MOTIVATE XR

Maintenance, Support & Operation Training using Immersive Virtual and Augmented Technology for Efficiency with XR

D7.3 Pilot Activities and Evaluation Report

30/11/2025

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D7.3 PILOT ACTIVITIES AND EVALUATION REPORT

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Abstract	This report presents presents the consolidated cross-pilot evaluation report for the Motivate XR beta phase. It synthesises evidence from five industrial training pilots to assess the platform's technological maturity, user acceptance, usability, and operational impact, providing a foundation for iterative refinement and final-phase validation planning.
Keywords	Cross-Pilot Evaluation; Technology Acceptance; Usability; XR Training

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EXECUTIVE SUMMARY

This document, Deliverable D7.3, constitutes the Cross-Pilot Evaluation Report for the beta phase of the MOTIVATE XR project. It consolidates and analyses evidence gathered from the five distinct industrial pilots in Aerospace Manufacturing, Home Appliance Production, Aluminium Fabrication, Electricity Distribution, and Human-Robot Collaborative Manufacturing.

The report's primary objective was to generate a harmonised and comparable evidence base to validate the beta version of the MOTIVATE XR tool suite and identify priorities for the next development cycle. It applied a standardised evaluation framework, integrating quantitative data from Technology Readiness Level (TRL) assessments, Technology Acceptance Model 3 (TAM3) surveys, and System Usability Scale (SUS) scores with rich qualitative insights from facilitator observation logbooks and system analytics.

The analysis yields a clear and actionable diagnosis. The core pedagogical value of XR for industrial training is strongly affirmed, with high user engagement and perceived usefulness reported across sectors. However, the pathway to adoption is primarily governed by Perceived Ease of Use. Pilots where usability was rated as acceptable (Aluminium, Energy Distribution, Human-Robot Collaboration) showed stable or increased intention to use the system. In contrast, pilots facing significant usability challenges saw a drop in adoption intention or a more constrained vision for application. Recurring feedback also highlighted hardware ergonomic concerns and the need for greater software stability and feature completeness.

The report concludes that the beta phase has successfully validated the technological foundation (TRL 6-7) and core value proposition of the Motivate XR platform. The immediate imperative for the mid-term iteration phase is to decisively address the identified friction points in usability, comfort, and reliability. The findings directly feed into a prioritised refinement backlog and action plan, ensuring the platform evolves into a polished, user-ready system prepared for the rigorous KPI-level validation in the final project phase.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AMM	Aircraft Maintenance Manual
AR	Augmented Reality
ATA	Specific part of the airplane subjected of maintenance
MR	Mixed Reality
SPL	Spare Part List
UX	User Experience
VR	Virtual Reality
XR	eXtended Reality

1 INTRODUCTION AND SCOPE

This document presents the cross-pilot evaluation of the MOTIVATE XR beta phase. Its purpose is to consolidate evidence generated across the five industrial pilots and to assess how the MOTIVATE XR components (authoring, experiencing, devices and analytics) performed under real operational conditions. The evaluation builds directly on the methodological foundations defined in D7.1 and uses harmonised instruments to generate comparable data across pilots.

The analysis covers all training activities performed during the beta window, integrating questionnaire results, trainer observations, system logs and standardised evaluation tools. The document also outlines how these findings inform the refinement strategy leading into the final validation phase.

1.1 PURPOSE OF THE CROSS-PILOT EVALUATION

The cross-pilot evaluation aims to assess how the MOTIVATE XR tool suite performs across five distinct industrial training environments, each with its own operational constraints, workforce profiles and learning objectives. Its primary purpose is to generate a harmonised and comparable evidence base that supports both the validation of the beta version and the identification of priorities for the next development cycle.

This evaluation is not a repetition of pilot-specific reports, but a consolidated analytical process that highlights convergences, divergences and emerging patterns in the adoption and effectiveness of XR-supported training. By applying standardised tools such as TRL, TAM3, SUS, UEQ and structured task observations, the cross-pilot evaluation enables a rigorous understanding of how different components of the MOTIVATE XR ecosystem (authoring, experiencing, devices and analytics) contribute to learning efficiency, usability and operational performance across contexts.

1.2 SCOPE AND BOUNDARIES OF THE REPORT

The scope of this deliverable is limited to the training activities, datasets and evaluation instruments deployed during the beta-phase implementation. Specifically, the report includes:

- evidence collected from ex-ante and ex-post questionnaires administered to trainees;
- trainer logbooks documenting real-world conditions and interactions during the sessions;
- system logs and analytics associated with task execution and user behaviour;
- assessments performed using standardised instruments (TRL, TAM3, SUS, UEQ).

Activities that precede the evaluation window—such as onboarding sessions, internal demonstrations by technology providers, or preparatory workshops—are explicitly excluded from the scope, as they fall outside the formal evaluation perimeter defined in D7.1.

The report does not assess the final version of the MOTIVATE XR platform, nor does it measure long-term learning retention or operational integration. These aspects will be analysed in the next project phase.

1.3 STRUCTURE OF THE DOCUMENT

The structure of this report is as follows:

- **Section 2**: Overview of each pilot, including context, objectives and XR training implementation.
- **Section 3**: Evaluation methodology and instruments.
- **Section 4**: Consolidated cross-pilot results and comparative analysis.
- **Section 5**: Discussion and interpretation of findings.
- **Section 6**: Recommendations and iteration plan for the next development phase.
- **Section 7**: Next steps and directions for future research.

2 PILOT PROGRAM OVERVIEW

The MOTIVATE XR beta phase was deployed across five industrial pilots representing distinct operational environments, training needs, and levels of digital maturity. This diversity is intentional and central to the project's validation strategy: it allows the evaluation to capture how the MOTIVATE XR tool suite performs under varied organisational, technical and workflow constraints.

Each pilot implemented a tailored training programme aligned with the methodological guidelines defined in D7.1 [1], ensuring comparability of data while allowing pilots to address their specific industrial requirements. The pilot activities spanned the full beta window, covering onboarding, trainer preparation, execution of XR-based training modules and collection of evaluation data.

The sections that follow describe each pilot individually, focusing on the training context, objectives and the implementation of the XR sessions. These descriptions provide the necessary background for understanding the cross-pilot analysis presented later in the report.

2.1 OVERVIEW OF PARTICIPATING PILOTS

The five pilots involved in the MOTIVATE XR beta phase represent complementary sectors and training use cases, enabling a holistic assessment of the platform's versatility and industrial relevance. Below is a concise overview of their positioning within the project:

- **Pilot 1 – Aerospace Manufacturing:** Focuses on complex, safety-critical maintenance and inspection tasks requiring high procedural accuracy. The aim is to assess how XR can support standardisation and error reduction.
- **Pilot 2 – Home Appliance Production:** Targets assembly-line procedures and quality-control tasks, using XR to reinforce consistent execution and accelerate training for new workers.
- **Pilot 3 – Aluminium Fabrication:** Concentrates on manual operations requiring precision and safety awareness, exploring XR as a tool for skill reinforcement and task planning.
- **Pilot 4 – Electricity Distribution:** Applies XR to field-oriented procedures, emphasising risk mitigation, remote assistance and standardised training in high-stakes environments.
- **Pilot 5 – Human-Robot Collaboration:** Investigates XR-based training for hybrid workspaces where operators interact with robotic systems, focusing on spatial awareness, workflows, and safety protocols.

Together, these pilots form a representative testbed for evaluating XR-enabled training across manufacturing, industrial services and human-machine interaction contexts. The following sections (2.2–2.6) describe each pilot in detail, providing the foundation for the evaluation presented in Section 4.

2.2 PILOT 1: AEROSPACE MANUFACTURING

The aerospace industry faces a critical challenge: a shortage of qualified maintenance operators. As aircraft systems grow more complex and fleets expand, the demand for skilled professionals who can ensure safety, reliability, and regulatory compliance has never been greater.

To meet this challenge, training must scale efficiently, safely, and cost-effectively. **Extended Reality (XR)** offers a transformative solution.

XR-based training delivers:

- Immersive, hands-on simulations of real-world maintenance tasks.
- Scalable learning environments adaptable to multiple sites and diverse aircraft models.
- AI-driven feedback for continuous skill improvement and higher training quality.

The **MOTIVATE XR Pilot1** aims to demonstrate how XR can revolutionize aircraft maintenance training by making it more engaging, effective, and aligned with the industry's evolving needs.

2.2.1 TRAINING CONTEXT AND OBJECTIVES

For the Aerospace Pilot, the objective is to validate how AI and XR technologies can automate the conversion of aircraft technical documentation into an XR training application, exploiting an Aircraft Digital Mock-Up and extensive technical manuals.

Pilot1 brings together key aerospace industry partners to deliver an XR-based maintenance training solution dedicated to the **MRO profession (Maintenance, Repair, and Overhaul)**.

The MOTIVATE XR Pilot1 solution offers significant benefits for the aerospace industry:

- **Reducing time and costs** to produce XR maintenance training systems.
- **Making training more engaging** and addressing the shortage of maintenance technicians.
- **Improving training quality** while minimizing the need to immobilize real aircraft.
- **Reducing errors** in interpreting documentation and modeling procedures through AI-driven conversion tools.

Four MOTIVATE XR entities are collaborating with this pilot:

- **Aerospace Valley:** Leading Aerospace cluster, Aerospace Valley is the Pilot1 owner, responsible for coordination, scenario definition, partner coordination, and overall evaluation.
- **Aerocampus Aquitaine:** EASA PART 147-certified training centre, responsible for hosting XR training sessions and participant evaluation on real conditions (relevant population of Aero students, certified instructors)
- **CS GROUP:** French XR and simulation provider, offering Inscape VTS no-code authoring platform for scenario creation, enhanced with a dedicated creation assistant to address MOTIVATE XR objectives, allowing interaction with AI models from SOP.
- **Sopra Steria:** Provides AI-powered knowledge models (GraphRAG) to enrich XR scenarios with interactive technical documentation.

