance of personalized training and support in driving operational excellence at SPACE.

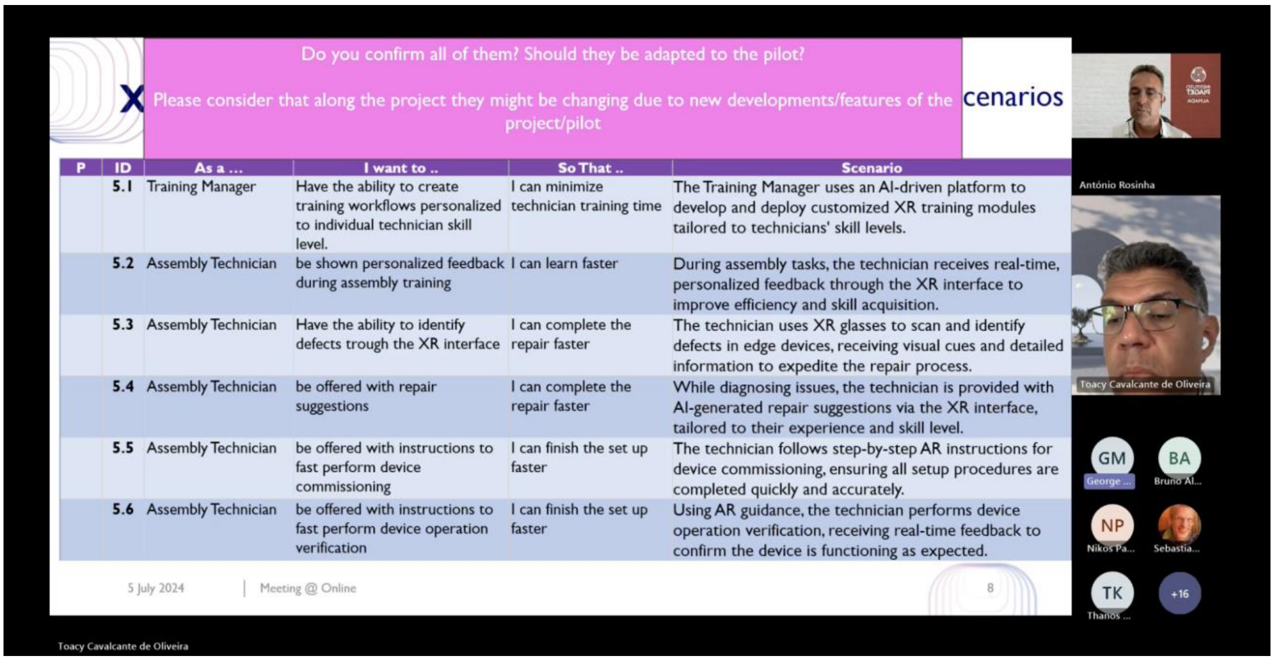
Figure 5 – Pilot Personas



4. User Stories

A comprehensive discussion was held on user stories relevant to the development and implementation of XR solutions at SPACE. The focus was on identifying the specific needs of different roles within the organization, particularly the Training Manager and Assembly Technicians. This discussion was crucial in outlining the functionality required from XR systems to ensure they improve efficiency, reduce training time, and enhance the quality of repairs and assemblies. Figure 6 represents the distribution of personas across scenarios.

Figure 6 – User Stories



4.1. Analysis of User Stories

The user stories were examined to understand how each contributes to the overall objectives, and their prioritization was determined based on their potential impact. The analysis also delved into the specific features and benefits that each user story would bring to the table, emphasizing the importance of personalization and real-time feedback in both training and on-the-job tasks.

4.2. Prioritization Of User Stories

Based on the discussion, the user stories have been categorized and prioritized (Table 1).
Prioritization of user stories is essential to allocate resources effectively and ensure that the most critical tasks are addressed first. The following table categorizes the user stories based on their roles, description, and the priority they have been assigned in the project.
In summary, the analysis and prioritization of user stories highlight the strategic focus on enhancing training and support mechanisms for SPACE's technical team. The highest priorities are given to developing AI-driven personalized training workflows (User Story 5.1), ensuring easy access to training materials (User Story 5.2), and providing quick, clear instructions for device configuration (User Story 5.5). These priorities reflect the need to improve both the efficiency and effectiveness of training, ultimately leading to better performance in assembly and repair tasks. The lower priority user stories are important but can be addressed in subsequent phases, allowing the team to focus on the most impactful areas first.

Table 1 - User Story Prioritization

User Story Number	Role	Description and Analysis	Prioritization
5.1	Training Manager	Focuses on creating personalized training workflows using AI to enhance efficiency and engagement.	Priority 1 High
5.2	Assembly Technician	Emphasizes the need for accessible, cloud-based training materials to support ongoing learning and quick access.	Priority 2 High
5.3	Assembly Technician	Involves the development of additional support tools but is less critical compared to other priorities.	Lower Priority
5.4	Assembly Technician	Related to non-essential tasks that can be postponed without impacting core objectives.	Lower Priority
5.5	Assembly Technician	Focuses on providing quick configuration instructions to increase productivity and reduce setup time.	Priority 3 High
5.6	Assembly Technician	Supports the enhancement of existing workflows but does not require immediate attention.	Lower Priority

4.3. Key Discussion Points

As the user stories were discussed, several key themes emerged that are central to the success of SPACE's XR initiatives. These points highlight the importance of customization, the need for immediate, actionable feedback, and the strategic prioritization of tasks that will most significantly enhance operational efficiency. These discussions were critical in shaping the direction of the project, ensuring that the XR solutions developed are not only innovative but also practical and aligned with the real-world needs of SPACE's technicians and managers.

- Customization and Personalization: There was a strong focus on ensuring that training and support are tailored to the individual needs and skill levels of technicians. This personalized approach is seen as essential for improving efficiency and reducing errors.
- Real-time Feedback and Assistance: The provision of real-time feedback, whether during training or actual repair tasks, was highlighted as a critical feature for helping technicians work more efficiently and effectively.
- Prioritization: The user stories were prioritized based on their impact on the overall efficiency of the training and operational processes. User story 5.1 was given significant attention for its role in minimizing training time, while 5.4 and 5.5 were noted for their contributions to faster and more accurate repairs and commissioning.

4.4. Synthesis

The discussion of the user stories reflects a strategic focus on enhancing both training and operational workflows through the use of XR technologies. The prioritization of user stories indicates a clear understanding of which features will have the most immediate and significant impact on SPACE's operations, with an emphasis on personalization, real-time support, and task efficiency. The involvement of Nikos Papadakis helped ensure that these priorities align with the broader goals of optimizing technician performance and improving overall operational outcomes.

5.0. Personas

5.1 - Training Manager

- Objective: The Training Manager needs to create training workflows that are personalized to each technician's skill level.
- Benefit: This capability allows for the minimization of technician training time, optimizing the learning process.
- Implementation: The Training Manager uses an AI-driven platform to develop and deploy customized XR training modules, ensuring that the content is tailored to the technicians' individual skill levels.
- Priority: This user story was marked with priority 2 during the discussion, indicating its significant importance.

5.2 - Assembly Technician

- Objective: Assembly Technicians should receive personalized feedback during assembly training.
- Benefit: This approach enables technicians to learn faster by improving their efficiency and skill acquisition during training sessions.
- Implementation: Technicians receive real-time, personalized feedback through the XR interface, which guides them during the assembly tasks.
- Priority: Although not explicitly stated, the importance of this user story lies in its contribution to faster learning curves and improved on-the-job performance.

5.3 - Assembly Technician

- Objective: The ability to identify defects through the XR interface.
- Benefit: Technicians can complete repairs more quickly by using XR glasses to scan and identify defects in edge devices, receiving visual cues and detailed information.
- Implementation: The XR interface provides the necessary tools to identify defects, enabling technicians to diagnose and fix issues faster.

5.4 - Assembly Technician

- Objective: Technicians should be offered repair suggestions via the XR interface.
- Benefit: This feature helps technicians complete repairs faster by providing AI-generated repair suggestions tailored to their experience and skill level.
- Implementation: The XR system offers real-time, experience-based repair suggestions to assist technicians during the diagnostic and repair process.
- Priority: This user story was assigned priority 3, highlighting its role in enhancing the speed and accuracy of repairs.

5.5 - Assembly Technician

- Objective: Technicians need instructions to quickly perform device commissioning.
- Benefit: This allows technicians to finish setup tasks faster, improving overall efficiency.
- Implementation: Step-by-step AR instructions guide technicians through the device commissioning process, ensuring all setup procedures are completed swiftly and correctly.
- Priority: This user story was also emphasized for its importance in operational efficiency.

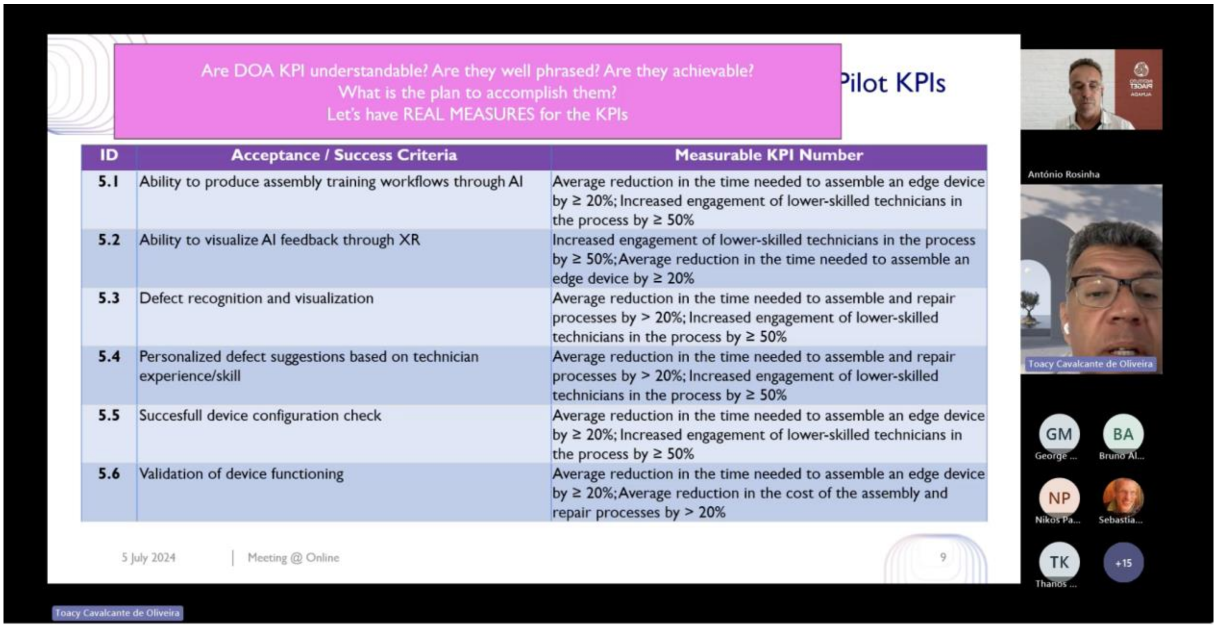
5.6 - Assembly Technician

- Objective: Instructions for fast device operation verification should be provided.
- Benefit: Technicians can complete the setup faster by using AR guidance to perform operation verification, receiving real-time feedback.
- Implementation: The system ensures that the device is functioning as expected by guiding the technician through the necessary verification steps.

6. KPIs

Key Performance Indicators (KPIs) are essential metrics used to evaluate the success and impact of the user stories discussed in the SPACE XR initiative. During the meeting, several KPIs were identified and analyzed to ensure that the development and implementation of XR solutions would lead to measurable improvements in training efficiency, technician performance, and overall operational effectiveness. (Figure 5).

Figure 5 - Key Performance Indicators



ID	Acceptance / Success Criteria	Measurable KPI Number
5.1	Ability to produce assembly training workflows through AI	Average reduction in the time needed to assemble an edge device by ≥ 20%; Increased engagement of lower-skilled technicians in the process by ≥ 50%
5.2	Ability to visualize AI feedback through XR	Increased engagement of lower-skilled technicians in the process by ≥ 50%; Average reduction in the time needed to assemble an edge device by ≥ 20%
5.3	Defect recognition and visualization	Average reduction in the time needed to assemble and repair processes by > 20%; Increased engagement of lower-skilled technicians in the process by ≥ 50%
5.4	Personalized defect suggestions based on technician experience/skill	Average reduction in the time needed to assemble and repair processes by > 20%; Increased engagement of lower-skilled technicians in the process by ≥ 50%
5.5	Succesfull device configuration check	Average reduction in the time needed to assemble an edge device by ≥ 20%; Increased engagement of lower-skilled technicians in the process by ≥ 50%
5.6	Validation of device functioning	Average reduction in the time needed to assemble an edge device by ≥ 20%; Average reduction in the cost of the assembly and repair processes by > 20%

6.1. Analysis of the Discussion on KPIs

The meeting covered a detailed analysis of Key Performance Indicators (KPIs) for the user stories, focusing on their acceptance criteria and measurable outcomes. Below is a breakdown of the discussion on KPIs related to each user story, highlighting how they align with the project's goals of improving efficiency and engagement.

User Story 5.1

- Acceptance / Success Criteria: Ability to produce assembly training workflows through AI.
- Measurable KPI Number:
  - o Time Reduction: The goal is to achieve an average reduction in the time needed to assemble an edge device by at least 20%.
  - o Engagement Increase: Additionally, there should be a ≥ 50% increase in engagement from lower-skilled technicians during the assembly process.

Discussion Summary:

- The focus here was on the dual objective of reducing assembly time and increasing engagement among less experienced technicians. The use of AI to create personalized training workflows was emphasized as a critical factor in achieving these outcomes. By tailoring the training to individual skill levels, the project aims to both streamline the assembly process and make it more accessible to all technicians, regardless of their initial skill level.

User Story 5.2

- Acceptance / Success Criteria: Ability to visualize AI feedback through XR.
- Measurable KPI Number:
    - o Engagement Increase: A ≥ 50% increase in engagement among lower-skilled technicians.
    - o Time Reduction: A target of a ≥ 20% reduction in the time needed to assemble an edge device.

Discussion Summary:

- The visualization of AI-driven feedback through XR was seen as a key enabler for enhancing technician engagement. The ability to receive real-time, personalized feedback while performing assembly tasks is expected to significantly boost the confidence and performance of lower-skilled workers, leading to faster and more accurate completions of their tasks.

User Story 5.3

- Acceptance / Success Criteria: Defect recognition and visualization.
- Measurable KPI Number:
    - o Time Reduction: Aimed at reducing the time needed for assembly and repair processes by over 20%.
    - o Engagement Increase: Goal of increasing lower-skilled technician engagement by ≥ 50%.