In addition, Pilot1 actors establish collaborations with key players in the aeronautics industry to work on real-world use cases,

- The first technical collaboration started with **Liebherr Aerospace**, that supplies detailed technical scenarios and documentation for A320 air conditioning systems.
- Pilot1 actors are currently in discussions with other aerospace companies to establish additional collaboration agreements.

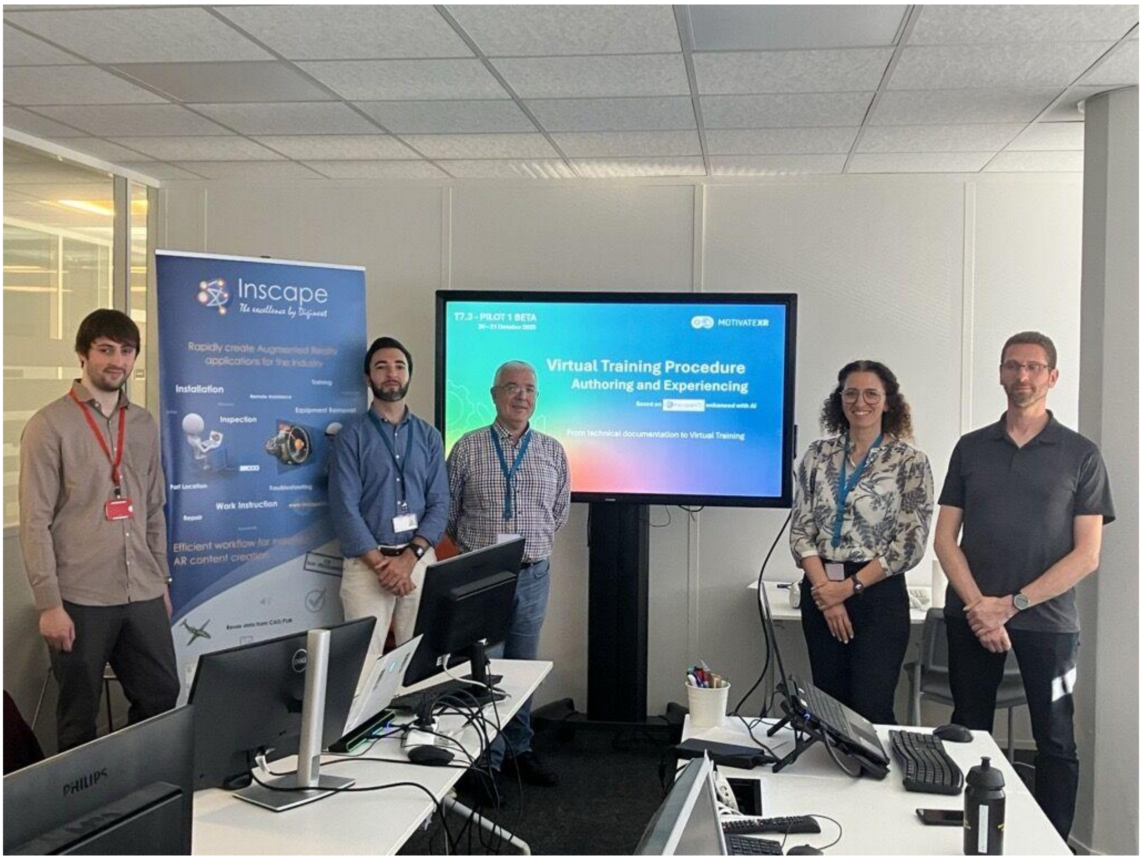

FIGURE 1 - PILOT1 PARTNERS AND LIEBHERR AEROSPACE FOR AUTHORING EVALUATION, ON CS PREMISES

<u>Beta evaluation Scope:</u>

The beta test evaluates the efficacy and usability of the MOTIVATE XR platform for training maintenance technicians in aircraft system inspections, specifically focusing on **the Airbus A320 air conditioning pack,** manufactured by Liebherr aerospace.

In accordance with Liebherr aerospace, the beta scenario focused on a specific maintenance procedure on the Liebherr's air conditioning pack: the **Primary Heat Exchanger (PHX) Inspection.**

a. Inspection steps include disassembly, visual checks, and reassembly.
b. Realistic interactions and error management are integrated.

This procedure was selected due to frequent operational use and complexity, providing rich data for evaluation.

<u>Expected learning outcomes:</u>

- Technicians demonstrate increased accuracy and speed in performing maintenance inspections.
- Technicians effectively use Virtual & XR tools to access and interpret technical documentation.
- Supervisors efficiently monitor and assess trainee performance in Virtual & XR sessions.

2.2.2 XR TRAINING IMPLEMENTATION DESCRIPTION

Training Objectives

The training programme is designed to ensure that:

- Instructors can autonomously create and adapt XR training scenarios
- Trainees can navigate and interact with XR scenarios within the Player environment.

Training Structure

The training is organised into three phases:

1. **Onboarding session**
2. **Authoring Evaluation**
3. **Experiencing Evaluation**

Evaluation Phase Details

On boarding sessions:

- Dates:
    1. 21/08/2025: Instructor onboarding
    2. 30/09/2025: End-users onboarding
- Location: Remote
- Participant Profiles: Instructors and end-users
- Instructor: CS Group
- Environment: Computer-based

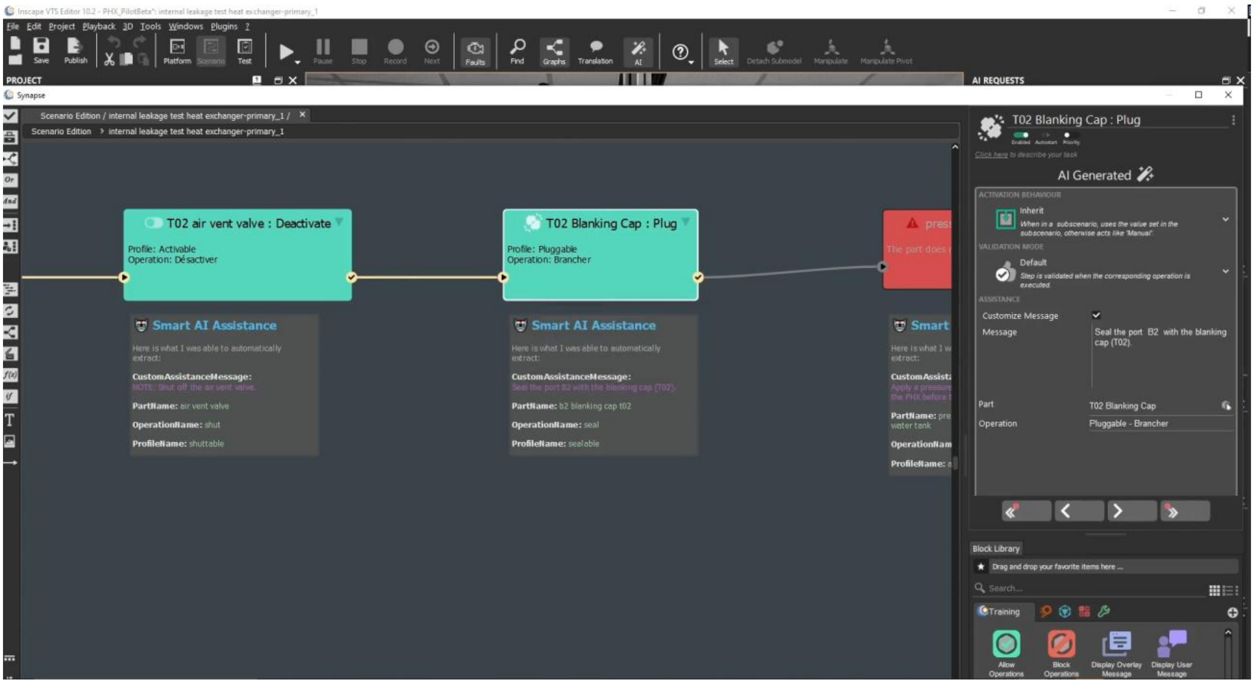

FIGURE 2 - SCREENSHOT OF THE AUTHORING INTERFACE FOLLOWING AI-GENERATED PROCEDURE CREATION

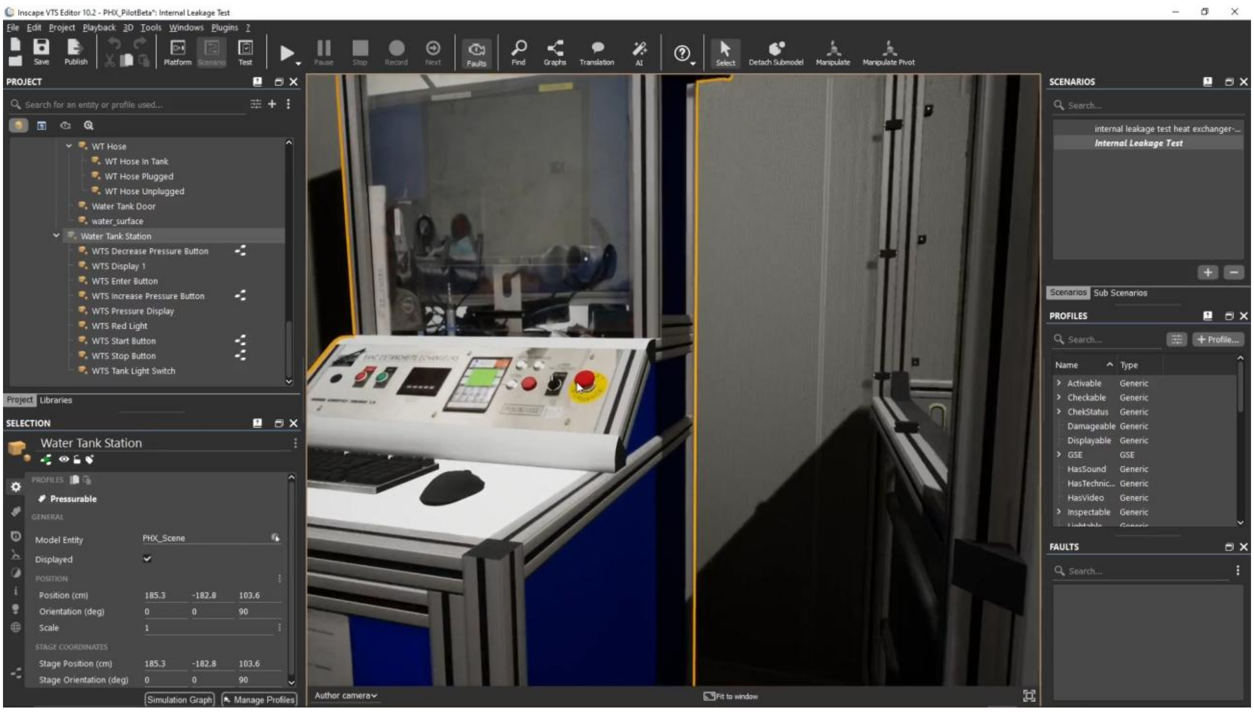

FIGURE 3 - SCREENSHOT OF THE INSCAPE AUTHORING INTERFACE

Authoring Evaluation

This phase is designed for trainers and content creators, focusing on practical, hands-on activities such as project setup, scenario creation, 3D asset integration, behaviour scripting, and leveraging AI-assisted features.