Discussion Summary:

- The capability of recognizing and visualizing defects using XR tools was discussed as a crucial feature for speeding up repair processes. This function not only enhances the technicians' ability to identify issues quickly but also engages them more deeply in their work by providing them with clear, actionable information.

User Story 5.4

- Acceptance / Success Criteria: Personalized defect suggestions based on technician experience/skill.
- Measurable KPI Number:
    - o Time Reduction: A > 20% reduction in the time required for assembly and repair.
    - o Engagement Increase: A ≥ 50% increase in engagement from lower-skilled technicians.

Discussion Summary:

- Providing personalized defect suggestions tailored to the technician's skill level was highlighted as a significant improvement in the repair process. The use of AI to offer suggestions based on real-time analysis of the technician's performance was seen as a way to both speed up the repair process and improve the learning experience, making it more engaging for lower-skilled technicians.

User Story 5.5

- Acceptance / Success Criteria: Successful device configuration check.
- Measurable KPI Number:
    - o Time Reduction: An average reduction in assembly time by ≥ 20%.
    - o Engagement Increase: A ≥ 50% increase in engagement among lower-skilled technicians.

Discussion Summary:

- The importance of providing clear, step-by-step instructions for device configuration was discussed, with the objective of reducing the time required for this task. Ensuring that even lower-skilled technicians can perform configurations correctly and efficiently was a key focus, as this not only improves overall productivity but also boosts technician confidence and job satisfaction.

User Story 5.6

- Acceptance / Success Criteria: Validation of device functioning.
- Measurable KPI Number:
  - Time Reduction: A ≥ 20% reduction in the time needed for assembly.
  - Cost Reduction: A > 20% reduction in the cost of assembly and repair processes.

Discussion Summary:

- The validation of device functioning was tied to both time and cost savings. By ensuring that devices are functioning correctly before deployment, the project aims to reduce the need for costly repairs and rework. This KPI emphasizes the importance of thorough verification processes that can be carried out efficiently, contributing to both operational and financial improvements.

Synthesis

The KPIs discussed during the meeting were clearly aligned with the overarching goals of improving efficiency, reducing time, and enhancing engagement, particularly among lower-skilled technicians. Each user story was associated with specific, measurable targets that reflect the project's commitment to delivering tangible benefits through the implementation of XR technologies. The dual focus on time reduction and engagement increase indicates a holistic approach, aiming not just for faster processes but also for more motivated and capable technicians. These KPIs will serve as critical benchmarks for evaluating the success of the project as it progresses.

7. Human Factors

The discussion covered data collection to measure user experience and the physiological and psychological impacts of using these technologies, highlighting the following points (Figure 6)

Figure 6 – XR5 Human Factors

XR5.0 Human Factors	Will it be used?	In which User Story (ID)?
Questionnaires		
Fatigue	NO	
Task load index	YES	5.2
Digital Skills	YES	5.2
User Experience	YES	5.2
Emotion/mood	NO	
Perceived Effectiveness	YES	5.1
Physiological metrics		
Heart rate variability (stress, cognitive load, engagement)	YES	
Galvanic Skin Response (stress & engagement)	YES	
Capture & maintenance of attention (assessed by eye-tracking)	NO	
Pupil dilation (assessed by eye-tracking)	NO	
Gaze behavior (assessed by eye-tracking)	NO	

In the meeting, the discussion of human factors centered around how these elements would influence the development and evaluation of the XR solutions in Pilot 5. The focus was on understanding how these factors would be measured and applied within different user stories to enhance the overall effectiveness and user experience of the XR tools.

7.1. Key Human Factors Discussed

7.1.1. Questionnaires

1. Task Load Index
    - o Relevance: Task load index was identified as an important factor in User Story 5.2, which involves providing real-time, personalized feedback through the XR interface during assembly tasks. The task load index will be used to measure the cognitive load placed on technicians as they interact with the XR tools.
    - o Main Discussion Point: The team discussed how the task load index could be used to ensure that the XR interface does not overwhelm technicians, especially those with lower digital skills. By monitoring this index, adjustments can be made to balance the complexity of the tasks with the technicians' abilities, ensuring that the XR tools remain effective and user-friendly.
2. Digital Skills
    - o Relevance: Also associated with User Story 5.2, digital skills were discussed as a critical factor in determining how effectively technicians could interact with the XR tools. The varying levels of digital literacy among technicians necessitate a design that is accessible and easy to use for all skill levels.
    - o Main Discussion Point: The discussion emphasized the need to design the XR interface in a way that accommodates technicians with varying levels of digital skills. This includes simplifying navigation, providing clear instructions, and incorporating intuitive features that do not require extensive training to use effectively.
3. User Experience
    - o Relevance: User experience was highlighted in User Story 5.2 as a key metric for evaluating the success of the XR tools. This factor involves assessing how enjoyable and efficient the XR interactions are for the technicians.
    - o Main Discussion Point: The discussion focused on how to measure and improve user experience through continuous feedback and iterative design. Ensuring that the XR tools are engaging and easy to use will be critical for their adoption and effectiveness. The team considered using questionnaires and other feedback mechanisms to regularly assess user satisfaction and identify areas for improvement.
4. Perceived Effectiveness
    - o Relevance: This factor was linked to User Story 5.1, which focuses on the ability of the Training Manager to create personalized training workflows. Perceived effectiveness relates to how useful and impactful the users believe these workflows are in helping them perform their tasks.
    - o Main Discussion Point: The team discussed the importance of perceived effectiveness as a subjective but crucial measure of the success of the training programs. If technicians perceive the training as effective, they are more likely to engage with it fully and apply what they learn in their work, leading to better outcomes.

7.1.2. Physiological Metrics

5. Heart Rate Variability (Stress, Cognitive Load, Engagement):
    - o Relevance: Used to assess how stressed or engaged technicians are while using the XR tools.
    - o Main Discussion Point: Monitoring heart rate variability was discussed as a method to gauge the cognitive load and stress levels of technicians. This data will be important in adjusting the difficulty and pacing of the XR tasks to ensure they are challenging but not overwhelming.
6. Galvanic Skin Response (Stress & Engagement):

  - Relevance: Also used to measure stress and engagement levels.
  - Main Discussion Point: Similar to heart rate variability, galvanic skin response was discussed as a way to monitor how technicians physically respond to the XR environment. High stress levels might indicate that the tasks are too difficult or that the interface is not user-friendly, requiring adjustments to the design or the training content.

Human Factors Not Used

- Fatigue, Emotion/Mood, Eye-Tracking Metrics (Capture & Maintenance of Attention, Pupil Dilation, Gaze Behavior):
  - These factors were not considered relevant in the current scope of the XR tools development. The team decided to focus on more directly measurable and impactful metrics like stress, cognitive load, and engagement.

7.3. Summary of Main Discussion Points on Human Factors

Table 2 encapsulates the core points discussed regarding human factors, their relevance to the user stories, and the main considerations in ensuring the XR tools are effective and user-friendly

Table 2 - Main Points on Human Factors

Human Factor	User Story (ID)	Relevance	Main Discussion Points
Task Load Index	5.2	Measures cognitive load on technicians.	Ensures XR tools are not overwhelming and are balanced with technicians' abilities.
Digital Skills	5.2	Assesses technicians' ability to interact with XR tools.	Design must accommodate varying digital skills; simplify navigation and provide clear instructions.
User Experience	5.2	Evaluates enjoyment and efficiency of XR interactions.	Continuous feedback and iterative design to improve user satisfaction and tool engagement.
Perceived Effectiveness	5.1	Reflects users' belief in the utility of training workflows.	Crucial for engagement; perceived effective training leads to better application in tasks.
Heart Rate Variability (Stress, Cognitive Load, Engagement)	All	Monitors stress and cognitive load during XR tasks.	Used to adjust task difficulty and pacing, ensuring tasks are challenging but manageable.
Galvanic Skin Response (Stress & Engagement)	All	Measures physical stress and engagement levels.	Monitors technician response to XR environment to identify necessary adjustments.
Fatigue, Emotion/Mood, Eye-Tracking Metrics	N/A	Not used in this scope.	These factors were not considered relevant for the current XR tool development focus.

The discussion on human factors highlighted the importance of designing XR tools that are not only effective but also user-friendly and adaptive to the needs of technicians with varying skills. By focusing on task load, digital skills, user experience, perceived effectiveness, and physiological metrics, the project aims to create a balanced and supportive environment for technicians, enhancing both their performance and overall satisfaction with the tools. These considerations will be critical in ensuring the successful adoption and impact of the XR solutions in SPACE's operations.

8. Technical Components

The use of different technical components of XR5.0 was discussed across various user stories. The discussion addressed the applicability of each technical component and how they contribute to achieving the objectives of the respective tasks (Figure 7).

Figura 7 - Technical component

Task	XR5.0 Technical Component	Will it be used?	In which User Story (ID)?	How
T3.3	Workers' digital twins	No		
T3.4	Personalized XR content	Yes	All	N/A for now (skill, Heart rate variability, stress level)
T4.1	Human-centered XAI models	Maybe	5.4,5.5,5.6	Provide AI generated explanations about the offered suggestions
T4.2	XR-enabled Active Learning	Maybe	5.3-5.6	N/A for now
T4.2	Neurosymbolic AI models	Maybe	5.3-5.6	N/A for now
T4.3	Generative AI models	YES	5.1&5.2	Will be used to generate random training scenarios based on specific training objectives (no GDPR needed mostly)
T4.4	Visualization of XAI explanations	No		
T4.5	Visualization of AI recommendations	Yes	5.4, 5.5, 5.6	Display the recommendations
T5.1	Training material	Yes	5.1	Develop and deliver XR-based training materials and demonstrators for industrial scenarios.
T5.2	Cloud-based repository	Yes	5.1 & 5.2	The cloud repository will be the host of all training material (XR & traditional)
T5.3	Hololight Hub	Yes	All	The XR apps developed for the pilot needs (use case1 app & use case2 app) will be hosted in Hub and streamed to the devices
T5.4	Training programs	Yes	5.1 & 5.2	Follow the guidelines from 5.4

8.1. Main Discussion Points on Technical Components

The discussion surrounding the technical components of the XR solutions for Pilot 5 highlighted the integration of various technologies to support the development, deployment, and effectiveness of the XR tools. Each technical component was analyzed for its applicability to the different user stories, with a focus on how these components would enhance the overall functionality and user experience of the XR systems.

Key Technical Components Discussed

1. Personalized XR Content (T3.4)
   - Usage: Yes, applicable to all user stories.
   - Main Discussion Point: The development of personalized XR content is central to the project, though specific customization based on skill levels, heart rate variability, and stress levels is yet to be fully defined. The content will be tailored to the individual needs of technicians, ensuring that training and support are effective and relevant.
2. Human-Centered XAI Models (T4.1)
   - Usage: Maybe, in User Stories 5.4, 5.5, and 5.6.
   - Main Discussion Point: These models may be used to provide AI-generated explanations for the suggestions offered during the XR training and operational tasks. The focus is on making

the AI outputs understandable and actionable for technicians, enhancing their decision-making process.

3. XR-Enabled Active Learning (T4.2)
   - Usage: Maybe, in User Stories 5.3 to 5.6.
   - Main Discussion Point: Although not yet fully defined, XR-enabled active learning could play a significant role in enhancing the learning experience by providing real-time, interactive learning opportunities. This component would allow technicians to engage with the material more deeply, potentially improving skill retention and application.
4. Neurosymbolic AI Models (T4.2)
   - Usage: Maybe, in User Stories 5.3 to 5.6.
   - Main Discussion Point: Similar to XR-enabled active learning, these models are still under consideration. If implemented, they could integrate symbolic reasoning with neural networks to improve the AI's ability to handle complex tasks and scenarios within the XR environment.
5. Generative AI Models (T4.3)
   - Usage: Yes, in User Stories 5.1 and 5.2.
   - Main Discussion Point: Generative AI will be utilized to create random training scenarios tailored to specific training objectives. This allows for a dynamic and varied training environment, helping technicians prepare for a wide range of potential real-world situations. The use of generative AI also sidesteps GDPR concerns by not relying on sensitive data.
6. Visualization of AI Recommendations (T4.5)
   - Usage: Yes, in User Stories 5.4, 5.5, and 5.6.
   - Main Discussion Point: This component will be used to display AI-generated recommendations directly to technicians. The focus is on providing clear, actionable advice that can be easily understood and applied during training and operational tasks, thereby improving decision-making and efficiency.
7. Training Material (T5.1)
   - Usage: Yes, in User Story 5.1.
   - Main Discussion Point: XR-based training materials and demonstrators will be developed for industrial scenarios. This material is crucial for ensuring that technicians are adequately prepared for the tasks they will encounter, with content designed to be immersive and engaging.
8. Cloud-Based Repository (T5.2)
   - Usage: Yes, in User Stories 5.1 and 5.2.
   - Main Discussion Point: The cloud repository will serve as the central hub for all training materials, both XR and traditional. This ensures that all content is easily accessible, up-to-date, and can be delivered seamlessly to technicians regardless of their location.
9. Hololight Hub (T5.3)
   - Usage: Yes, applicable to all user stories.
   - Main Discussion Point: The Hololight Hub will host and stream the XR apps developed for the pilot, including those for use case 1 and use case 2. This platform is essential for delivering the XR experiences to the devices used by technicians, ensuring reliable access and performance.
10. Training Programs (T5.4)
    - Usage: Yes, in User Stories 5.1 and 5.2.
    - Main Discussion Point: Training programs will be developed following the guidelines of user story 5.4. These programs are designed to ensure that technicians receive comprehensive, structured training that aligns with the project's objectives of enhancing skill levels and operational efficiency.

8.2. Summary of Main Discussion Points on Technical Components

Table 3 summarizes the main discussion points regarding the technical components, their applicability to the user stories, and their role in the overall project.

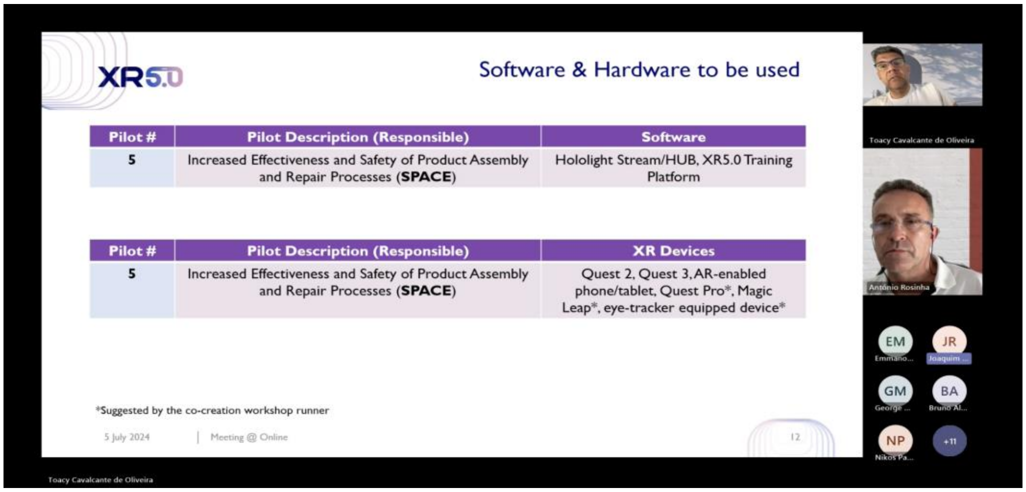
Task ID	Technical Component	Will it be Used?	User Story (ID)	Main Discussion Points
T3.3	Workers' Digital Twins	No	N/A	Not applicable to current user stories.
T3.4	Personalized XR Content	Yes	All	Central to the project, with future potential for customization based on skills and stress levels.
T4.1	Human-Centered XAI Models	Maybe	5.4, 5.5, 5.6	May provide AI-generated explanations for recommendations, focusing on clarity and usability.
T4.2	XR-Enabled Active Learning	Maybe	5.3 to 5.6	Potential role in enhancing interactive learning, though specifics are yet to be defined.
T4.2	Neurosymbolic AI Models	Maybe	5.3 to 5.6	Under consideration for integrating symbolic reasoning with neural networks.
T4.3	Generative AI Models	Yes	5.1, 5.2	Used to generate random training scenarios, avoiding GDPR concerns.
T4.4	Visualization of XAI Explanations	No	N/A	Not being used in the current scope.
T4.5	Visualization of AI Recommendations	Yes	5.4, 5.5, 5.6	Will display AI recommendations to enhance decision-making during tasks.
T5.1	Training Material	Yes	5.1	Development of XR-based training materials for industrial scenarios.
T5.2	Cloud-Based Repository	Yes	5.1, 5.2	Hosts all training materials, ensuring easy access and delivery.
T5.3	Hololight Hub	Yes	All	Hosts and streams XR apps for the pilot, essential for reliable access to XR experiences.
T5.4	Training Programs	Yes	5.1, 5.2	Follows guidelines to deliver structured and comprehensive training programs.

The discussion highlighted the need to integrate advanced AI and XR technologies for personalized and effective tools. Key components, like generative AI models and the Hololight Hub, are defined, while others, such as XAI models and XR-enabled learning, are under review. The goal is to equip technicians with efficient, user-friendly systems adaptable to varying skill levels.

9. Software and Hardware Analysis

The primary objective of Pilot 5 is to enhance the effectiveness and safety of product assembly and repair processes, particularly within the SPACE environment. This involves the use of advanced XR (Extended Reality) tools and software platforms to improve training outcomes and streamline operational workflows for technical staff (Figure 8).

Figure 8 – Software & Hardware



9.1. Software Analysis:

1. Hololight Stream/HUB:
   - Purpose: The Hololight Stream/HUB platform is essential for developing and hosting XR applications. It centralizes the development of immersive experiences, facilitating real-time collaboration and data visualization in a virtual environment.
   - Application in Pilot 5: This software will be utilized to create interactive training modules that guide technicians through complex assembly and repair tasks. It supports a remote, collaborative approach, which is crucial for personalized training and troubleshooting processes.
2. XR5.0 Training Platform:
   - Purpose: This platform is designed for immersive training, leveraging both virtual and augmented reality to provide hands-on experience in a controlled environment.
   - Application in Pilot 5: The XR5.0 platform will be used to simulate real-world scenarios for the assembly and repair of devices. This includes the creation of customized content tailored to the experience levels of different technicians, which is a critical component of the training strategy.

9.2. Hardware Analysis:

1. Quest 2, Quest 3:

   - Purpose: These VR headsets offer immersive experiences that are essential for engaging training sessions and hands-on practice.
   - Application in Pilot 5: The Quest devices will be employed to deliver VR-based training, allowing technicians to practice assembly and repair tasks in a simulated environment.

2. AR-enabled phone/tablet:

- o Purpose: These devices provide augmented reality capabilities, overlaying digital information onto the physical world.
- o Application in Pilot 5: AR-enabled devices will be used for on-the-job support, providing real-time guidance and troubleshooting steps to technicians during the actual assembly or repair processes. This aligns with the goal of improving real-time problem-solving skills as discussed.

3. Quest Pro and Magic Leap (with eye-tracking features):

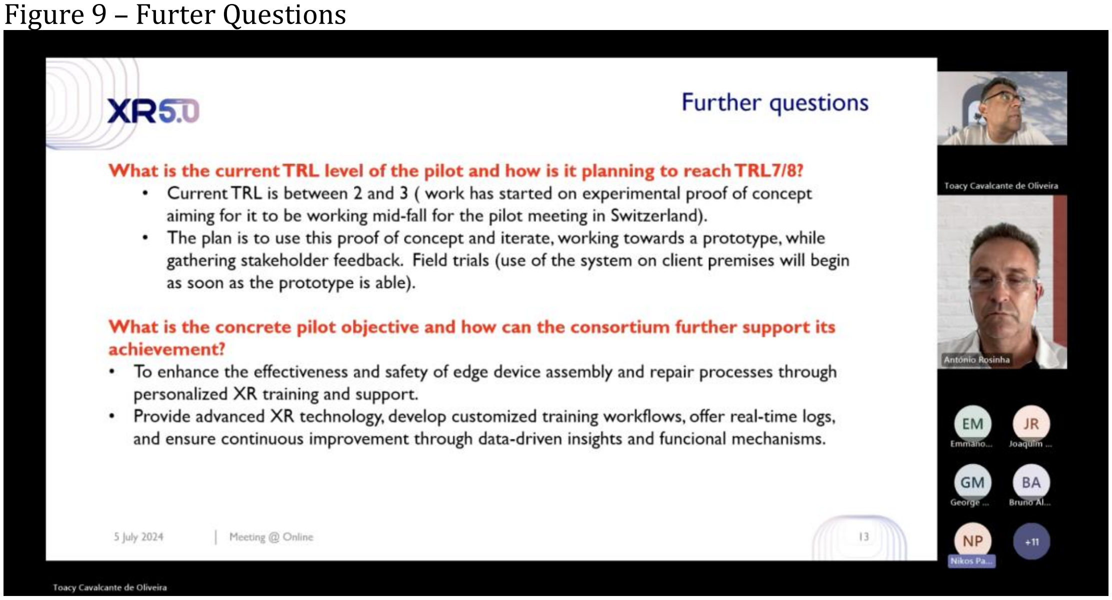
- o Purpose: Advanced XR headsets with enhanced features like eye-tracking improve user interaction and data collection during training.
- o Application in Pilot 5: These devices will be utilized for more advanced training modules where precise tracking and feedback are critical. They support the development of user-specific training content and allow for detailed analysis of technician performance, which is key to refining training workflows.

Conclusion: The combination of Hololight Stream/HUB and XR5.0 Training Platform software, alongside a range of XR devices, enables a robust, immersive training environment tailored to the specific needs of the SPACE project. This setup enhances both the effectiveness and safety of assembly and repair processes, ensuring that technicians are well-prepared to handle real-world tasks with confidence and precision.

10. Analysis of the Pilot Readiness and Support

The final discussion of the meeting focused around critical questions pertaining to the progress and objectives of Pilot 5, which is focused on enhancing the effectiveness and safety of edge device assembly and repair processes through the use of advanced XR (Extended Reality) technologies (Figure 9). These discussions aimed to clarify the current status of the pilot in terms of its Technology Readiness Level (TRL) and to outline the steps necessary to achieve higher TRL levels. Additionally, the conversation addressed the concrete objectives of the pilot and explored how the consortium can best support the achievement of these goals. The following provides a detailed overview of the key points discussed.

Figure 9 – Furter Questions



Here's a breakdown of the key points:

1. What is the current TRL level of the pilot and how is it planning to reach TRL7/8?
    - Current TRL Level: The pilot is currently at TRL 2-3. The work has begun on an experimental proof of concept, with the goal of having it operational by mid-fall for the upcoming pilot meeting in Switzerland.
    - Plan to Reach TRL7/8: The approach involves using the proof of concept as a foundation, iterating on it, and developing a prototype. This process will include gathering feedback from stakeholders and conducting field trials, where the system will be deployed on client premises as soon as the prototype is ready.
2. What is the concrete pilot objective and how can the consortium further support its achievement?
    - Pilot Objective: The primary goal is to improve the effectiveness and safety of edge device assembly and repair processes by utilizing personalized XR training and support.
    - Consortium Support: To achieve this objective, the consortium should focus on providing advanced XR technology, developing customized training workflows, offering real-time logs, and ensuring continuous improvement through data-driven insights and functional mechanisms.

The workshop concluded by emphasizing the need to develop a proof of concept by mid-fall and to use an iterative approach, incorporating stakeholder feedback, to advance towards a prototype.

ANNEX VI – WORKSHOP DETAILS FOR PILOT 6

Human Centric Guidance and Troubleshooting for Customer Service

Motivation: Maintenance and troubleshooting are critical to ensure smooth operations and avoid downtime. However, current maintenance and troubleshooting XR instructions are often not personalised, making it overwhelming for beginners and unnecessarily time-consuming for experienced personnel who need to sift through irrelevant information and steps. Additionally, troubleshooting can be stressful, especially when equipment is down. While XR glasses are used in the industry, personalisation is often lacking as creating personalised instructions is time-consuming.

Concept & Description: This pilot will illustrate how XR5.0 addresses the "limited personalisation" challenge through AI-driven functionalities that improve the personalisation, relevance, and accuracy of XR environments, including guidance for maintenance and troubleshooting. In this pilot, this guidance will be tailored to the needs of individuals e.g., to their level of experience, preferred interaction mode, and stress levels. The UCs will be based on ALMER's AR glasses and software, as well as on the LNS bar feeder (see side figures).

Date	Name Contacts	email
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1. General Context

Saurer Philipp from LNS discussed various topics related to the implementation of digital technologies and solutions in the company. He began by addressing the use of chatbots to gauge customer willingness to adopt this technology. He mentioned that the chatbot was recently launched and that the initial results were positive, despite the lack of promotion. He then explained how the company handles machine alarms, emphasizing that they do not directly monitor alarms but rely on customers to report issues. Customer experiences vary, with some able to resolve problems on their own while others need assistance.

Philipp also introduced the personas used by the company to define their digital offerings. He highlighted that the company primarily sells to OEMs (Original Equipment Manufacturers) and ODMs (Original Design Manufacturers), which means they often do not have direct contact with end customers. The shipping coordinator was mentioned as an example of a marginally relevant persona for the XR5.0 project, while the end customer technician was identified as a primary persona, responsible for keeping the machines running smoothly and contacting the company for preventive or corrective maintenance (Table 1).

Table 1 - Content Analysis

Dimension	Subdimension	Exact Examples from the Discourse
Technology	Chatbot	"We launched on July 1st, and the initial results are quite positive."
		"The chatbot aims to check if people are willing to use this tool."
Monitoring	Alarms	"We don't monitor the alarms directly; we rely on customers."
		"Some customers are very experienced... others call us."
Personas	Expedition Coordinator	"The expedition coordinator is important because they need to ensure that our machine is shipped along with theirs."
	End Customer Technician	"Here we really have the people whose job is to ensure that the machines are running smoothly."

This analysis shows how Philipp addressed specific topics of technology and monitoring, as well as discussing the different relevant personas for the project, highlighting the complexity and importance of collaborating with customers and partners.

2. Troubleshooting And Maintenance Process

2.1. Phases

Saurer Philipp describes the approach to digital transformation, focusing on three main phases in the troubleshooting and maintenance process:

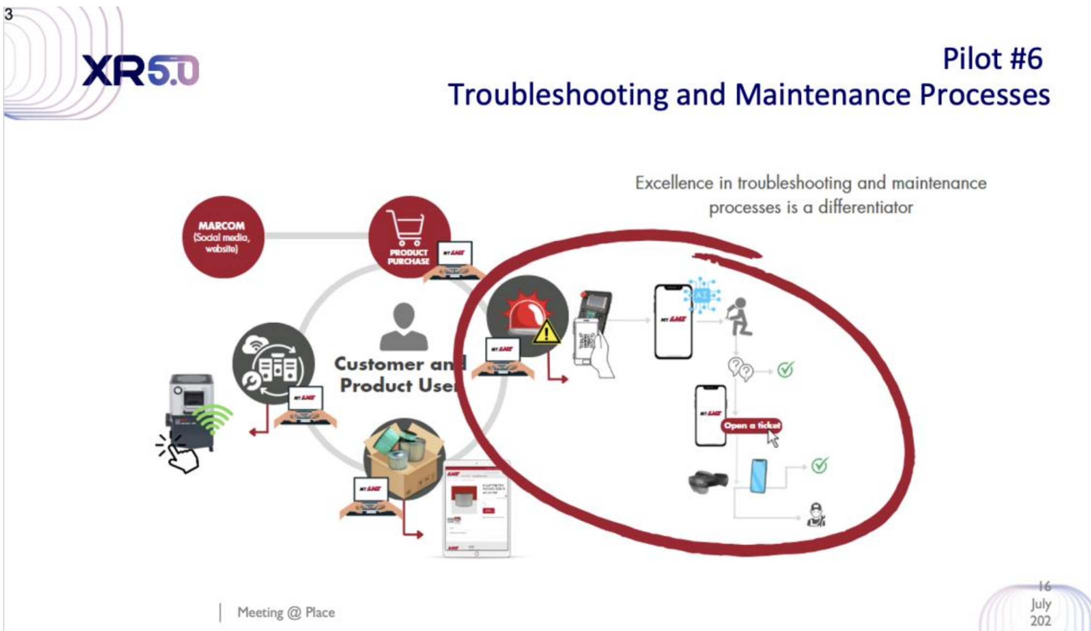
1. Self-Service Phase:
   - This phase currently relies heavily on the skill of the end customer technician. A physical manual of about 100 pages is provided with each machine, which is not very user-friendly.
   - There is a QR code that directs the technician straight to the correct alarm documentation, which has already been implemented.
   - There is also a chatbot in development to assist with troubleshooting, available 24/7, which already has a simple version on the website for frequently asked questions and ticket creation.
2. Ticket Creation:
   - Traditionally, this process involves phone calls, which lack visual elements. The use of digital tools such as phones or augmented reality glasses (HoloLens) could significantly improve this process.
3. Service Technician Intervention:

- This stage is the last resort and is avoided as much as possible by improving the previous phases. The lack of qualified service technicians and the time required to train them make efficiency in the first two phases essential.