Authoring Evaluation: tailored for trainers and content creators through hands-on activities such as covering projects & Scenario creation, 3D asset integration, behaviour scripting, AI-assisted features.

- Logistics
    - Dates: 20 and 21 October 2025
    - Location: CS Group site – Toulouse - France
    - Participant Profile: Liebherr aerospace stakeholders
    - Instructor: CS Group
    - Environment: Training room equipped with computers and VR headsets

Key Steps

1. Project Setup: Creating a new Inscape VTS project, importing 3D models (e.g.,PHX), and defining scenario metadata.
2. Component Behaviour Definition: Associating behaviours to components (e.g., disassembly steps, inspection logic).
3. Procedure Scripting: Using the visual logic editor to define step-by-step workflows.
4. AI-Powered Enhancements: Using an AI-based creation assistant to transform technical documentation information into scenario steps.
5. Testing & Export: Validating the scenario and exporting it for use in the Player.

FIGURE 4 - EVALUATION SESSION WITH LIEBHERR AND CS GROUP'S INSTRUCTOR

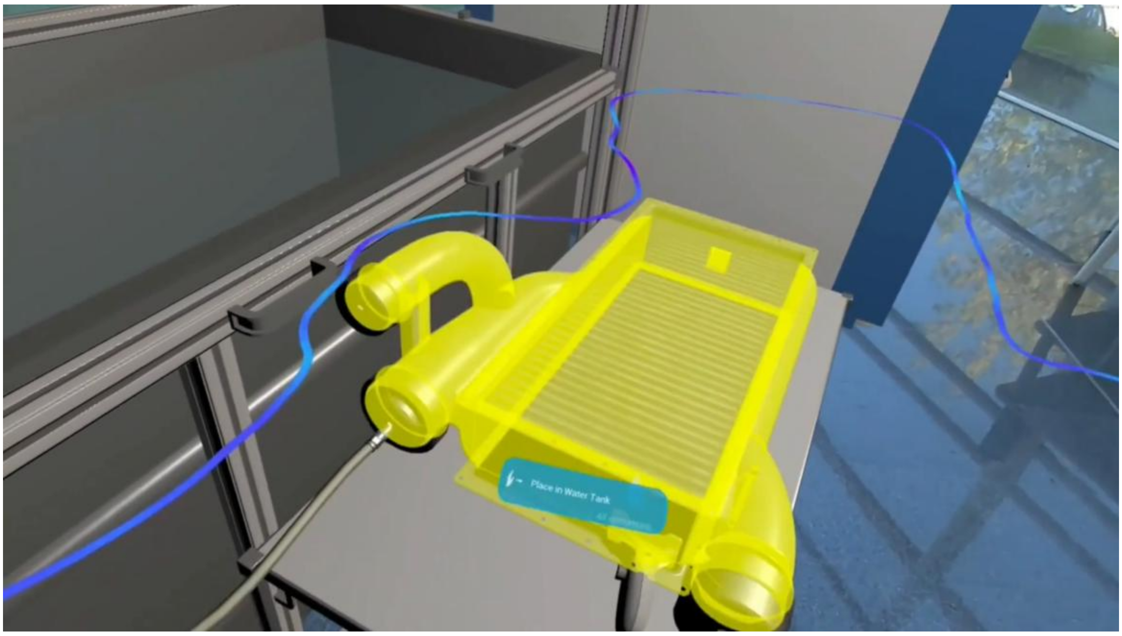

FIGURE 5 - SCREENSHOT OF THE LIEBHERR SCENARIO DISPLAYED ON

Experiencing Evaluation: This phase is designed for trainees and instructors, focusing on immersive scenario execution, dynamic interaction with virtual components, and the use of advanced supervision tools.

- Logistics
  - Dates: Multiple sessions from 13/10/2025 to 31/10/2025
  - Location: Aerocampus Aquitaine site – Bordeaux, France
  - Participant Profile: Maintenance operator apprentices
  - Instructor: Qualified maintenance instructor from Aerocampus Aquitaine - AA
  - Environment: Classroom equipped with computers and VR headsets

Key Steps:

1. Scenario Launch: Loading the XR scenario on the headset or desktop player.
2. Interaction Training: Performing inspection tasks using controllers or gestures.
3. Supervision Tools: Instructors monitor progress, trigger hints, and collect logs.
4. Feedback & Logging: System logs and observation notes are collected for evaluation.

FIGURE 6 - EVALUATION SESSION WITH XR HEADSET AT AEROCAMPUS AQUITAINE

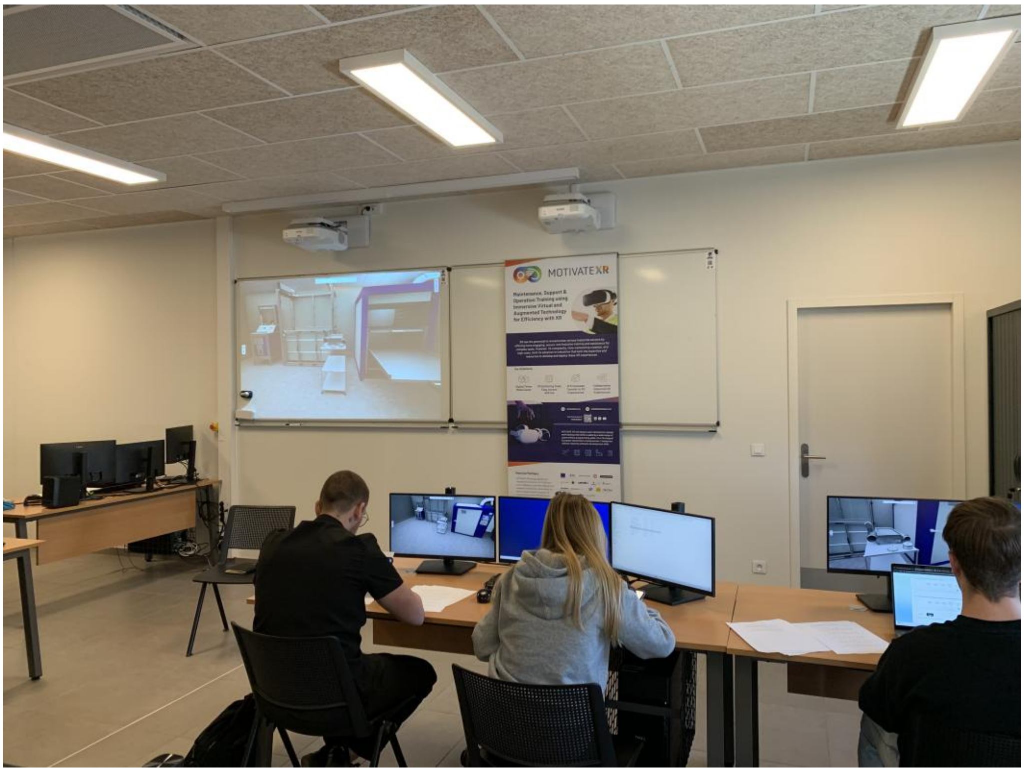

FIGURE 7 - EVALUATION SESSION HELD IN AN AEROCAMPUS AQUITAINE CLASSROOM

Evaluation synthesis

The evaluation sessions resulted in an overall positive assessment of the proposed solution.

The XR beta experience was tested by a diverse group of participants, and feedback was collected through structured questionnaires, observation notes, and instructor input. The tool proved to be intuitive, highly realistic in its graphics, immersive, and offered a significant time-saving advantage for creating immersive training scenarios.

Participants expressed genuine enjoyment in navigating this extended reality environment, appreciating its realistic visuals. Training professionals highlighted several key benefits:

- Time savings in scenario generation enabled by AI-driven features
- Ease of integrating their own training paths into the pilot solution
- Portability of the system
- Seamless integration with the existing Liebherr LMS platform

The pilot clearly demonstrated the potential of MOTIVATE-XR tools to transform aircraft maintenance training.

These insights will guide future improvements and ensure the pilot project remains aligned with user expectations and the overall objectives of the program.

2.3 PILOT 2: HOME APPLIANCE PRODUCTION

Home Appliance Repair Training (Pilot 2) was designed to validate the MOTIVATE XR platform for real-world industrial use within the home appliance sector. The primary aim was to assess how XR technologies — across authoring, experiencing, remote assistance, and 3D content generation — could enhance the competencies of field technicians, improve maintenance workflows, and support end-users with safer, more intuitive troubleshooting instructions.

During this trial, Pilot 2 progressed with the completion of the demo case setup and the preparation of all necessary technical documentation. The team tested the following tools: KAYROX, KAYROX AMR player, KAYROX ASSISTANCE, and INSCAPE VTS [2] [3]. The beta XR experience was trialed by several participants, and their feedback was systematically gathered through surveys to inform further improvements and ensure the pilot remains closely aligned with user requirements and overall project objectives.

2.3.1 TRAINING CONTEXT AND OBJECTIVES

Gorenje, as the pilot owner, oversaw a large and diverse network of service technicians responsible for installing, troubleshooting, and repairing home appliances. Prior to the pilot, training activities relied heavily on static manuals, 2D diagrams, service videos, and in-person sessions. These methods presented several challenges:

- Limited interactivity and low engagement during learning.
- Difficulty interpreting 2D spare part lists, leading to identification errors and longer repair times.
- Knowledge gaps among end-users, who often felt uncertain when performing basic maintenance tasks.
- Performance variability among technicians, particularly new or inexperienced staff.

The pilot sought to address these gaps by introducing XR workflows featuring 3D visualization, guided stepwise instructions, real-time support, and performance tracking. The technical focus of the beta test was the troubleshooting and repair of Washing Machine Error-07 - a common pumping/drainage failure in field operations.

To support content creation, deployment, and execution of XR training, Gorenje tested four tools from the MOTIVATE XR ecosystem:

- KAYROX-authoring – XR online content creation on PC
- KAYROX-ARM player – On-device (mobile phone / tablet) AR/MR experience player
- KAYROX Assistance – Remote expert support tool (mobile phone / tablet)
- INSCAPE VTS – scenario simulation platform on PC

The training objectives were defined across three user groups: service technicians, end-users, and instructors/supervisors.

- Objectives for Technicians
    - Improve diagnostic accuracy and speed when identifying the root cause of E7 errors.
    - Strengthen abilities to work with 3D spare part lists and XR-guided repair steps.
    - Reinforce procedural knowledge, including wiring checks, sensor adjustments, hose inspections, and pump servicing.
    - Enable seamless access to digital manuals and interactive 3D content within XR.

- Objectives for End Users
    - Increase confidence in performing safe, simple troubleshooting tasks (e.g., filter cleaning, siphon inspection).
    - Reduce unnecessary technician call-outs by supporting guided XR self-help flows.
    - Provide clear visual workflows for basic maintenance steps.

- Objectives for Instructors and Supervisors
    - Facilitate remote monitoring and performance evaluation during XR training sessions.
    - Learn to deploy, calibrate, and manage XR experiences using KAYROX and INSCAPE tools.
    - Efficiently collect system logs, performance metrics, and qualitative feedback.

The pilot demonstrated several key learning outcomes. Participants showed increased accuracy and speed when performing technician maintenance tasks. They also developed greater familiarity with XR tools, which enabled them to use spatially anchored instructions independently. In addition, supervisors gained improved insights through the system's detailed logs and observation data.

Evaluation was carried out using questionnaires, log analysis, instructor notes, and interviews to ensure a comprehensive qualitative and quantitative assessment.

2.3.2 XR TRAINING IMPLEMENTATION DESCRIPTION

Gorenje prepared the on-site environment for the training activities, delivered washing machine samples to the project partners, and selected the E7 troubleshooting scenario as the focus of the pilot. All necessary technical documentation — such as STEP 3D models, instructional videos, and troubleshooting flowcharts — was provided in advance to technology developers in order to prepare necessary elements to support the development of the XR training materials.

For the training we engaged service instructors, service engineers, constructors, and trainees worked on training and support activities related to the maintenance and self-repair procedures for Gorenje washing machines (error 07 troubleshooting).

Throughout this training, they advanced by completing the demo case setup and preparing all required technical documentation. The team tested several MOTIVATE XR tools, including KAYROX, the KAYROX AMR player, KAYROX ASSISTANCE, and INSCAPE VTS.

The KAYROX-authoring training introduced participants to the complete process of creating and deploying XR training content using the KAYROX platform. Trainees learned how to import and structure assets such as 3D models, videos, and manuals, develop interactive decision flows, and apply semantic annotations to build clear and effective instructional steps. Hands-on exercises guided them through configuring spatial alignment, refining user interactions, and testing their content. The session concluded with feedback and best-practice discussions, enabling participants to confidently design, validate, and deploy immersive XR training experiences for real maintenance and troubleshooting tasks.

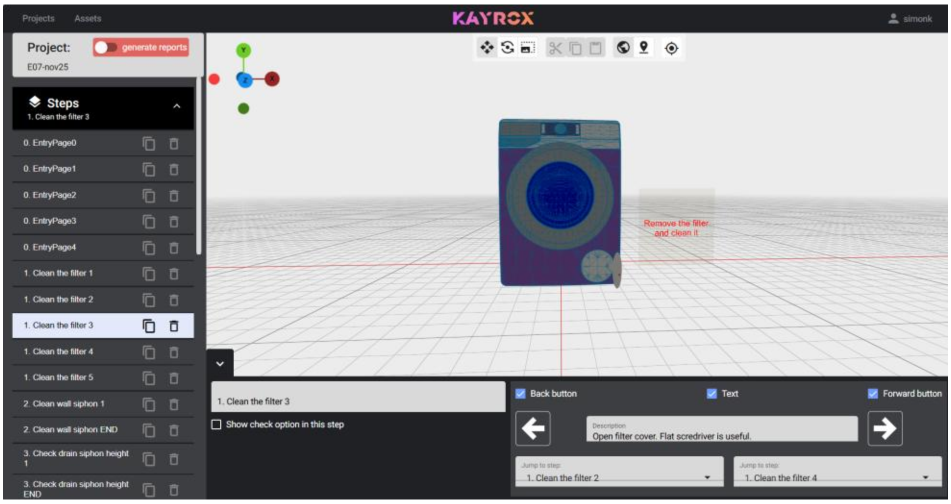

FIGURE 8 - CREATING THE XR TRAINING MANUALS FOR THE MAINTENANCE AND SELF-REPAIR OF WASHING MACHINE (KAYROX)

The KAYROX-AMR Player training provided participants with a practical introduction to using the player application for viewing, navigating, and executing XR training experiences in real operational environments. During the session, trainees learned how to launch assigned procedures, interact with spatially anchored instructions, and follow visual overlays aligned with real equipment. They practiced using the player's interface, gesture controls, and navigation tools while completing guided maintenance steps, allowing them to understand how XR content supports task execution. The training also covered device setup, marker calibration, and troubleshooting common usability issues, ensuring that participants could confidently operate the AMR Player on tablets. Through hands-on exercises and instructor feedback, users gained the necessary skills to effectively access and run the immersive training modules created within the KAYROX ecosystem.

FIGURE 9 - EXPERIENCING THE XR TRAINING MANUALS FOR THE MAINTENANCE AND SELF-REPAIR OF WASHING MACHINE (KAYROX ARM PLAYER)

The KAYROX-Assistance training introduced participants to the remote-support capabilities of the KAYROX platform, focusing on how experts can guide technicians in real time through XR-enabled communication. Trainees learned to initiate assistance sessions, share live video streams, place spatial annotations, and follow step-by-step instructions projected onto real equipment. The training emphasized effective collaboration between the on-site user and the remote expert, demonstrating how the tool enhances problem-solving, reduces downtime, and improves accuracy during maintenance tasks. Through hands-on practice, participants gained confidence in using the system to deliver and receive immediate, context-aware technical support.

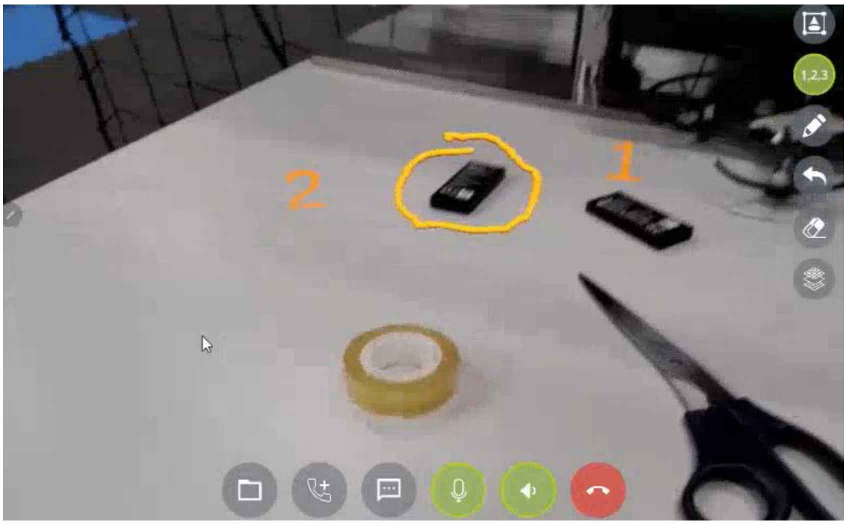

FIGURE 10 - TRAINING ON KAYROX-ASSISTANCE

The INSCAPE VTS training focused on introducing participants to the platform's capabilities for creating interactive, simulation-based training scenarios. During the session, trainees learned how to assemble virtual environments, structure procedural workflows, and integrate multimedia elements such as animations, dialogues, and triggers to guide learners through complex operations. The training emphasized intuitive design principles and user-friendly authoring tools, enabling participants to quickly prototype and refine immersive learning experiences. Through hands-on exercises and guided demonstrations, users gained the skills needed to build, test, and adjust virtual training simulations that support skill development and operational understanding.