2.2. Key Points in Troubleshooting and Maintenance

Figure 1 illustrates the Troubleshooting and Maintenance Process that will be described next.

Figure 1 - Troubleshooting and Maintenance Process



2.2.1 Efficiency and Quality:

- The use of XR (Extended Reality) is proposed to aid in the rapid identification of problems and solutions, improving the efficiency and quality of troubleshooting.
- Detailed documentation of maintenance and troubleshooting is essential for subsequent data analysis.

2.2.2 Technician Satisfaction and Stress:

- In stressful troubleshooting situations, the clarity and detail of the information provided to technicians are crucial for reducing stress and increasing efficiency.
- The use of XR and chatbots can offer immediate and visual support, reducing the need for direct intervention and allowing less experienced technicians to perform maintenance and troubleshooting more effectively.

2.2.3 Reduction of Time and Errors:

- Reducing planned maintenance and troubleshooting time is a key KPI, along with decreasing error rates and the time required to onboard new technicians.

2.2.4 Digital Tools and AI:

- The adoption of digital tools such as chatbots and virtual assistants is seen as a way to significantly improve self-service and support during troubleshooting.

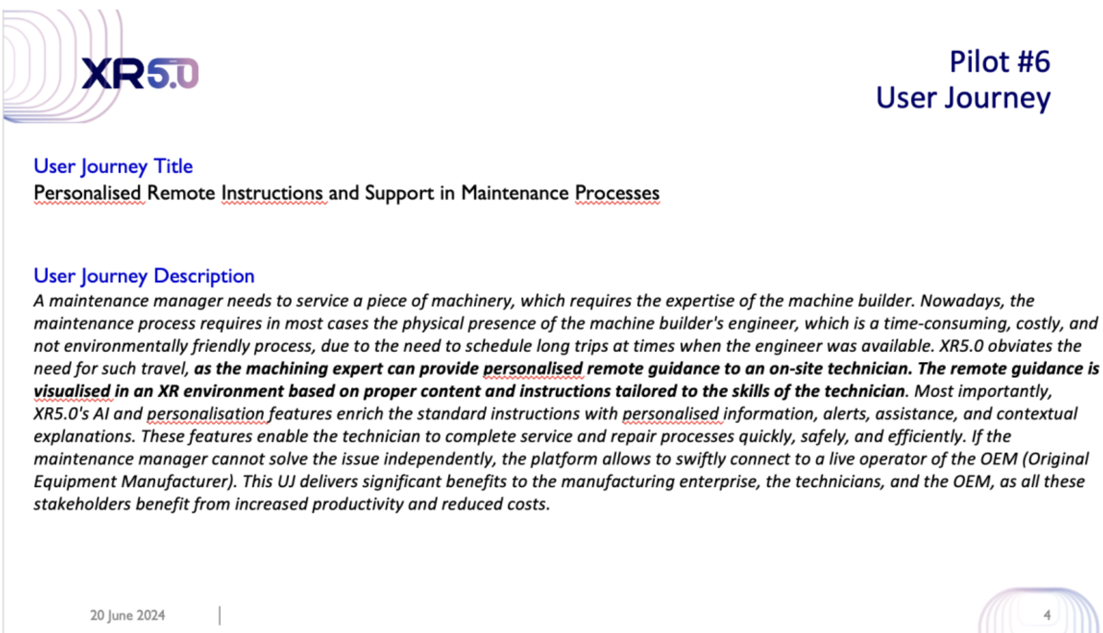
- These tools not only enhance efficiency but also help in automatically documenting the steps taken during maintenance, facilitating subsequent analysis and continuous process improvement.

The importance of digital transformation in troubleshooting and maintenance processes was emphasized, highlighting the potential of digital tools and augmented reality to enhance efficiency, reduce technician stress, and decrease resolution times and error rates. Detailed documentation and data analysis are crucial for continuous improvement and the swift integration of new technicians, addressing the shortage of skilled professionals in the industry.

3. User Journey

The user journey for machine maintenance (Figure 2) was discussed, with a focus on assisting on-site maintenance technicians using XR components (Augmented Reality/Virtual Reality) for troubleshooting and planned repairs. The current challenge of relying on a specialist familiar with all machines and their failures was highlighted, as it leads to time loss for the company

Figure 2 – User Journey - Personalized Remote Instructions and Support



The importance of providing clear and detailed instructions to technicians, particularly under high-stress conditions, was emphasized. Clarity in documentation was highlighted as essential for reducing stress and improving task efficiency. Questions were raised during the discussion seeking clarification on the context of increased stress levels.

Table 2 presents the content analysis, highlighting some dimensions and subdimensions.

Table 2 - Content Analysis

Dimension	Subdimension	Exact Examples from Bastien Perrissoud's Discourse
User Journey	Maintenance	"our pilot is about maintenance"
		"our goal is to help the on-site technician with the XR components"
Problems	Expertise	"it's hard to have someone experienced who knows all the machines"
		"it results in a lot of wasted time for the company"
Assistance	Remote Support	""he can quickly request remote assistance from some specialists"
Documentation	Clarity and Detail	"the documentation received by the technician should be clearer or more detailed"
		"this should help him manage his stress better"

This analysis reveals Bastien's focus on improving the efficiency and effectiveness of maintenance technicians through the use of XR technology and improving the clarity of instructions provided, addressing both practical and emotional issues faced by technicians during their tasks.

4. Persona Analysis

A detailed analysis of the personas involved in the company's product support and maintenance process was presented, highlighting the importance of understanding and defining these personas to enhance digital offerings to customers (Figure 3). Below are the main personas discussed and their characteristics:

1. OEM (Original Equipment Manufacturer) Shipment Coordinator:
- Function: Responsible for ensuring that the company's products are shipped along with the OEM's machines to the end customer.
- Relevance: Marginal in the context of the Excel 5.0 project but crucial for logistical coordination and installation planning.
- Competencies: This coordinator is responsible for ensuring that the machines are shipped simultaneously with their own machines. Skills needed include logistics, shipment coordination, and installation planning.

2. End Customer Technician:
- Function: Can be either an operator or a dedicated maintenance department ensuring the continuous operation of the machines.
- Relevance: Primary target persona, responsible for contacting the company in case of problems or preventive maintenance. Has access to documentation and the technical support portal.
- Competencies: The skill level of this persona varies greatly. Some technicians have a deep knowledge of the products, equivalent to or even exceeding that of the company's younger technicians. Others may be young, inexperienced operators who need detailed guidance. Skills range from deep technical knowledge of the products to basic operation and maintenance abilities.

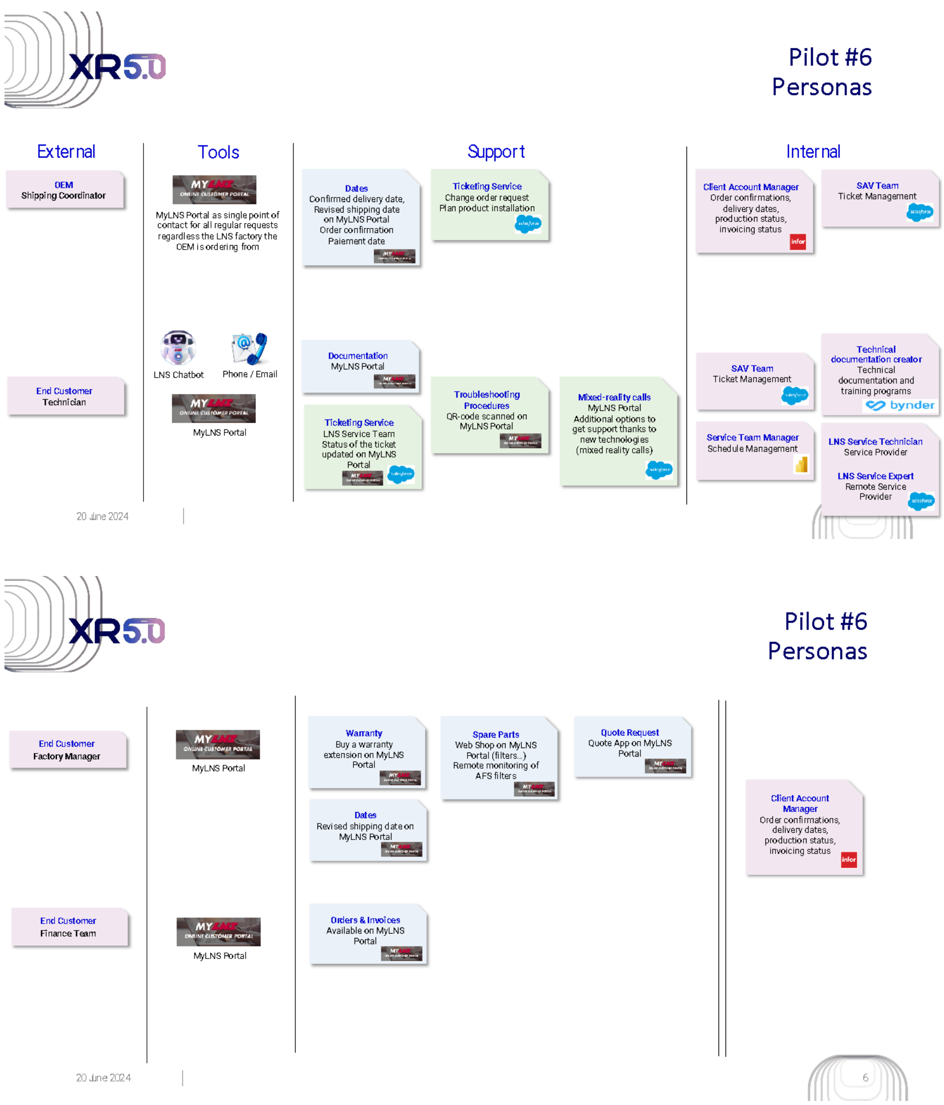
3. End Customer Factory Manager or Operations Manager:
- Function: Higher hierarchical level, responsible for the overall management of the company's products at the customer site.

- o Relevance: Provides an overview of the products, remote monitoring, access to the spare parts store, and new product quotes.
- o Competencies: This manager needs a comprehensive view of the products and their conditions. Must be capable of managing consumables, ordering spare parts, and using portal tools for monitoring and management. Skills include operations management, data analysis, and the ability to make decisions based on detailed product information.

4. End Customer Finance Team:

- o Function: Manages orders and invoices, with easy access to financial information online.
- o Relevance: Less relevant to the Excel 5.0 project but important for financial and order management.
- o Competencies: Responsible for managing orders and invoices, these individuals need skills in finance, accounting, and the use of digital financial management systems.

Figure 3 – Persona Distribution



4.1. Competencies that Differentiate the Personas

The primary competency that differentiates these personas is the level of specific technical knowledge of the products (Table 3):

- Experienced Technicians: Possess deep knowledge, able to solve complex problems and perform preventive maintenance without much external support.
- Inexperienced Technicians/Operators: Require detailed guidance and personalized documentation to solve basic problems and perform maintenance tasks.
- Factory/Operations Managers: Need a global overview and management skills to monitor the state of the products and make informed decisions.
- Finance Team: Focuses on financial management, requiring access to accurate order and invoice information to ensure efficient operations.

Table 3 - Persona Analysis – Competencies

Persona	Main Competencies	Level of Technical Knowledge	Specific Needs
OEM Shipment Coordinator	Logistics, shipment coordination, planning	Medium	Support for planning and shipment coordination
Experienced Technician	Deep product knowledge, complex problem solving	High	Advanced and detailed documentation
Inexperienced Technician/Operator	Basic operation, needs guidance	Low	Personalized documentation and detailed support
Factory/Operations Manager	Operations management, data analysis	Medium	Monitoring and management tools on the portal
Finance Team	Finance, accounting, financial systems management	Low	Access to order and invoice information

This table summarizes the different personas and the competencies that distinguish them, as well as highlights the specific needs of each group to ensure an efficient and effective operation.

Table 4 presents the analysis of the personas based on their relevance in Project XR 5.0.

Table 4 - Personas Analysis – Relevance

Persona	Role	Relevance in Project XR 5.0	Interaction with the Company
Expedition Coordinator (OEM)	Coordinates the shipment of products along with OEM machines	Marginal	Customized portal for installation support
End Customer Technician	Operates or maintains the machines, contacts for support	High	Support portal, documentation, direct contact
Factory/Operations Manager	General management of products at the end customer	Medium	Remote monitoring, parts store, quotations
Customer Financial Team	Management of orders and invoices	Low	Access to financial and order information online

It was highlighted that there is significant variation in knowledge and experience levels among customer technicians. Some have deep product knowledge, while others require more personalized support due to limited understanding. This personalization is essential for ensuring customer satisfaction and the effectiveness of the support provided.

This analysis underscores the importance of tailoring digital tools and services to the specific needs of each persona, thereby ensuring a better customer experience and more efficient operation of the company's products.

4.2. Analysis of Communication Between Personas

Communication between customers and technicians varies based on factors like geographic location, customer familiarity, and available communication channels. With around 500,000 units installed globally, technicians can be anywhere. Communication typically occurs via phone, chatbots, online portals, or email, as shown in Table 5. The level of closeness between customers and technicians differs by region. In countries like Switzerland, where the company has a strong presence, relationships are more personal. In larger markets like the U.S. or Spain, communication is more distant, often going through agents. The familiarity between customers and technicians depends on the region and the company's presence.