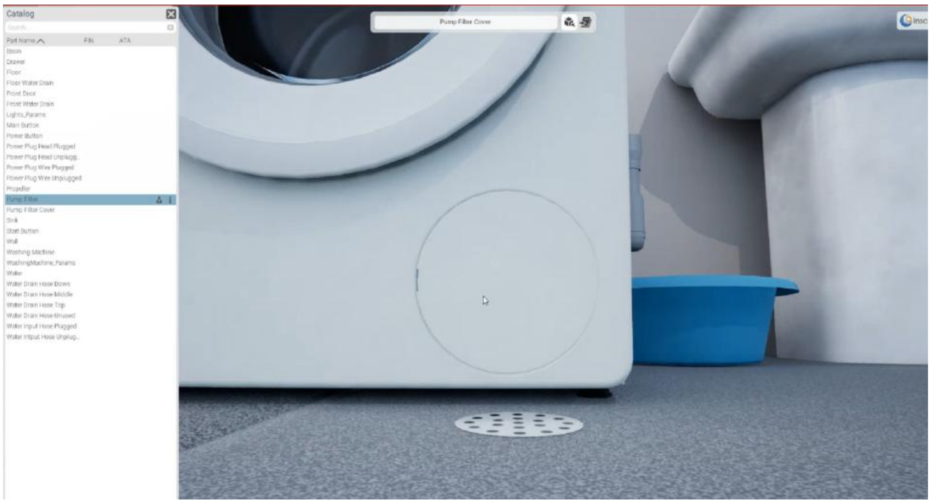

FIGURE 11 - TRAINING ON INSCAPE VTS

During the Pilot 2 beta testing, all four above mentioned MOTIVATE-XR tools were evaluated for usability, effectiveness, and alignment with training objectives.

- KAYROX-authoring enabled participants to create structured XR experiences and integrate 3D models, videos, and interactive flows; however, users experienced difficulties with 3D object manipulation, multi-object selection, and project copying, and noted the absence of an undo function and full-step preview, highlighting areas for improvement in authoring efficiency.
- The KAYROX AMR Player proved effective for executing XR content in real environments, allowing technicians to follow spatially anchored instructions, but challenges were observed in object anchoring, scaling, and marker alignment, as well as the need for fullscreen modes and persistent control panels.
- KAYROX ASSISTANCE performed reliably as a remote support tool, allowing experts to guide on-site technicians through live video, annotations, and stepwise instructions, and was generally well-received with minimal issues reported.
- INSCAPE VTS offered a stable platform for creating and running interactive training scenarios, supporting the design of immersive procedural workflows with multimedia integration.

Overall, the pilot confirmed that the MOTIVATE-XR tools have strong potential to enhance maintenance training and troubleshooting, while also identifying usability and interaction challenges that should be addressed to optimize the authoring, deployment, and user experience in future iterations.

The beta XR experience was evaluated by multiple participants, and their feedback was collected through structured surveys. This input will serve to guide further improvements and ensure that the pilot remained aligned with user needs and the overall project objectives.

2.4 PILOT 3: ALUMINIUM FABRICATION

Pilot 3, led by the Architectural Aluminium Academy (AAA) in close collaboration with D-Cube (D3), focuses on validating the Motivate XR ecosystem within the aluminium fabrication and construction domain. The pilot introduces a fully digitalised XR-assisted workflow for assembling architectural aluminium systems, combining 3D manuals, animated stepwise instructions, on-device XR guidance, and real-time remote export support.

The objective is to enable constructors, fabricators, engineers, and trainees to practise the assembly of complex aluminium profiles, using immersive XR glasses, while receiving continuous support from structured instructions and remote expert supervision.

2.4.1 TRAINING CONTEXT AND OBJECTIVES

Training activities were carried out at AAA's industrial training facilities, where aluminium fabricators, engineers, and trainees engaged directly with the MOTIVATE XR tools. Prior to the pilot, learning workflows relied heavily on traditional documentation: printed manuals, 2D drawings, large technical catalogues, and instructor-led guidance. These methods posed several challenges:

- Difficulty interpreting 2D technical drawings and profile cross-sections.
- Knowledge variability between novice and experienced fabricators.
- Limited ability to visualise multi-step assemblies and interlocking components.
- Lack of remote support mechanisms for on-site constructors.

The pilot aimed to address these gaps by deploying three key tools from the D3 Motivate XR suite:

- **Narrative Editor –** for creating structured XR instructional content, importing 3D aluminium profiles, defining assembly sequences, animations, safety notes, and step-by-step guidance.
- **RTXR Player –** an XR application running on XR glasses that presents the authored 3D manuals, and dynamic animations overlaid onto the real working environment.
- **Streaming Editor –** a remote assistance and supervision tool enabling AAA engineers to monitor trainees in real time, visualise their field of view, provide corrections, and track task progress.

Through these tools, the core training objectives were:

- Ensure accurate understanding of aluminium assembly procedures through immersive 3D manuals and animated sequences.
- Support safe and efficient operation, with integrated safety notes and stepwise instructions.
- Provide real-time remote assistance to identify user errors, propose corrective actions, and enhance confidence during the assembly process.
- Build long-term capacity at AAA, enabling instructors and engineers to independently author, deploy, and update XR-based training materials tailored to different aluminium systems.

The pilot ultimately aimed to ensure that Motivate XR solutions could be seamlessly integrated into AAA's ongoing upskilling programs and operational training workflows.

2.4.2 XR TRAINING IMPLEMENTATION DESCRIPTION

The implementation of the XR training was jointly designed and carried out by AAA and D3. The process followed a structured evaluation flow, incorporating authoring, experience, and remote assistance components of the MOTIVATE XR ecosystem.

1. **Narrative Editor – Authoring of XR Training Content**

AAA, in collaboration with D3 for training and technical support, created the M450 assembly training scenario using the Narrative Editor.

Key actions included:

- Importing 3D models of aluminium profiles and accessory components.
- Defining stepwise assembly procedures, including ordering, alignment and fitting of parts.
- Creating animated demonstrations showing correct handling and positioning.
- Adding instructor narrations, captions and contextual explanations.
- Structuring safety notes and checkpoints to reinforce acceptable fabrication practices.

This authoring stage evaluation allowed AAA engineers and technicians to gain first-hand experience with content creation, enabling them to refine the instructional flow and ensure accuracy with respect to real manufacturing practice.

2. **RTXR Player – XR Guided Assembly**

During the experience evaluation, trainees used XR glasses equipped with the RTXR Player to follow the authored M450 training scenario. The application provided:

- 3D Animated instructions of the assembly.
- Multimedia supplementary content, such as images, video, audio and pdf documents.

- Enhanced UI tailored for the aluminium assembly procedure, providing best possible user experience.
- Multi-user collaboration that enabled the possibility of two trainees wearing the XR glasses, to be on the same training session.

Trainees interacted with a highly intuitive interface using gestures and gaze, improving clarity and reducing ambiguity in interpreting traditional 2D manuals.

3. **Streaming Editor – Remote XR Assistance**

AAA engineers and instructors used the Streaming Editor to monitor trainees during the hands-on sessions. The tool enabled:

- Real-time video streaming from the trainee's XR headset, showing their exact viewpoint.
- Immediate corrective guidance, improving accuracy and reducing assembly errors.
- Documentation of observations, screenshots, and session logs for later analysis.

This remote expert support layer proved essential in validating the feasibility of XR-enabled supervision for industrial training and future on-site applications.

The full pilot evaluation was conducted in three stages:

1. **Stage 1 – Instructor & End-User Training (Early September)**

D3 delivered targeted training sessions to AAA instructors on how to use the Narrative Editor and RTXR Player. This ensured that AAA staff could independently create XR content and operate the headset-based experiences.

2. **Stage 2 – Authoring Evaluation (September – Mid October)**

AAA and D3 jointly tested and refined the authored M450 assembly scenario. Feedback was addressed iteratively, focusing on clarity, animation accuracy, step segmentation, and usability within XR.

3. **Stage 3 – Experience Evaluation (Mid-October – Mid November)**

Trainees assembled the M450 aluminium window using the RTXR Player, assisted by onsite instructors and remote supervision through the Streaming Editor. Data were collected through:

- questionnaires
- observation notes
- video/photo documentation
- instructor feedback

These insights were used to assess usability, comprehension, workflow accuracy, and opportunities for further tool improvement.

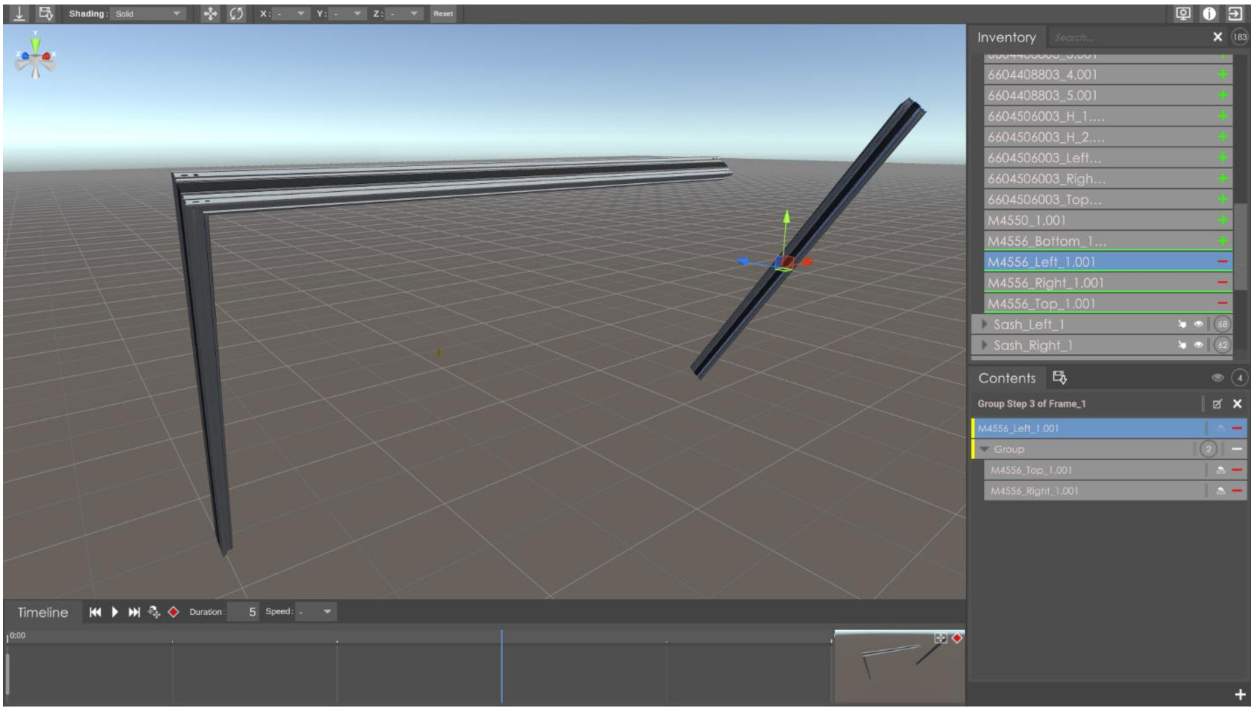

FIGURE 12 - CREATING A 3D ANIMATION ASSEBLY STEP USING THE NARRATIVE EDITOR DURING THE AUTHORING EVALUATION PERIOD

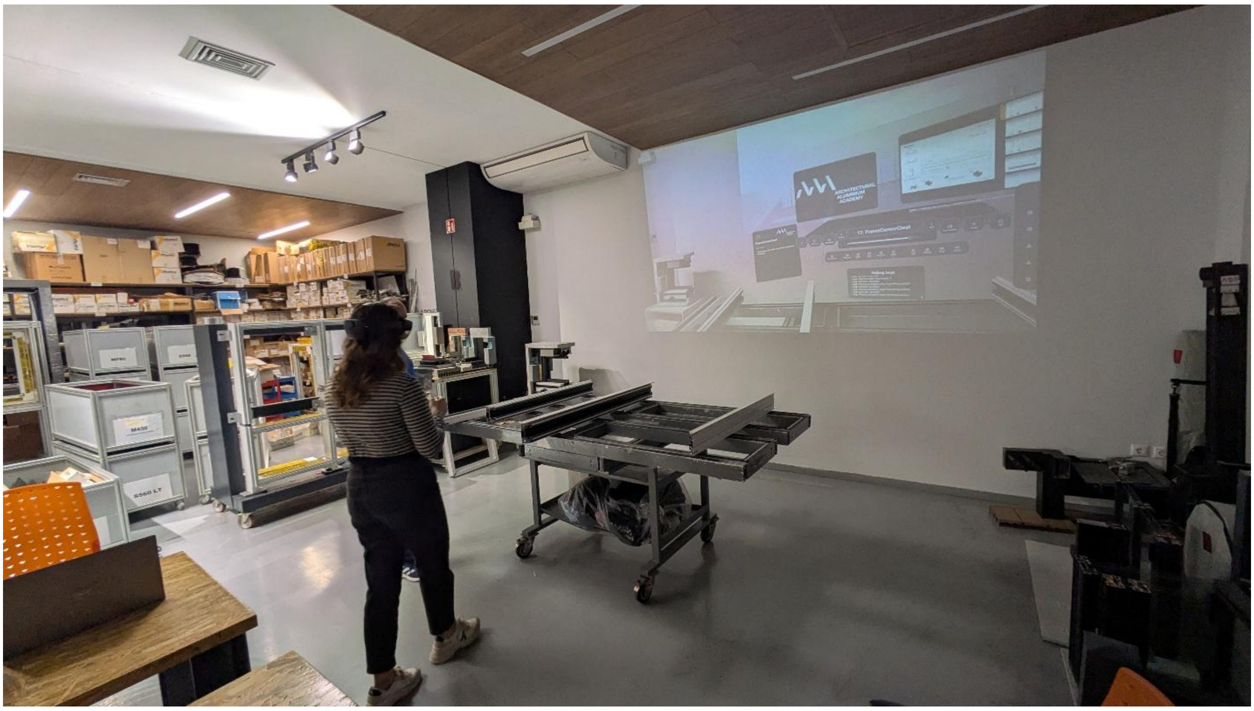

FIGURE 13 - TESTING THE XR REMOTE ASSISTANCE TOOL DURING THE EXPERIENCE EVALUATION PERIOD

FIGURE 14 - TWO TRAINEES ARE ASSEMBLING THE M450 ALUMINIUM WINDOW WITH THE HELP OF THE RTXR APPLICATION

The pilot demonstrated that the Motivate XR toolchain can effectively support aluminium assembly training. Users reported increased clarity, reduced ambiguity in interpreting complex profile geometries, and improved confidence during hands-on construction tasks. The collaboration between D3 and AAA confirmed the tools' strong potential for future industrial adoption, while also providing valuable insights for refining usability and scaling XR workflows across AAA's wider training programmes.

2.5 PILOT 4: ELECTRICITY DISTRIBUTION

For the Electricity distribution Pilot, the goal is to validate how XR technologies can help on real use cases regarding the inspection and maintenance procedures on power grid infrastructure. Field technicians can benefit from the opportunities provided by XR technologies in shortening the time needed on these procedures, ensuring more precise measurements, record keeping and generally enhancing efficiency and safety.

2.5.1 TRAINING CONTEXT AND OBJECTIVES

HEDNO (HED), as the pilot owner of Pilot 4, set the training scenario specifically on the procedure of wooden pole inspection and maintenance. For the tasks related to this procedure, training of the technical personnel needs to be carried out, which can be time-consuming. Also, during the wooden pole inspection and maintenance, the technicians must make calculations based on a specific algorithm and fill all the important data in forms. It is important to mention that the number of wooden poles installed over the length of the Greek distribution network exceeds one million. Considering all these, the need for a more simplified and less time-consuming process is imperative. Towards this end and in collaboration with the partners involved in this Pilot, HED designed all the training modules that introduce XR technology capabilities in the above-mentioned procedure. The XR system aims to simplify workflow processes for trainees, instructors, and technical personnel by offering:

- Reduced working time for inspection and maintenance of wooden poles
- Efficient training of technicians
- Error prevention
- Easy access to digital files, illustration of tasks using 3D models and animations and view of important data
- Improved operational efficiency and safety

The objective of the training is to familiarize the trainees with the XR environment, through:

1. Authoring: Designing the training material in a specialized environment without any use of programming.
2. Experiencing: Following the procedure designed in the authoring stage for wooden pole inspection and maintenance.

2.5.2 XR TRAINING IMPLEMENTATION DESCRIPTION

For the implementation of the XR training scenario, certain Motivate XR Tools were used for this Pilot:

1. KAYROX- authoring (on PCs)
2. KAYROX ARM player (on tablet and on XR headset)

Two (2) trainees used the KAYROX platform to design the XR training manual. It was necessary to engage with the platform for a certain amount of time to gain familiarity. Otherwise, its use was easy and manageable. Certainly, there are some features that could be added and improve the use of the platform (undo button, preview of the created experience, animation set up).

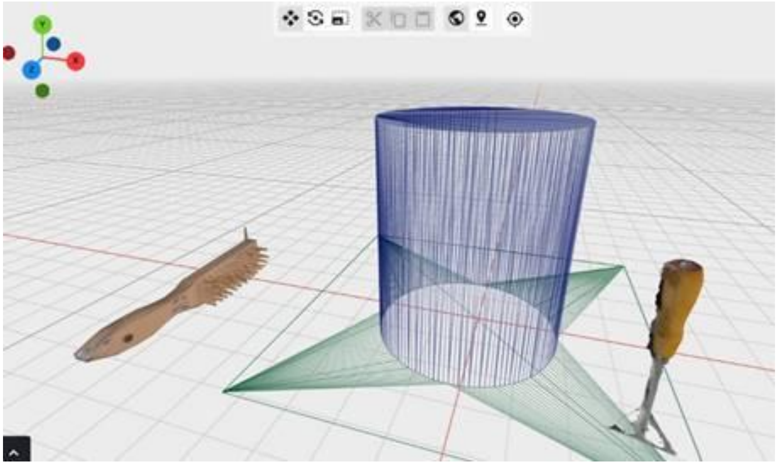

FIGURE 15 - CREATING THE AR TRAINING MANUAL FOR WOODEN POLE INSPECTION AND MAINTENANCE USING THE KAYROX PLATFORM ON PC (AUTHORING)

FIGURE 16 - EXECUTION OF THE TRAINING MANUAL USING AR HEADSET (EXPERIENCE)

In total sixteen (16) participants with an engineering background were trained in four (4) different sessions on the process followed for the inspection and maintenance of the wooden poles and tested the created XR training manual. All training sessions took place in HEDNO's premises. The trainees showed that they are more confident executing the process followed for the inspection and maintenance of wooden poles although they mentioned some minor challenges regarding the visibility using the XR headset and the interaction with real tools.

FIGURE 17 - TRAINING SESSION

FIGURE 18 - TESTING THE XR TRAINING SCENARIO ON WOODEN POLE INSPECTION AND MAINTENANCE

The evaluation was carried out using questionnaires and log analysis to ensure a comprehensive qualitative and quantitative assessment.

2.6 PILOT 5: HUMAN-ROBOT COLLABORATION

BI-REX serves as Pilot 5 within the MOTIVATE XR project and has undertaken significant efforts to support the validation of the platform by designing and implementing a use case of strong industrial relevance. This use case integrates XR technologies with the interaction of an anthropomorphic robot, with the overarching objective of developing an advanced collaborative assembly application.

2.6.1 TRAINING CONTEXT AND OBJECTIVES

The proposed scenario focuses on assisting an operator who may be inexperienced or performing the assembly of a medium-to-high complexity mechanical component for the first time. The solution to complete the assembly task successfully aims to provide comprehensive, step-by-step guidance and all necessary information to successfully complete the assembly task. In addition to these digital instructions, the operator benefits from the support of a robotic arm that delivers the required components during the process. This approach is intended to enhance operator confidence, streamline assembly operations, and, where feasible, enable certification of assembly procedures—ultimately reducing the likelihood of errors and improving overall process reliability.

For the Beta release, BI-REX developed a dedicated test bed featuring a gearbox manufactured through additive manufacturing at a full 1:1 scale. In collaboration with KAYROX, an interactive experience was created, incorporating animations and instructional videos that illustrate each assembly phase in a clear, sequential manner. To ensure a thorough evaluation, BI-REX engaged a diverse group of volunteers with varying levels of familiarity with the assembly task. This diversity allowed for the identification of strengths and weaknesses of the platform across different user profiles, sensitivities, and approaches.