Table 5 - Interaction Analysis

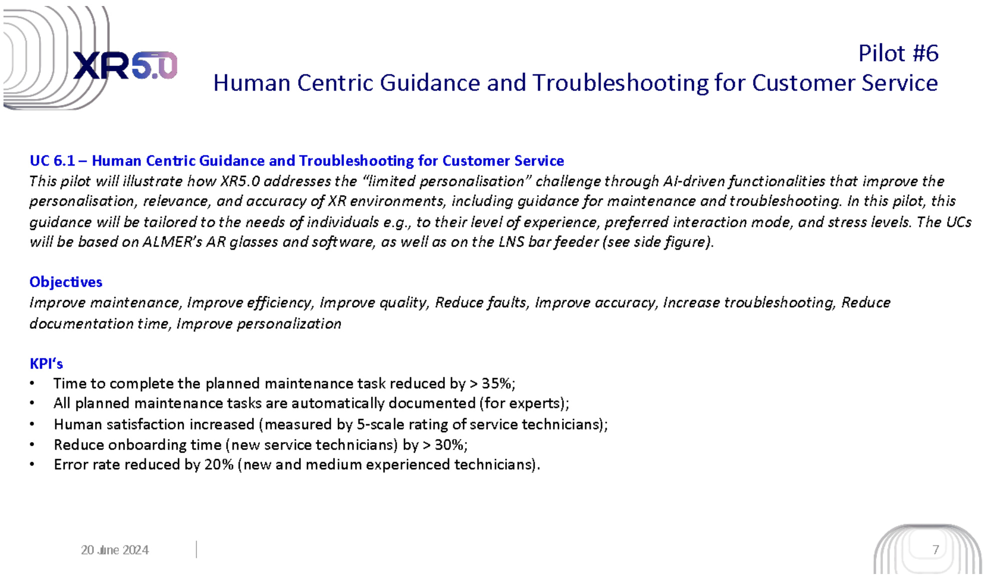
Dimension	Subdimension	Exact Quotes from Saurer Philipp
Communication Channels	Tools Used	"They communicate via telephone or digital tools such as chatbots, portals, and email."
Proximity and Familiarity	Familiarity with Technicians	"In Switzerland, customers may know our technicians personally or professionally."
Regional Variation	Company Presence in Different Regions	"In Spain, communication goes through agents... In the U.S., the connection is much smaller."
Communication Situations	Dependence on the Situation	"This depends a lot on the situation in terms of tools."
Proximity Example	Swiss Market	"In Switzerland, proximity is probably the highest because it is a small market, but also one of our largest markets."
Distance Example	American Market	"In the U.S., the number of customers is much larger, so the connection is much weaker."

In summary, communication between personas and the company technicians varies significantly based on geographic location, the level of familiarity and closeness between customers and technicians, and the available communication channels. In smaller markets with a long and established company presence, such as Switzerland, communication tends to be more personal and closer. In larger markets or where the company uses intermediaries, such as in Spain or the U.S., the connection tends to be weaker and less personal. These variables directly influence the effectiveness and efficiency of communication in supporting and maintaining the products.

5. USER CASE

5.1. User Case 6.1: Troubleshooting

User Case 6.1 (Figure 4) addresses troubleshooting situations where urgent action is required, but the problem and solution are unknown. The primary goal of XR (Augmented Reality) is to assist in identifying issues and helping the technician resolve these problems as quickly as possible.



5.1.1. Analysis

Objectives:

- Improve maintenance and troubleshooting efficiency.
- Enhance work quality by avoiding errors.
- Reduce aircraft maintenance time.
- Document all maintenance and troubleshooting for future analysis.
- Increase technician satisfaction in stressful situations.
- Reduce onboarding time for new technicians.
- Decrease error rates.

Key Performance Indicators (KPIs):

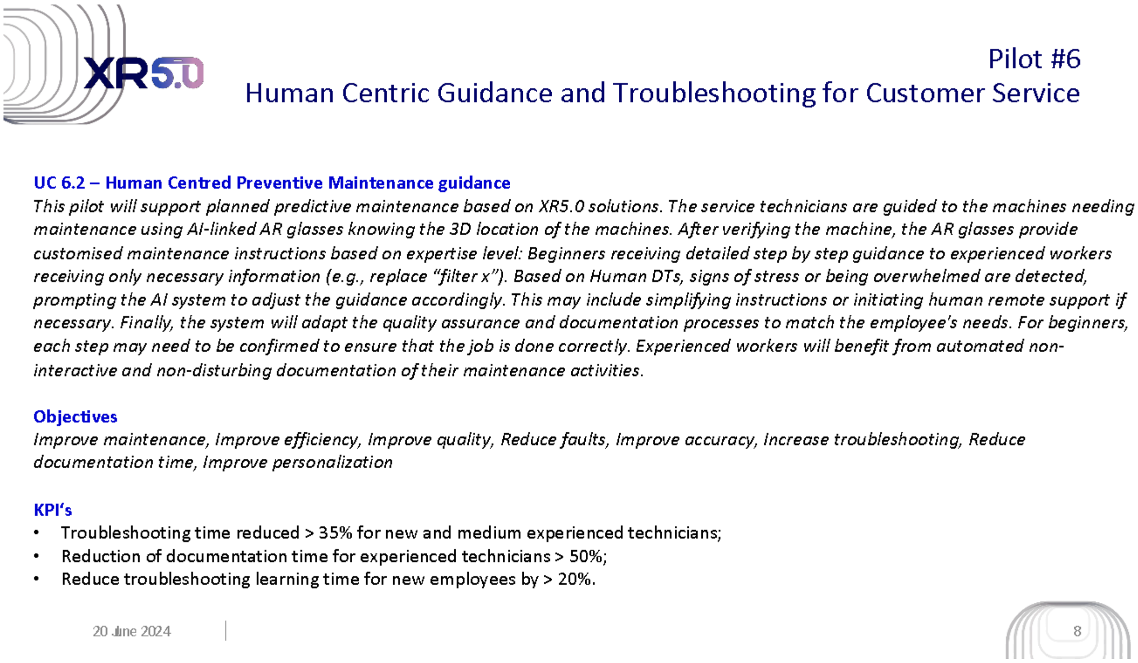
- Reduced maintenance time.
- Detailed documentation of procedures.
- Technician satisfaction.
- Reduced onboarding time.
- Minimized error rates.

Benefits:

- Accurate and complete documentation for future analysis.
- Increased operational efficiency through real-time support.
- Improved technician satisfaction by providing tools that reduce stress.
- Reduced time needed to train new technicians, optimizing the onboarding process.

5.2.User Case 6.2: Preventive Maintenance

Description: User Case 6.2 (Figure 5) focuses on preventive maintenance, where tasks are planned in advance. The XR (Augmented Reality) system is intended to assist the technician in performing maintenance efficiently by displaying information, steps, and guidance appropriate to the technician's level of experience.



5.2.1. Analysis

Objectives:
- Assist the technician in performing preventive maintenance efficiently.
- Display detailed information and steps for novice technicians and less detailed guidance for experienced technicians.
- Adapt instructions based on the technician's stress level.

Key Performance Indicators (KPIs):
- Reduced preventive maintenance time.
- Automatic documentation of maintenance steps.
- Improvement in technician skills through continuous, personalized learning.

Benefits:
- More efficient preventive maintenance with less time spent on repetitive tasks.
- Automatic documentation that facilitates data analysis and continuous process improvement.
- Continuous and personalized learning for technicians, aiding skill development and reducing future errors.

The two user cases analyze different aspects of maintenance: troubleshooting and preventive maintenance. The first aims to resolve urgent issues quickly and efficiently, while the second focuses on the efficiency and quality of planned maintenance. Both cases benefit from the use of XR to provide better documentation, reduce errors, and improve technician efficiency, enhancing satisfaction and decreasing the training time for new employees.

6. Traditional Training Material

In Figure 6, we can see the distribution of training materials by domain

Pilot #6
Traditional Training Material

#	Job Tasks	Pilot #	Use Case(s) #	Difficulty Level	Standards and Guidelines	Industrial Domain
1	Maintenance	6	6.1 & 6.2	1. Beginner	Routine Inspection Protocols Basic Safety Requirements Quality controls	Machine Manufacturing and Maintenance
2	Troubleshooting	6	6.1 & 6.2	2. Intermediate - 3. Advanced	Fault Diagnosis Procedures Operational Testing Protocols	Machine Manufacturing and Maintenance
3	Corporate Training	6	6.1 & 6.2	2. Intermediate	Corporate Training Standards Educational Content Standards Training Evaluation Standards Manufacturer's Training Guidelines E-learning Platform Standards Online Education Standards	Machine Manufacturing and Maintenance Corporate Training
4	Documentation	6	6.1 & 6.2	1. Beginner - 2. Intermediate	Technical Documentation Standards Documentation Requirements E-learning Content Standards	Machine Manufacturing and Maintenance Corporate Training
5	Technology Integration	6	6.1 & 6.2	3. Advanced	Simulation Software Standards Augmented/Virtual Reality Training Guidelines	Machine Manufacturing and Maintenance Corporate Training

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6.1. Description of Traditional Training Materials:

Overview of Materials:

- o There is a wide variety of training materials.
- o These materials include manuals that are necessary for product shipment, although they are not always user-friendly.
- o There is an investment in documents that assist the customer at the precise moment a problem occurs.

Types of Documents:

- o Regulatory Manuals: These are required to comply with regulations and facilitate product shipment.
- o Customer Support Documents: These include guides and procedures that help customers respond to specific alarms and resolve common issues.
- o Internal Documentation: Such as Standard Operating Procedures (SOPs), quality control, inspection protocols, and safety requirements.
- o Fault Technology Documents: Related to resolving specific alarms.

Format and Accessibility:

- o Previously, materials were in paper format but are now available electronically and accessible through a web portal.
- o There are plans to use XR (Augmented Reality) technology to provide training guidelines, both on smartphones and in physical markets.

Multilingualism:

- o Materials are available in multiple languages. The website is maintained in about eight or nine major languages, including English, German, French, Spanish, Italian, Chinese, and Japanese.
- o More specific documents are also available in other European languages such as Bulgarian and Polish.

Automation and Translation:

- A simple chatbot is used to adapt the language based on the user's browser settings, with English as the default if the language is not available.
- There are ongoing efforts to explore the use of AI for automatic document translation, while maintaining the primary documentation in English.

6.2. Analysis of Traditional Training Materials:

Strengths:

- Scope and Compliance: The availability of manuals and regulatory documents ensures that all products comply with legal standards.
- Customer Support: The creation of specific guides to resolve alarms and common issues facilitates customer support, enabling faster and more effective responses.
- Digital Accessibility: The transition to digital formats improves the accessibility and distribution of training materials.
- Multilingualism: Providing materials in multiple languages is essential to support a global customer base.

Challenges:

- Complexity of Materials: Regulatory documents, while necessary, can be complex and not very user-friendly for customers.
- Dependence on Automatic Translations: Relying on automatic translation can lead to inaccuracies, especially in complex technical contexts.
- Need for Additional Data: For issues not related to alarms, there is a continuous need to collect data and develop appropriate training materials.

Future Innovations:

- Use of XR: Adopting augmented reality to guide customers through problem-solving processes could revolutionize the training and support experience.
- Improvement of AI: Enhancing the chatbot and using more sophisticated AI for translations could significantly increase the efficiency and quality of customer support.

This analysis (Table 6) highlights ongoing efforts to improve training and customer support materials by adapting to modern technological needs and ensuring regulatory compliance.

Table 6 – Differentiation of Various Types of Training and Customer Support Materials

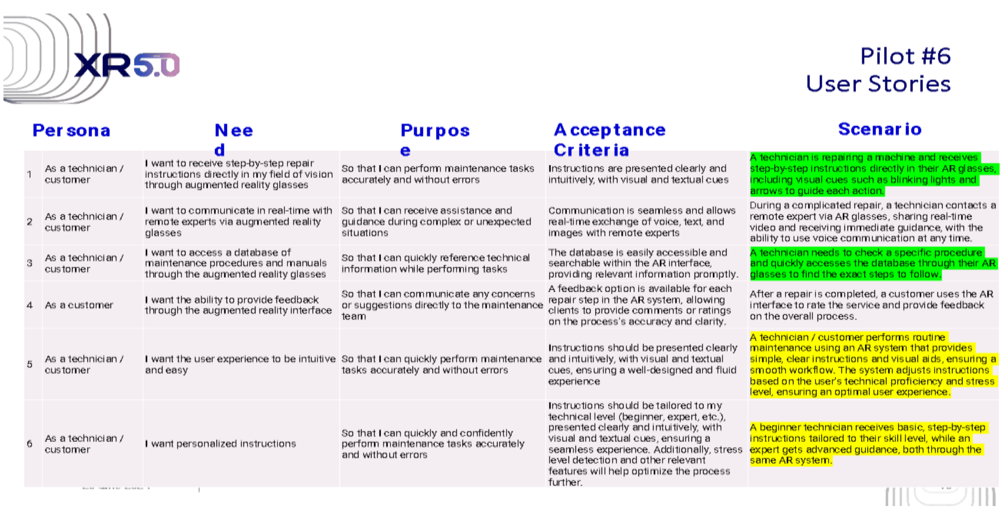
Dimension	Subdimension	Explanation	Concrete Examples of Statements
Types of Documents	Regulatory Manuals	Documents required for product shipment, usually mandated by legal regulations.	"Manuals are necessary for shipping a product, although they are not always customer-friendly."
	Support Documents	Guides and procedures that help customers resolve issues and respond to specific alarms.	"They are investing in documents that assist the customer at the exact moment a problem occurs."
	Internal Documentation	Standard operating procedures, quality controls, inspection protocols, and safety requirements.	"Documentation such as standard operating procedures (SOPs), quality controls, inspection protocols, and safety requirements."
	Technological Documents	Information related to resolving specific alarms.	"Fault technology documents related to resolving specific alarms."

Dimension	Subdimension	Explanation	Concrete Examples of Statements
Format and Accessibility	Digitalization	Transition from paper materials to electronic formats accessible through a web portal.	"Previously, materials were in paper format, but now they are electronic and accessible through a web portal."
	XR Technologies	Use of augmented reality to provide training and support guidelines, both on smartphones and in physical markets.	"There are plans to use XR (augmented reality) technology to provide training guidelines."
Multilingualism	Language Diversity	Availability of training materials in several major languages and some additional European languages.	"The website is maintained in about eight or nine major languages, including English, German, French, Spanish, Italian, Chinese, and Japanese."
Automation and Translation	Automatic Translation	Use of AI for automatic translation of documents, with primary documentation maintained in English.	"They are exploring the use of AI for automatic translation of documents."
	Adaptive Chatbot	Use of a simple chatbot that adapts the language based on the user's browser settings.	"They use a simple chatbot that adapts the language based on the user's browser settings, with English as the default if the language is not available."

This table synthesizes the main dimensions and subdimensions of traditional training materials discussed by Saurer Philipp, providing a detailed explanation and concrete examples derived from his statements. The analysis highlights the variety of documents, the transition to digital formats, support in multiple languages, and innovation through technologies such as augmented reality and AI-based automatic translation.

7. USER STORIES

Figure 7 represents the distribution of personas across scenarios, with the most prioritized ones highlighted in green and the intermediate ones in yellow.