The outcome of this initiative was a highly valuable experimental exercise that generated critical feedback for refining both the user experience and the underlying platform. These insights will inform future iterations, contributing to the development of a robust, user-centric solution that aligns with the goals of Industry 4.0 and 5.0 by combining immersive technologies with collaborative robotics.

2.6.2 XR TRAINING IMPLEMENTATION DESCRIPTION

Following the selection and production of the testbed for the beta-testing phase, the BI-REX team undertook a comprehensive preparation process aimed at ensuring the successful development of extended reality (XR) training materials. This process included the collection of all essential technical documentation—such as STEP-format 3D models, detailed instructional videos, and high-resolution images—and the organization of all supporting elements required for the authoring and deployment of the XR training scenario.

For the authoring phase, the team utilized **KAYROX Authoring** software on PC, which enabled the creation of an interactive and immersive XR experience tailored to the training objectives. In this beta-test configuration, interaction with the collaborative robot was achieved through direct physical contact. The robot, responsible for handing over assembly components one at a time, relied on its integrated sensors to detect touch and respond accordingly. Looking ahead, the final version of the system is expected to feature full synchronization between the robot and the XR environment, incorporating embedded commands within the XR application to enable seamless coordination.

Participants in the training sessions were equipped with XR headsets running the **KAYROX ARM Player**, providing them with an immersive and guided assembly experience. Over several weeks of testing, a total of **14 individuals** engaged with the application. Prior to commencing the assembly task, each participant completed a pre-survey and attended a concise introductory briefing designed to explain the interaction mechanics and familiarize them with the XR interface.

The practical exercise involved assembling a **gearbox** composed of multiple mechanical components, including shafts, bearings, gears, covers, seals, and screws. Importantly, participants had no prior knowledge of the object to be constructed and relied exclusively on the step-by-step instructions delivered through the XR system. This structured guidance enabled all testers to successfully complete the assembly task, demonstrating the effectiveness of the XR-based training approach.

The group of testers represented diverse professional backgrounds and levels of technical expertise. Despite these differences, all participants expressed a positive evaluation of the XR training tool, highlighting its utility and potential for improving industrial training processes. They also provided constructive feedback and suggestions for future enhancements. Throughout the sessions, the trainer collected qualitative observations regarding user interaction patterns and overall engagement with the application. Following the assembly activity, participants completed a post-survey to capture their impressions and recommendations.

The beta-test confirmed the feasibility and value of integrating XR technologies into industrial training workflows. The insights gathered during this phase will inform subsequent refinements, including the planned synchronization between robotic systems and XR environments, ultimately contributing to a more advanced and interactive training solution.

3 EVALUATION FRAMEWORK AND DATA COLLECTION METHODOLOGY

The evaluation of the Motivate XR beta phase relies on a structured, multi-layered framework designed to capture learning effectiveness, usability, user acceptance and operational impact in a comparable manner across all pilots. The framework builds directly on the methodological foundations established in D7.1 [1] and integrates both quantitative and qualitative instruments to ensure robustness and cross-pilot coherence.

The methodology combines pre- and post-training surveys, observational data collected through logbooks, system-generated analytics and standardised assessment tools such as TAM3, TRL, SUS and UEQ. This mixed-methods approach enables the consolidation of evidence from diverse industrial environments, while maintaining methodological consistency. Data collection activities were coordinated collaboratively among pilot owners, technology providers, and the WP7 leadership team, ensuring alignment with the evaluation windows foreseen in the beta schedule.

This section outlines the complete evaluation strategy, detailing how each instrument was deployed, how data were gathered across sites, and how the various components of the framework converge to support the cross-pilot analysis presented in Section 4.

3.1 OVERARCHING EVALUATION STRATEGY

The overarching evaluation strategy for the Motivate XR beta phase followed a pragmatic, evidence-driven approach focused on the beta window (M14–M18). The primary aim was to collect comparable, robust evidence across all five pilots to assess initial feasibility, usability, learning impact, and operational performance. This strategy was built directly on the methodological framework defined in D7.1 and was designed to support immediate iteration and refinement ahead of future development cycles.

A continuous feedback loop was embedded throughout the beta period, enabling pilot data to inform real-time adjustments to training scenarios and platform features. Emphasis was placed on cross-pilot harmonisation, all pilots applied the same core instruments and protocols, ensuring that the data collected would support a rigorous comparative analysis in this report.

3.2 DATA COLLECTION INSTRUMENTS

To ensure comprehensive and consistent data capture during the beta phase, the evaluation employed a suite of instruments, each tailored to address specific dimensions of the training experience.

3.2.1 EX-ANTE AND EX-POST QUESTIONNAIRES

The trainee perspective was captured through two comprehensive, standardized questionnaires administered at key points in the training cycle.

The **Ex-Ante Questionnaire** was distributed to participants before any interaction with the MOTIVATE XR system. Its purpose was to establish a baseline profile and set of expectations. It collected essential background information, including the participant's role, years of experience, and prior familiarity with XR technologies. Crucially, it contained a tailored pre-adoption Technology Acceptance Model 3 (TAM3) survey. This section measured initial expectations regarding the system's Perceived Usefulness (e.g., "I expect that using the system would improve my performance in my job"), Perceived Ease of Use, Computer Self-Efficacy, Computer Anxiety, and Behavioural Intention to use the technology, all based on a description or demonstration of the planned training.

The **Ex-Post Questionnaire** was administered immediately following the completion of the XR training modules. It was designed as a composite instrument to measure the immediate impact of the hands-on experience. It contained three core, validated tools:

- A full post-adoption TAM3 survey, which reassessed the acceptance constructs after actual use and added measurements for Perceived Enjoyment and Objective Usability.
- The System Usability Scale (SUS), a 10-item instrument where participants rate statements like "I thought the system was easy to use" on a 5-point scale, yielding a single, benchmarkable usability score from 0 to 100.
- The User Experience Questionnaire (UEQ), a 26-item tool where participants rate their experience on semantic differential scales between opposite adjectives (e.g., "annoying" to "enjoyable"), providing a detailed profile across six dimensions: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation, and Novelty.

3.2.2 OBSERVATION LOGBOOKS

To capture the training session from an external, facilitator-led perspective, structured Observation Logbooks were used. Instructors documented real-time events, trainee behaviours, and contextual factors that surveys, and system logs could not capture. The logbooks prompted notes on technical performance (e.g., device tracking issues, software stability), trainee engagement and visible signs of difficulty, adherence to the training protocol, and any spontaneous questions or comments from participants. This qualitative record provided essential narrative context for interpreting the quantitative data, highlighting practical implementation challenges and user interaction patterns.

3.2.3 SYSTEM LOGS AND ANALYTICS

Objective behavioural and performance data was automatically generated by the Motivate XR platform itself. Configured to a unified specification, the system logs recorded detailed, timestamped interaction telemetry during every training session. This included metrics such as task initiation and completion times, sequences of actions performed, errors or deviations from the correct procedure, usage of help features, and overall module completion status. These anonymized logs provided an unbiased dataset for analysing operational efficiency, error rates, and user proficiency, serving as a ground-truth complement to the subjective survey responses.

3.3 STANDARDIZED EVALUATION TOOLS

The Ex-Ante and Ex-Post questionnaires were built around established, academically validated tools to ensure the measurement of key constructs was robust, comparable, and benchmarkable.

3.3.1 TECHNOLOGY READINESS LEVEL (TRL) ASSESSMENT

To objectively assess the implementation maturity of the MOTIVATE XR ecosystem within each pilot, a standardized Technology Readiness Level (TRL) assessment was conducted. The TRL framework, originating from NASA [4] and widely adopted by the European Commission [5] and other international bodies, provides a common 9-level scale to track the progression of a technology from basic research (TRL 1) to successful operational deployment (TRL 9). For the beta phase, this assessment served as a critical baseline activity.

Each pilot team evaluated their specific deployment, spanning the authoring tools, experiencing applications, XR devices, and analytics modules, against a detailed checklist of criteria for each TRL level (1-9). Applying this framework provided a clear, quantitative snapshot of the technological starting point for each pilot, highlighting disparities in deployment readiness and creating a vital benchmark against which future progress in subsequent project phases can be definitively measured.

TABLE 1 – TECHNOLOGY READYNESS LEVELS

Technology Development Stage	TRL	Definition	Description	Checklist of activities to achieve this level
Fundamental Research	1	Basic principles observed and reported	Scientific research begins with properties of a potential technology observed in the physical world. These basic properties are being reported in the literature.	☐Basic research activities have been conducted and basic principles have been defined ☐Principles and findings have been published in the literature (e.g., research articles, peer-reviewed papers, white papers)
	2	Technology and/or application concept formulated	Applied research begins with the identification of practical applications of basic scientific principles. There is an emphasis on understanding the science better and corroborating the basic scientific observations made during TRL 1 work. Analysis of the feasibility of speculative applications is being conducted and reported in scientific studies.	☐Applications of basic principles have been identified ☐Applications and supporting analysis have been published in the literature (e.g., analytical studies, small code units for software, papers comparing technologies)
Research and Development	3	Experimental proof of concept	Active research and development begins. The applications are being moved beyond the paper stage to experimental work. The feasibility of separate technology components is being validated through analytical and laboratory studies. There is not yet an attempt to integrate components into a complete system.	☐Proof of concept and/or analytical and experimental critical function has been developed ☐Separate components have been validated in a laboratory environment
	4	Validation of component(s) in a laboratory environment	Basic technological components are integrated "ad-hoc" to establish that they will work together in a laboratory environment. The "ad- hoc" system would likely be a mix of on hand equipment and a few special-purpose components that may require special handling, calibration, or alignment in order to function.	☐"Ad-hoc" integrated components, sub systems and/or processes have been validated in a laboratory environment ☐How "ad-hoc" integration and test results differ from the expected system goals is understood
	5	Validation of semi-integrated component(s) in a simulated environment	The integrated basic technological components are performing for the intended applications in a simulated environment. Configurations are being developed but can undergo fundamental changes. The technology and environment at TRL 5 is more similar to the final application than TRL 4.	☐Semi-integrated component(s)/ subsystems or processes have been validated in a simulated environment ☐How the simulated environment differs from the expected operational environment and how the test results compare with expectations is understood
Pilot and Demonstration	6	System and/or process prototype demonstrated in a simulated environment	A model or prototype, that represents a near desired configuration, is being developed at a pilot scale, generally smaller than full scale. Testing of the model or prototype is being conducted in a simulated environment.	☐Pilot scale model or prototype developed ☐Pilot scale model or prototype system is near the desired configuration in performance, and volume but generally smaller than full scale ☐Pilot scale prototype or model system has been demonstrated in a simulated environment ☐How the simulated environment differs from the operational environment, and how results differed from expectations is understood