Pilot #6
User Stories

	Persona	Need	Purpose	Acceptance Criteria	Scenario
1	As a technician / customer	I want to receive step-by-step repair instructions directly in my field of vision through augmented reality glasses	So that I can perform maintenance tasks accurately and without errors	Instructions are presented clearly and intuitively, with visual and textual cues	A technician is repairing a machine and receives step-by-step instructions directly in their AR glasses, including visual cues such as blinking lights and arrows to guide each action.
2	As a technician / customer	I want to communicate in real-time with remote experts via augmented reality glasses	So that I can receive assistance and guidance during complex or unexpected situations	Communication is seamless and allows real-time exchange of voice, text, and images with remote experts	During a complicated repair, a technician contacts a remote expert via AR glasses, sharing real-time video and receiving immediate guidance, with the ability to use voice communication at any time.
3	As a technician / customer	I want to access a database of maintenance procedures and manuals through the augmented reality glasses	So that I can quickly reference technical information while performing tasks	The database is easily accessible and searchable within the AR interface, providing relevant information promptly.	A technician needs to check a specific procedure and quickly accesses the database through their AR glasses to find the exact steps to follow.
4	As a customer	I want the ability to provide feedback through the augmented reality interface	So that I can communicate any concerns or suggestions directly to the maintenance team	A feedback option is available for each repair step in the AR system, allowing clients to provide comments or ratings on the process's accuracy and clarity.	After a repair is completed, a customer uses the AR interface to rate the service and provide feedback on the overall process.
5	As a technician / customer	I want the user experience to be intuitive and easy	So that I can quickly perform maintenance tasks accurately and without errors	Instructions should be presented clearly and intuitively, with visual and textual cues, ensuring a well-designed and fluid experience	A technician / customer performs routine maintenance using an AR system that provides simple, clear instructions and visual aids, ensuring a smooth workflow. The system adjusts instructions based on the user's technical proficiency and stress level, ensuring an optimal user experience.
6	As a technician / customer	I want personalized instructions	So that I can quickly and confidently perform maintenance tasks accurately and without errors	Instructions should be tailored to my technical level (beginner, expert, etc.), presented clearly and intuitively, with visual and textual cues, ensuring a seamless experience. Additionally, stress level detection and other relevant features will help optimize the process further.	A beginner technician receives basic, step-by-step instructions tailored to their skill level, while an expert gets advanced guidance, both through the same AR system.

Pilot #6
User Stories

	Persona	Need	Purpose	Acceptance Criteria	Scenarios
7	As a technician/customer	I want to receive alerts in case of danger	So that I am aware of the risks and can proceed confidently	Implementing a system of alerts and ensuring a safe working environment	During maintenance, a technician / customer receives real-time alerts on potential dangers like high voltage or hazardous conditions through their AR glasses, ensuring they can proceed with caution.
8	As a Business Analyst	I want to be able to track the data generated by the system	So that I can make analyses, drive continuous improvement, and ensure efficient resource allocation	The data must be recorded, readily accessible, and securely stored	A business analyst accesses raw data from the system, enabling detailed reporting and analysis for informed decision-making.
9	As a technician/customer	I want to ensure that if I require assistance, the appropriate expert is promptly contacted	So that I receive the best advice in minimal time	Direct link established between the issue and the team to be contacted	During a complex repair, if a technician requires assistance, the AR system automatically connects them with the relevant expert, ensuring quick and effective support.
10	As a customer	I want to be flexible in managing my time effectively during the maintenance task	So that I am flexible in managing my time effectively during the maintenance task	The system provide time to completion before starting, real-time progress updates and allow users to pause the process, save their progress, and proceed at a later time without losing any data or progress	A customer starts a maintenance task, receives an estimated time for completion, pauses the process, and resumes later, with real-time progress updates and access to expert help if needed.
11	As a technician/customer	I want a seamless transition of the instructions if my stress level is increasing or reducing	So that I'm not even more stressed or disracted	The adaptation of the instructions are not visible	As a technician or customer's stress level changes during a task, the AR system dynamically adjusts instruction complexity without disrupting the workflow.
12	As a technician	I want to register automaticly the use cases and associated resolution tasks	So that further problems or questions can be answerded rapidely	that the data is stored and easily accessible	After completing a maintenance task, a technician's AR system automatically logs the use case and associated tasks for future reference and analysis.

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Pilot #6
User Stories

	Persona	Need	Purpose	Acceptance Criteria	Scenarios
13	As a Service Team Manager	I want technicians to be trained in XR methods	so that they can effectively utilize extended reality technologies in their work processes	Development of XR training modules covering essential methods and applications, tailored to technician learning needs	A technician undergoes XR training sessions to familiarize himself with essential methods and applications. They participate in hands-on exercises to apply XR techniques in simulated repair scenarios under supervision.
14	As a technical documentation worker	I want to be trained in XR tools for documentation compliance	So that I can create compliant documents efficiently using XR tools	Development of XR training modules focusing on tools for technical documentation compliance	A technical documentation worker participates in XR training sessions specifically designed for using XR tools to efficiently create compliant technical documents. They practice converting existing documentation into XR-enhanced formats, ensuring adherence to industry standards and optimizing information delivery.

7.1. Analysis of User Stories

The following is an analysis of the user stories, creating dimensions and sub-dimensions for analysis.

1. Step-by-Step Instructions:
   - Sub-Dimension: Maintenance Instructions
   - Analysis: This user story focuses on utilizing advanced technology to provide detailed real-time instructions directly in the technicians' field of view. This can improve efficiency and reduce errors during maintenance operations.
   - Priority: High, as it enables technicians to be self-sufficient in problem resolution.
2. Real-Time Communication:
   - Sub-Dimension: Communication with Experts
   - Analysis: Allowing technicians to communicate in real-time with remote experts enhances the ability to solve complex problems quickly and can reduce machine downtime.
   - Priority: Medium, as it is a phase of escalation after attempts at self-sufficiency.
3. Access to Information:
   - Sub-Dimension: Fast and Updated Access
   - Analysis: Fast and updated access to information and procedures is crucial to ensure that technicians always use the most current and effective practices, avoiding errors due to outdated procedures.
   - Priority: High, as it facilitates technicians' self-sufficiency and accuracy.
4. Maintenance Logging:
   - Sub-Dimension: Task and Data Recording

- o Analysis: Logging all performed maintenance tasks allows for detailed subsequent analysis, helping to identify failure patterns and areas for continuous improvement.
- o Priority: Medium to high, depending on the need for data analysis and continuous improvement.

Table 7 presents a description of the previously mentioned User Stories:

Table 7 – Analysis of User Stories

Dimension	Sub-Dimension	Explanation	Concrete Examples of Statements
Maintenance Instructions	Step-by-Step Instructions	Technicians receive detailed instructions directly in their field of view through augmented reality glasses.	"I want to receive step-by-step preparation instructions directly in my field of vision through augmented reality glasses."
Real-Time Communication	Communication with Experts	Technicians communicate in real-time with remote experts through augmented reality glasses.	"I want to communicate in real time with remote experts via augmented reality glasses."
Access to Information	Fast and Updated Access	Technicians have quick access to all updated information and procedures from a cloud-based system.	"The technician can access all the different information...so if the procedure is changing, it automatically changes in the system."
Maintenance Logging	Task and Data Recording	The system logs all performed maintenance tasks, including time and data for future analysis.	"The system can register all the information about the maintenance I just did...for analysis."

7.2. Prioritization

Based on discussions among team members, the user stories are prioritized as follows:

1. Step-by-Step Instructions: High priority, as it facilitates technicians' self-sufficiency.
2. Access to Information: High priority, as it ensures technicians always have access to the most updated information.
3. Real-Time Communication: Medium priority, necessary for escalating issues.
4. Maintenance Logging: Medium to high priority, depending on the need for data analysis for continuous improvement.

This prioritization follows the logic of enabling technicians to resolve problems autonomously before escalating to remote support and using data for future improvements.

7.3. Analysis of User Stories and Prioritization

The analysis and prioritization of user stories are based on the classification of technician/customer needs. Table 8 describes the analyzed user stories, with a focus on the highest priorities.

Table 8 – Analysis and Prioritization of User Stories

User Story	Role	Description and Analysis	Prioritization
1	Technician/ Customer	Description: I want to receive step-by-step instructions directly in my field of vision through augmented reality glasses. Analysis: Provides autonomy to technicians/customers, reducing the need for support. Priority Justification:High, as it promotes self-service, crucial for efficiency and customer satisfaction.	High

User Story	Role	Description and Analysis	Prioritization
3	Technician/ Customer	Description: I want to view real-time data during maintenance for more informed decision-making. Analysis: Enhances technician efficiency by providing relevant data instantly. Priority Justification: High, as it facilitates quick problem resolution, increasing productivity.	High
12	Technician	Description: At the end of maintenance, I want the system to log all task information, including time and details of future or pending tasks. Analysis:Ensures accurate and complete recording of maintenance activities, essential for history and future planning. Priority Justification: High, as it ensures data integrity for maintenance records.	High
5	Technician/ Customer	Description: I want to receive automatic notifications of common problems and their solutions. Analysis: Reduces diagnostic time by providing ready-made solutions for known issues. Priority Justification: Medium, as it improves efficiency but relies on a robust problem database.	Medium
6	Technician/ Customer	Description: I want to access a database of similar resolved problems for comparison and current issue resolution. Analysis: Utilizes past experience to address present problems. Priority Justification: Medium, as it depends on the implementation of a robust database.	Medium
7	Technician/ Customer	Description: I want to document and share my own solutions for unlisted problems. Analysis: Enriches the knowledge base with new solutions and technician experiences. Priority Justification: Medium, as it encourages collaboration and continuous learning.	Medium
10	Customer	Description: I want to schedule preventive maintenance directly through an online platform. Analysis: Facilitates planning and avoids unexpected disruptions. Priority Justification: Medium, as it improves customer experience but is not critical for daily operations.	Medium
11	Technician/ Customer	Description: I want to receive detailed reports after each maintenance, including diagnostics and future recommendations. Analysis: Provides transparency and aids in planning future actions. Priority Justification:Medium, as it adds value to both customer and technician but is not critical for immediate problem resolution.	Medium
2	Technician/ Customer	Description: I want to communicate in real time with remote experts through augmented reality glasses. Analysis: Facilitates remote support and resolution of complex issues. Priority Justification: Low, as it depends on the availability of experts and robust infrastructure.	Low
4	Customer	Description: I want to receive automatic updates on the status of my scheduled maintenance. Analysis: Keeps the customer informed and reduces anxiety about service status. Priority Justification: Low, as it is not critical for maintenance operations.	Low
8	Business Analyst	Description: I want to analyze maintenance data to identify trends and improve processes. Analysis: Crucial for continuous improvement and process optimization, but does not directly impact the daily operation of technicians/customers. Priority Justification: Low, as it is more strategic and less operational.	Low
9	Technician/ Customer	Description: I want to access a customizable checklist for each maintenance. Analysis: Ensures that all necessary steps are followed, increasing maintenance quality. Priority Justification: Low, as it is useful but not critical for immediate problem resolution.	Low

7.4. Prioritization of User Stories

User stories are categorized by priority with respective justifications:

- High Priority: User stories that promote self-service and increase the efficiency and autonomy of technicians/customers are prioritized. This is crucial for customer satisfaction and reducing operational costs.
- Medium Priority: User stories that enhance efficiency but depend on robust systems and databases are intermediate. They are important but can be implemented after high-priority items.
- Low Priority: User stories that do not directly impact problem resolution or are more strategic are of low priority. While valuable in the long term, they can be developed later.

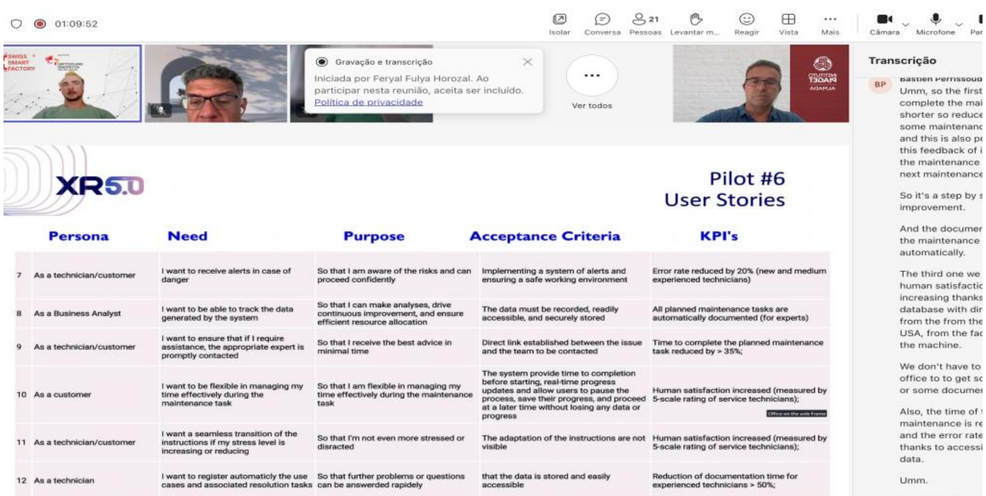
Prioritization follows the rule that functionalities improving self-service and immediate operational efficiency are the most important.

8. KPIs

8.1. Description of KPIs

To optimize the efficiency and satisfaction of technicians and customers, several crucial KPIs (Key Performance Indicators) have been defined (Figure 8).

Figure 8 - Key Performance Indicators



These KPIs aim to improve maintenance processes, reduce documentation times, and increase overall user satisfaction. Below is a detailed description of each KPI, along with concrete examples of statements that illustrate them (Table 9).

Table 9 - KPIs Description and Examples

KPI	Description	Concrete Example of Statement
Reduce Maintenance Task Execution Time	Decrease the time required to complete maintenance tasks by 35% through continuous feedback.	"We want to complete the maintenance task faster, reducing the time by 35%."
Automated Maintenance Documentation	Automate the documentation of completed maintenance tasks.	"Maintenance documentation should be done automatically."
Increase User Satisfaction	Enhance user satisfaction by providing direct access to necessary data, reducing errors.	"User satisfaction will improve with direct access to the database."

KPI	Description	Concrete Example of Statement
Reduce Documentation Time for Experienced Technicians	Decrease by 50% the time experienced technicians spend on documentation, allowing more field time.	"Reduce documentation time by 50% for experienced technicians."

8.2.Analysis of User Stories

The user stories were analyzed to identify how each one contributes to the established KPIs. This analysis helps prioritize features that will have the greatest impact on the efficiency and satisfaction of technicians and customers. The user stories were classified into three priority categories: high, medium, and low, based on their relevance and impact (Table 10).

High Priority

High priority user stories are those that significantly promote operational efficiency and technician autonomy. These include:

Medium Priority

Medium priority user stories are important but have a moderate impact.

Low Priority

Low priority user stories are valuable but do not directly impact the immediate problem-solving or are more strategic.

Table 10 – Classification of user stories by priority level

User Story	Description	Analysis	Related KPI	Priority
1	As a technician, I want to reduce maintenance time to increase efficiency.	Reducing maintenance time increases efficiency and allows for more tasks to be completed in less time.	Reduce the execution time of maintenance tasks	High
3	As a technician, I want to automate the documentation of maintenance tasks.	Automating documentation reduces the manual workload, allowing focus on high-priority activities.	Automatic maintenance documentation	High
12	As a technician, I want to reduce the time spent on documentation.	Reducing the time spent on documentation allows technicians to focus on maintenance and repairs.	Reduce documentation time for experienced technicians	High
5	As a technician, I want to access data directly at the workplace.	Direct access to data on-site reduces errors and increases the accuracy of maintenance tasks.	Increase user satisfaction	Medium
6	As a technician, I want continuous feedback to improve future tasks.	Continuous feedback allows incremental improvements in maintenance tasks, increasing overall efficiency.	Reduce the execution time of maintenance tasks	Medium
7	As a technician, I want to reduce machine downtime.	Reducing downtime improves productivity and operational efficiency.	Reduce the execution time of maintenance tasks	Medium
10	As a customer, I want maintenance to be completed quickly.	Rapid completion of maintenance tasks improves customer satisfaction and reduces downtime.	Reduce the execution time of maintenance tasks	Medium

User Story	Description	Analysis	Related KPI	Priority
11	As a technician, I want to minimize errors during maintenance tasks.	Minimizing errors increases the efficiency and effectiveness of maintenance tasks.	Increase user satisfaction	Medium
2	As a customer, I want direct access to maintenance information.	Direct access to information improves transparency and customer satisfaction.	Increase user satisfaction	Low
4	As a customer, I want detailed reports after maintenance.	Detailed reports provide clarity and ensure all tasks were completed correctly.	Increase user satisfaction	Low
8	As a business analyst, I want accurate data on maintenance tasks.	Accurate data is essential for strategic analysis and improvements.	Increase user satisfaction	Low
9	As a technician, I want tools that facilitate task documentation.	Tools that facilitate documentation increase efficiency and reduce manual work time.	Automatic maintenance documentation	Low

The analysis of the user stories, based on the established KPIs, helps identify the most critical features for the efficiency and satisfaction of technicians and customers. By prioritizing user stories that promote self-service and reduce maintenance and documentation time, we can significantly improve operations and user experience.

9. Human Factors

Human factors play a crucial role in the effectiveness and well-being of technicians and customers during the maintenance of complex systems. To ensure the optimization of these factors, various metrics that directly influence user experience, physiological health, and emotional performance during maintenance tasks are monitored. Below, we detail the human factors to be utilized and their respective user stories (Figure 8; Table 11).

Figure 8 – XR5 Human Factors

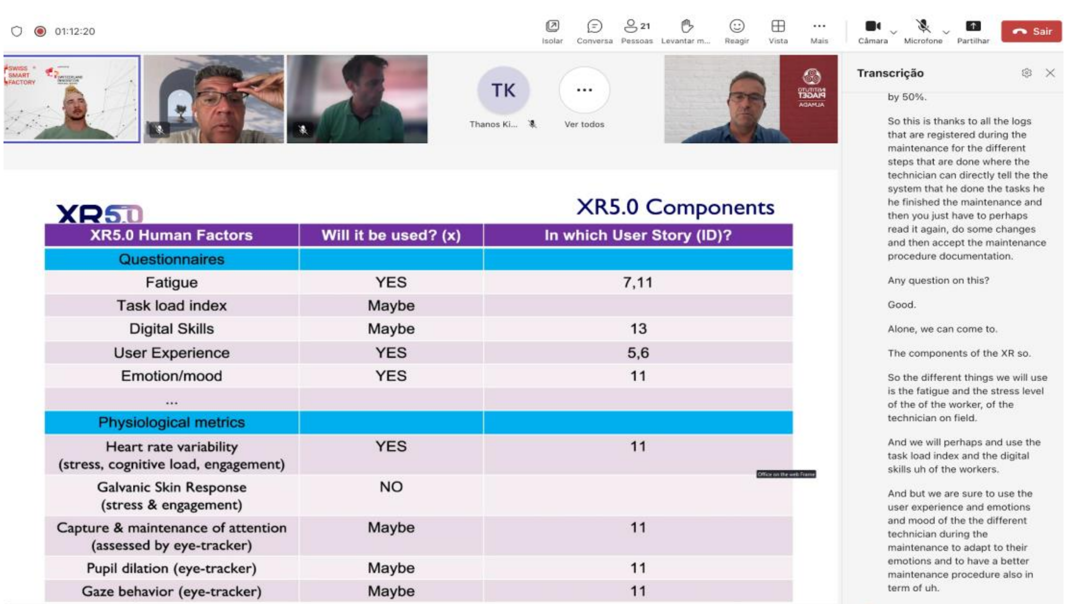


Table 11 – Prioritization of Human Factors

Human Factor	Will Be Used?	In Which User Story (ID)?	Description
Questionnaires			
Fatigue	YES	7, 11	Monitor technician fatigue levels to improve working conditions and prevent burnout.
Workload Index	Maybe		Use the workload index to evaluate and appropriately distribute tasks among technicians.
Digital Skills	Maybe	13	Assess and improve the digital skills of technicians to ensure efficient use of technological tools.
User Experience	YES	5, 6	Monitor user experience to adapt procedures as necessary.
Emotion/Mood	YES	11	Monitor the emotional state of technicians to adjust maintenance tasks, improving efficiency and safety.
Physiological Metrics			
Heart Rate Variability	YES	11	Use heart rate variability as a physiological metric to monitor stress and workload.
Galvanic Skin Response	NO		Monitor stress and engagement through galvanic skin response.
Attention Capture and Maintenance (Eye Tracking)	Maybe	11	Assess attention and cognitive load of technicians through eye tracking.
Pupil Dilation (Eye Tracking)	Maybe	11	Use pupil dilation to assess stress and cognitive load of technicians.
Gaze Behavior (Eye Tracking)	Maybe	11	Monitor gaze behavior to understand focus and attention of technicians during tasks.

9.1. Analysis of Human Factors

The analysis of human factors user stories is essential to identify how each metric will be applied and its impact on the well-being and efficiency of technicians and customers. Below is a summary of the user stories related to human factors:

1. User Story 5: Utilization of user experience to adapt procedures as necessary.
2. User Story 6: Monitoring user experience during maintenance tasks.
3. User Story 7: Evaluation and monitoring of technician fatigue to improve working conditions.
4. User Story 11: Implementation of physiological and emotional metrics, including heart rate variability, mood, and attention, to adjust maintenance tasks as necessary.
5. User Story 13: Assessment and improvement of technicians' digital skills to ensure efficient use of technological tools.

Monitoring human factors through the described user stories will allow for dynamic adaptation of maintenance procedures, aiming to improve the efficiency, safety, and well-being of technicians. Integrating these metrics into the maintenance process not only optimizes team performance but also contributes to a more positive and safe user experience.

9.2. Discussion on Wearables Collaboration and Synergy:

The importance of integrating human factors metrics and wearables efficiently and ethically, focusing on usability and adaptability of maintenance solutions, was also discussed. Collaboration between teams and consideration of ethical aspects are crucial for the success of the project. Regarding wearables, the following points are noteworthy:

1. Usability and Simplicity: The importance of wearables being easy to use without requiring extensive setup.
2. Integration and Universality: The idea of creating a solution that works for all pilots, avoiding the need for pilot-specific solutions.
3. Ethical and Data Security Considerations: The necessity of ensuring that the use of wearables and data collection are conducted ethically and in compliance with GDPR, highlighting the contribution of ethics specialists.

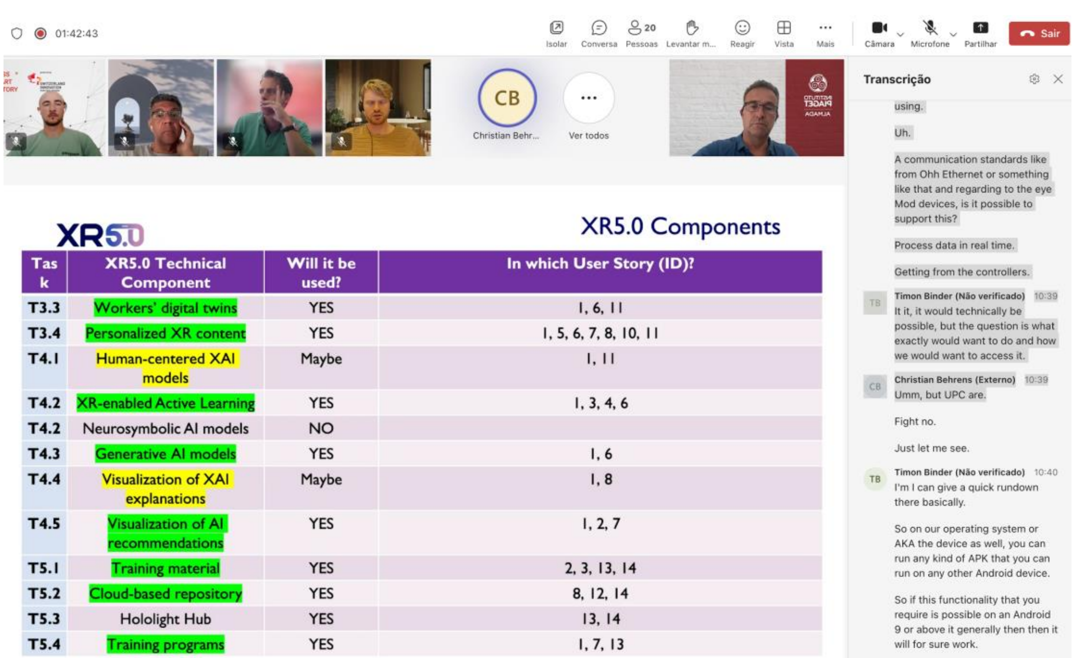
Regarding collaboration and synergy, the following points are noteworthy:

4. Transversal Use of Metrics: The idea that metrics such as stress levels and heart rate can be applied to all pilots.
5. Interaction with Smartphones: Considering the use of smartphone apps to connect with technicians' existing wearables, avoiding the need to provide new devices.
6. Contribution of Specialists: Involvement of ethics specialists from the beginning to ensure compliance with data security and ethical requirements.

10. Technical Components

The use of different technical components of XR5.0 was discussed across various user stories. The discussion addressed the applicability of each technical component and how they contribute to achieving the objectives of the respective tasks (Figure 9).

Figura 9 - Technical component



Task	XR5.0 Technical Component	Will it be used?	In which User Story (ID)?
T3.3	Workers' digital twins	YES	1, 6, 11
T3.4	Personalized XR content	YES	1, 5, 6, 7, 8, 10, 11
T4.1	Human-centered XAI models	Maybe	1, 11
T4.2	XR-enabled Active Learning	YES	1, 3, 4, 6
T4.2	Neurosymbolic AI models	NO	
T4.3	Generative AI models	YES	1, 6
T4.4	Visualization of XAI explanations	Maybe	1, 8
T4.5	Visualization of AI recommendations	YES	1, 2, 7
T5.1	Training material	YES	2, 3, 13, 14
T5.2	Cloud-based repository	YES	8, 12, 14
T5.3	Hololight Hub	YES	13, 14
T5.4	Training programs	YES	1, 7, 13

In this analysis, we present a table summarizing which technical components will be used, in which user stories, and a brief explanation of their use (Table 12).

Table 12 – XR5.0 Technical Components

Task	XR5.0 Technical Component	Will it be used?	In which User Story (ID)?	Details
T3.3	Workers' digital twins	YES	1, 6, 11	Creation of digital twins of workers for simulation and activity monitoring.
T3.4	Personalized XR content	YES	1, 5, 6, 7, 8, 10, 11	Personalization of XR experiences to meet the individual needs of users.
T4.1	Human-centered XAI models	Maybe	1, 11	Human-centered explainable AI models; feasibility will be evaluated based on initial results.
T4.2	XR-enabled Active Learning	YES	1, 3, 4, 6	XR-enabled active learning to create an interactive training environment.
T4.2	Neurosymbolic AI models	NO	-	This component will not be used in any user story.
T4.3	Generative AI models	YES	1, 6	Generative AI models for content creation and chatbot support.
T4.4	Visualization of XAI explanations	Maybe	1, 8	Visualization of explainable AI explanations, dependent on the use of XAI models.
T4.5	Visualization of AI recommendations	YES	1, 2, 7	Visualization of AI recommendations in an understandable manner for users.
T5.1	Training material	YES	2, 3, 13, 14	Development and distribution of training material to support training activities.
T5.2	Cloud-based repository	YES	8, 12, 14	Cloud-based repository for efficient storage and access to content and data.
T5.3	Hololight Hub	YES	13, 14	Central hub for managing XR devices and content.
T5.4	Training programs	YES	1, 7, 13	Structured training programs to ensure effective use of technologies.

10.1. Discussion of Technical Components

During the meeting, there was a detailed discussion about the application of technical components across various tasks and user stories, with emphasis on the following points:

1. Role of Task Leaders
    - Collaboration and Feedback: The role of task leaders in deciding the use of each technology was highlighted. It was suggested that leaders could explain or advocate for the need to use a particular technology.
    - Decision Changes: If a technology was marked as "Maybe," the task leader could provide additional details to decide whether it should be changed to "Yes" or "No."
2. Components with Indeterminate Use
    - Human-centered XAI Models (Task 4.1): Initially marked as "Maybe," it was discussed that the application of these models could be essential depending on the development of the underlying AI model. The discussion suggested validating results with end-users and creating a feedback loop.
    - Visualization of XAI Explanations (Task 4.4): Similarly, it was debated that the use of these components would depend on the clarity and applicability of the AI models.
3. Confirmed Components

- o Workers' Digital Twins and Personalized XR Content: These were clearly defined as essential and will be used in multiple user stories.
- o Generative AI Models and Visualization of AI Recommendations: Both confirmed for multiple user stories, with emphasis on supporting chatbots and AI recommendations.
- o Training Material and Cloud-based Repository: Critically important for training infrastructure and data storage.

4. Technical Issues and Integration
   - o Real-time Data Integration: The issue of integrating real-time data from PLC controllers was raised. Although technically feasible, it was emphasized that the choice of technology and compatibility with Android devices would be crucial.
   - o Security and Privacy: Discussions on data security and privacy when using third-party APIs, such as OpenAI, were held. It was agreed that while technically viable, technological choices need to align with project data security policies. Special attention to the use of chatbots and generative AI, indicating a constant concern for compliance and user data protection.

10.2. Summary and Next Steps

The discussion on XR5.0 technical components highlighted the need for ongoing collaboration among task leaders to ensure the appropriate selection and effective implementation of technologies. Critical components were confirmed for immediate use, while others require further clarification and development to ensure their applicability.

Recommended Actions

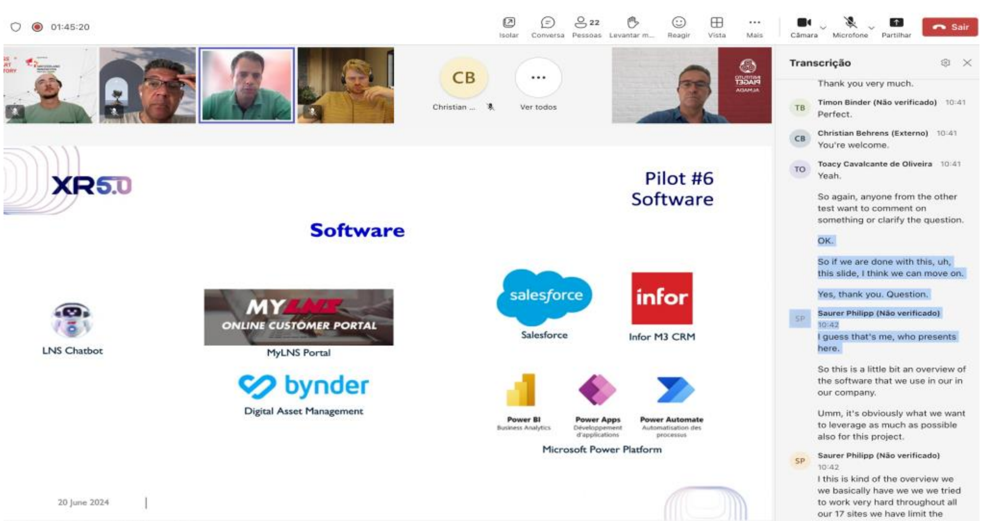
1. Review "Maybe" Components: Review with task leaders for a final decision.
2. Integration Planning: Develop detailed plans for real-time data integration and data security.
3. User Feedback: Implement feedback loops to validate and improve human-centered AI models.

This approach will ensure that XR5.0 technical components are used efficiently and effectively, meeting project needs and ensuring positive outcomes for all involved user stories.

10.3. Software Analysis

The software landscape utilized by the company and how it can be leveraged for the XR5.0 project was extensively discussed. The company aims to maintain a cohesive and efficient software environment, minimizing the diversity of systems in use (Figure 10). Below, we detail the key points of this discussion, including the software used and its integration.

Figure 11 – Software



10.3. Summary of Used Software

1. Main Partners:
    - CRM (Salesforce): Customer relationship management system.
    - ERP (Infor M3): Enterprise resource planning system.
    - Microsoft Power Platform: Includes Power BI, Power Apps, Power Automate, and Power Virtual Agent.
    - Custom Portal: Developed by an external web-specialized partner.
2. Auxiliary Systems:
    - Binder: Digital asset management tool, currently in use but subject to replacement.

10.4. Software Structure and Integration

The company employs a highly integrated software structure to ensure consistency and efficiency in its global operations. Systems are standardized across regions (US, Europe, and Asia), ensuring uniform management of products and customers.

- ERP and CRM: These systems are interconnected, ensuring that product and customer information is globally consistent.
- Microsoft Power Platform: Facilitates the creation of custom applications, process automation, and data analysis.
- Custom Portal: Utilizes data from internal systems to provide relevant information to customers.

10.5. Discussion on Chatbot and Generative AI

A specific discussion was held regarding the evolution of the existing chatbot, which is currently rule-based and utilizes Microsoft Power Virtual Agent. The future intention is to incorporate generative AI capabilities, potentially using Microsoft Copilot.

- Current State: The current chatbot is an advanced FAQ system based on rules.
- Future Goal: To evolve to a generative AI-based chatbot to improve customer interaction and support.
- Considerations: The company is evaluating whether Microsoft remains the ideal partner for this evolution or if other options should be considered.

10.6. Integration and Customization

The company emphasizes the importance of maintaining simplicity and cohesion in the software environment, avoiding the introduction of new systems unless absolutely necessary. This includes careful integration of new elements, such as the chatbot, to ensure alignment with existing systems and not complicate the IT architecture.

- Automation and Integration: Extensive use of Power Automate to integrate different systems and automate processes.
- Continuous Evaluation: The company continuously evaluates new technologies and how they can be integrated efficiently.

In summary, the company seeks to maximize the use of existing systems, integrating them efficiently and evolving their capabilities with emerging technologies, such as generative AI, to continuously improve operations and customer support.

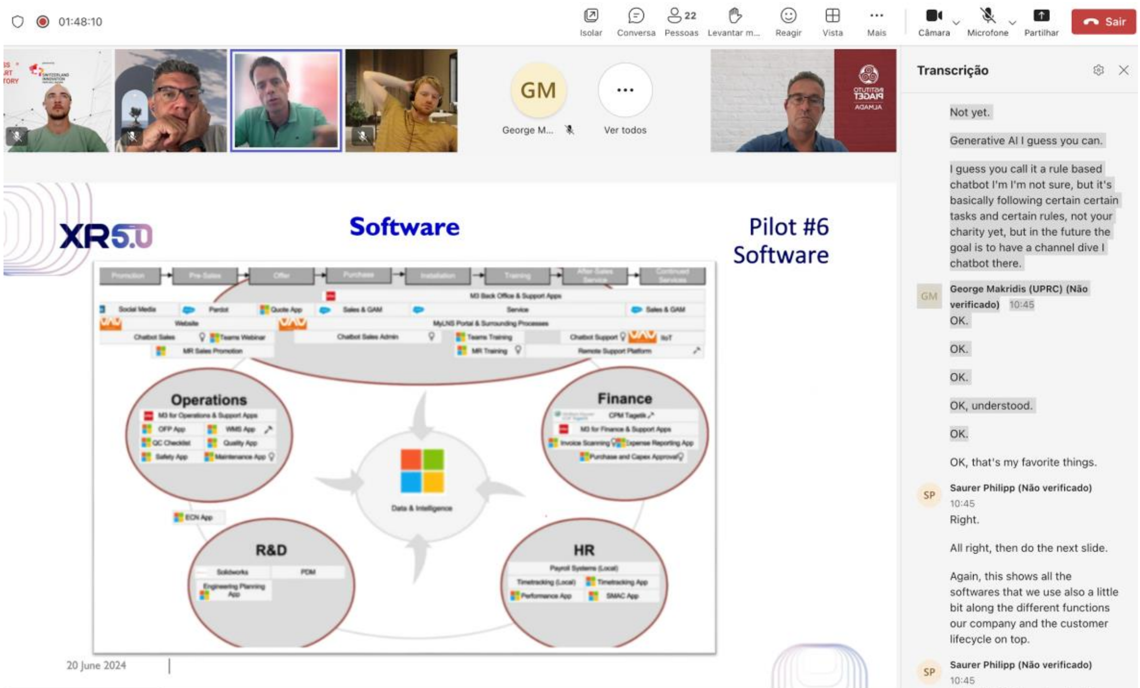
- System Integration: The importance of integrated and standardized systems globally.

- Chatbot and Generative AI: Transitioning from a rule-based chatbot to one based on generative AI, potentially using Microsoft Copilot.
- Maintaining Simplicity: The need to keep the software architecture clean and efficient, avoiding the introduction of new systems unless necessary.

10.7. Software Analysis for Finance, HR, R&D, and Operations

During the meeting, it was mentioned how the software used by the company integrates and supports various functional areas, including Finance, Human Resources (HR), Research and Development (R&D), and Operations (Figure 11). Below is a detailed look at how each of these areas is served by the existing systems and the importance of this integration.

Figure 11 – Software integration



Finance

- ERP (Infor M3): The main tool for financial management in the company. The ERP system allows for the standardization and integration of financial data globally, ensuring consistency and compliance across all locations.
- Power BI: Used for detailed financial analysis and reporting. It enables financial managers to visualize real-time data and make informed decisions.

Human Resources (HR)

- Salesforce: Used for managing employee relationships and automating HR processes. It may include modules or integrations for recruitment, onboarding, and performance management.
- Power Apps and Power Automate: Microsoft Power Platform tools used to create custom HR applications and automate processes such as vacation approvals, performance evaluations, and benefits management.

Research and Development (R&D)

- Custom Portal: Developed by an external partner, the portal may include specific features for R&D, such as project management, technical documentation, and team collaboration.
- Power BI: Used for analyzing R&D project data, allowing visualization of progress, resource allocation, and result analysis.
- Binder: May be used for managing technical documents and other digital assets related to R&D projects.

Operations

- ERP (Infor M3): Crucial for managing operations, including supply chain, production, logistics, and inventory control. The global standardization of ERP ensures efficient and consistent operations.
- Power BI and Power Automate: Used to monitor and optimize operations, providing real-time dashboards and automating operational processes.
- Custom Portal: Facilitates interaction with customers and suppliers, offering access to relevant information and enabling transactions and inquiries.

10.8. Integration and Effectiveness of Systems

The company emphasizes the importance of maintaining integrated systems to ensure cohesive and efficient operations. Below is how this integration is crucial for each area:

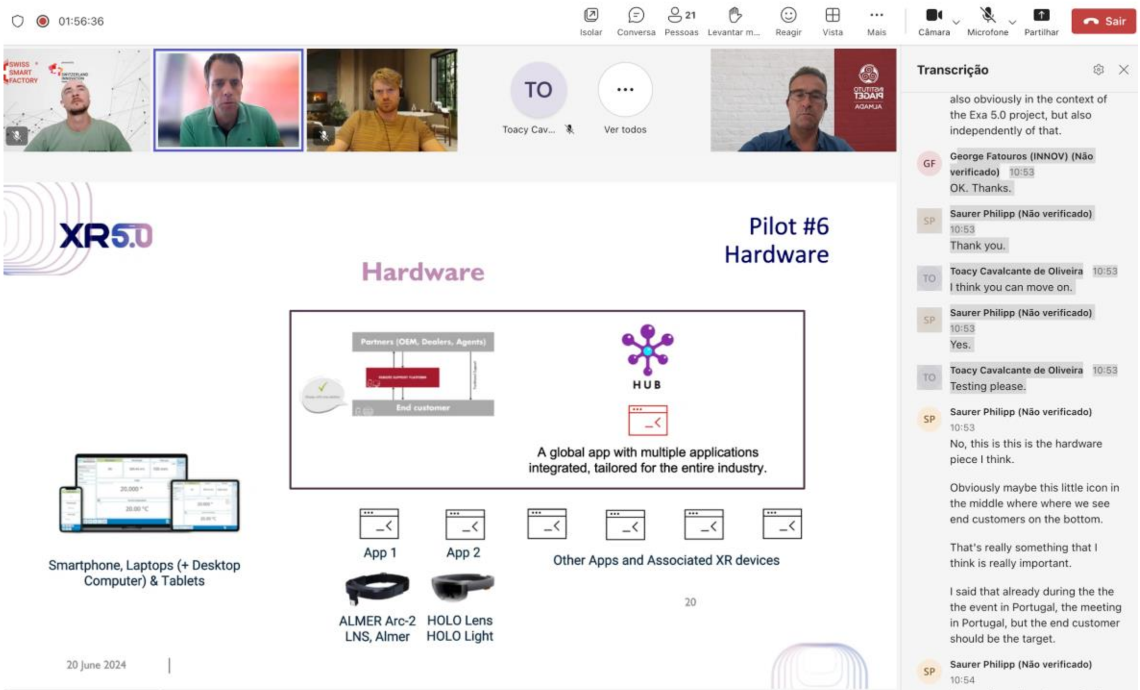
- Finance and ERP: The integration of ERP with Power BI allows for accurate and real-time financial analysis, facilitating strategic decision-making.
- HR and Automation: Using Power Apps and Power Automate to automate HR processes reduces administrative burden and improves operational efficiency.
- R&D and Collaboration: The custom portal and Binder facilitate collaboration among R&D teams and efficient management of projects and documents.
- Operations and ERP: The integration of ERP with analysis and automation systems ensures that operations are continuously monitored and optimized, enhancing productivity and reducing costs.

In summary, the company utilizes a variety of integrated software to support its operations in Finance, HR, R&D, and Operations. The integration of these systems not only ensures operational efficiency and consistency but also enables a swift adaptation to ever-changing business needs. The strategic approach of maintaining a cohesive software environment and avoiding the proliferation of unnecessary systems is key to the company's ongoing success.

10.9. Hardware Analysis

The discussion about hardware during the meeting highlighted several key points related to the use of physical devices to ensure that the proposed platform is accessible and efficient for end users (Figure 12). Below, we present a detailed analysis of these points.

Figure 12 - Hardware



10.9.1 Hardware Overview

Main Objective:

- Customer Satisfaction: The primary goal is to reduce machine downtime for end customers, ensuring that the platform can be accessed and used efficiently across a variety of devices.

Supported Devices:

- Computers, Smartphones, and Tablets: The platform should be compatible with a range of common devices used by end customers.
- Smart Glasses: There is a particular emphasis on smart glasses, with a focus on the use of Almer AR, although it is recognized that not all end customers will use this specific device.

Open and Multi-Device Platform

Platform Features:

- Open to Different Suppliers: The platform must be open to allow integration with multiple machine suppliers, facilitating a collaborative and comprehensive approach.
- Compatibility with Various Tools: It should support a variety of tools and devices, ensuring flexibility and accessibility.

Discussion on Holo Light and Holo Hub:

- Holo Light and Holo Hub: Although the exact role of the Holo Hub is not fully defined, it is mentioned as an integral part of the hardware ecosystem that should be explored and discussed further.

10.10. Additional Issues and Comments

Interaction between Hardware and Software:

- Software Platform with Physical Devices: The presentation emphasized the need for a robust software platform that supports multiple physical devices. This suggests a seamless integration where the software must operate efficiently across different types of hardware.

Feedback and Discussion:

- Participant Comments: There was a request for clarification on the nature of the platform (hardware or software). The response confirmed that the platform is predominantly software-based but supports a range of hardware devices.
- Preparation and Collaboration: Thanks were given for the collaboration and preparation of partners, highlighting the importance of additional details and continued preparation for upcoming workshops.

The hardware analysis highlighted the need for an open and multi-device platform that can be accessed through a variety of tools and devices, including computers, smartphones, tablets, and smart glasses. Customer satisfaction is a priority, with a clear focus on reducing machine downtime and providing an efficient and flexible user experience. Seamless integration between hardware and software is crucial for the success of the platform, and ongoing collaboration among partners is essential to achieving these objectives.