	7	Prototype system ready (form, fit and function) demonstrated in an appropriate operational environment	A full-scale prototype is being demonstrated in an operational environment but under limited conditions (i.e., field tests). At this stage, the final design is very close to completion.	☐ Full-scale prototype with ready form, fit and function developed ☐ Full-scale prototype demonstrated in an operational environment but under limited conditions
	8	Actual technology completed and qualified through tests and demonstrations	Technology is being proven to work in its final form and under expected conditions. This stage commonly represents the end of technology development. At this stage, operations are well understood, operational procedures are being developed, and final adjustments are being made.	☐Final configuration of the technology developed ☐Final configuration successfully tested in an operational environment ☐Technology's ability to meet its operational requirements has been assessed and problems documented; plans, options, or actions to resolve problems have been determined
Early Adoption	9	Actual technology proven through successful deployment in an operational environment	Actual application of the technology in its final form is being conducted under a full range of operational conditions. Sometimes referred to as "system operations", this stage is where technology is further refined and adopted.	☐The technology has been successfully deployed and proven under a full range of operational conditions ☐Operational, test and evaluation reports have been completed
Commercially Available	-	Technology development is complete	Technology is openly available in the marketplace and/or has been sold directly to a buyer in the public or private sector, in its current state or service offering for non-testing or development purposes. The technology is commercial and competitive but may need further integration efforts for widespread adoption.	☐The technology is openly available in the marketplace and/or has been sold in its current state of service offering for non-testing or development purposes.

3.3.2 TECHNOLOGY ACCEPTANCE MODEL 3 (TAM3) SURVEY

Understanding the human factors influencing adoption is as critical as measuring technical performance. To this end, the evaluation integrated the Technology Acceptance Model 3 (TAM3), a seminal and extensively validated academic framework in information systems research. TAM3 provides a nuanced model for diagnosing the determinants of technology acceptance, moving beyond simple satisfaction scores to explain why users intend to use a system [6].

The model captures a comprehensive set of cognitive, social, and control factors that influence two key perceptions: **Perceived Usefulness (PU)** and **Perceived Ease of Use (PEOU)**, which in turn drive Behavioral Intention to Use. Its constructs include foundational elements like **Computer Self-Efficacy** and **Computer Anxiety**, experiential factors like **Perceived Enjoyment**, and social influences like **Subjective Norm** and **Image**. By embedding tailored TAM3 surveys within both the Ex-Ante (to capture expectations) and Ex-Post (to capture experienced perceptions) questionnaires, the analysis can isolate the specific impact of hands-on XR training on these acceptance drivers. This provides deep, actionable insight into the likelihood of sustained adoption and identifies potential barriers unique to each industrial context and workforce profile.

TABLE 28 - TECHNOLOGY ACCEPTANCE MODEL 3 (TAM3) EX-ANTE SURVEY

TABLE 2 - TECHNOLOGY ACCEPTANCE MODEL 3 (TAM3)

Constructs		Items
Perceived Usefulness (PU)	PU1	I expect that using the system would improve my performance in my job.
	PU2	I believe that using the system in my job would increase my productivity.
	PU3	Using the system would enhance my effectiveness in my job.
	PU4	I think I would find the system to be useful in my job.
Perceived Ease of Use (PEOU)	PEOU1	I believe my interaction with the system would be clear and understandable.
	PEOU2	Interacting with the system would not require a lot of my mental effort.
	PEOU3	I expect I would find the system to be easy to use.
	PEOU4	I think it would be easy to get the system to do what I want it to do.
Computer Self-Efficacy (CSE)	- - - -	I am confident I could complete my job using this system...
	CSE1	...if there was no one around to tell me what to do as I go.
	CSE2	...if I had just the built-in help facility for assistance.
	CSE3	...once someone had shown me how to do it first.
	CSE4	...because I have used a similar system before to do the same job.
Perceptions of External Control (PEC)	PEC1	I expect I would have control over using the system.
	PEC2	I believe I will have the resources necessary to use the system.
	PEC3	I think that, given the necessary resources and knowledge, it would be easy for me to use the system.
	PEC4	I am concerned the system might not be compatible with other systems I use.
Computer Playfulness (CPLAY)	- - - -	The following questions ask you how you would characterize yourself when you use computers *or similar technologies*:
	CPLAY1	... spontaneous
	CPLAY2	... creative
	CPLAY3	... playful
	CPLAY4	... unoriginal
Computer Anxiety (CANX)	CANX1	Computers *or similar technologies* do not scare me at all.
	CANX2	Working with a computer makes me nervous.
	CANX3	Computers make me feel uncomfortable.
	CANX4	Computers make me feel uneasy.
Perceived Enjoyment (ENJ)	ENJ1	I think I would find using the system to be enjoyable.
	ENJ2	I expect the actual process of using the system would be pleasant.
	ENJ3	I imagine I would have fun using the system.
Objective Usability (OU)	----	Not applicable in the Ex-Ante Survey
Subjective Norm (SN)	SN1	I believe people who influence my behaviour will think that I should use the system.
	SN2	People who are important to me will likely think that I should use the system.
	SN3	I expect the senior management of this business will be helpful in the use of the system.
	SN4	I believe the organization will support the use of the system.
Voluntariness (VOL)	VOL1	I expect my use of the system will be voluntary.
	VOL2	My supervisor will not require me to use the system.
	VOL3	Although it might be helpful, using the system will not be compulsory in my job.
Image (IMG)	IMG1	I believe people in my organization who use the system will have more prestige than those who do not.
	IMG2	People who use the system will likely have a high profile.
	IMG3	I think having the system will be a status symbol in my organization.
Job Relevance (REL)	REL1	In my job, I believe usage of the system will be important.
	REL2	In my job, usage of the system seems relevant.
	REL3	The use of the system appears to be pertinent to my various job-related tasks.
Output Quality (OUT)	OUT1	I expect the quality of the output I get from the system to be high.
	OUT2	I don't anticipate problems with the quality of the system's output.
	OUT3	I believe I will rate the results from the system as excellent.

Result Demonstrability (RES)	RES1 RES2 RES3 RES4	I don't think I will have difficulty telling others about the results of using the system. I believe I will be able to communicate to others the benefits of using the system. The positive results of using the system will be apparent to me. I might have difficulty explaining why using the system may or may not be beneficial.
Behavioural Intention (BI)	BI1 BI2 BI3	Assuming I had access to the system, I intend to use it. Given that I had access to the system, I predict that I would use it. I plan to use the system in the next <n> months
Use (USE)	~~~~	Not applicable in the Ex-Ante Survey

3.3.3 SYSTEM USABILITY SCALE (SUS)

For a rapid, reliable, and industry-standard measure of perceived usability, the System Usability Scale (SUS) was employed. Developed by John Brooke in 1986 [7][8], the SUS has become one of the most widely used and referenced usability tools due to its simplicity, robustness, and strong psychometric properties. Its ten items, answered on a 5-point Likert scale, are designed to be technology-agnostic, making it perfectly suited for evaluating novel XR systems.

The SUS yields a single score on a 0-100 scale. Its great strength lies in its extensive normative database; thousands of SUS scores for various products and systems have been published, allowing the Motivate XR platform's score to be instantly benchmarked and categorized (e.g., as "excellent," "good," "marginal," or "poor" compared to industry averages). This provides the consortium with a clear, comparable, and universally understood KPI for the fundamental usability of the beta platform across all five diverse pilot environments.

1. I think that I would like to use this system frequently.

1. Strongly Disagree	2.	3.	4.	5. Strongly Agree
○	○	○	○	○

2. I found the system unnecessarily complex.

1. Strongly Disagree	2.	3.	4.	5. Strongly Agree
○	○	○	○	○

3. I thought the system was easy to use.

1. Strongly Disagree	2.	3.	4.	5. Strongly Agree
○	○	○	○	○

4. I think that I would need the support of a technical person to be able to use this system.

1. Strongly Disagree	2.	3.	4.	5. Strongly Agree
○	○	○	○	○

5. I found the various functions in this system were well integrated.

1. Strongly Disagree	2.	3.	4.	5. Strongly Agree
○	○	○	○	○

6. I thought there was too much inconsistency in this system.

1. Strongly Disagree	2.	3.	4.	5. Strongly Agree
○	○	○	○	○

7. I would imagine that most people would learn to use this system very quickly.

1. Strongly Disagree	2.	3.	4.	5. Strongly Agree
○	○	○	○	○

8. I found the system very cumbersome to use.

1. Strongly Disagree	2.	3.	4.	5. Strongly Agree
○	○	○	○	○

9. I felt very confident using the system.

1. Strongly Disagree	2.	3.	4.	5. Strongly Agree
○	○	○	○	○

10. I needed to learn a lot of things before I could get going with this system.

1. Strongly Disagree	2.	3.	4.	5. Strongly Agree
○	○	○	○	○

FIGURE 19 - SYSTEM USABILITY SCALE (SUS)

3.3.4 USER EXPERIENCE QUESTIONNAIRE (UEQ)

To complement the high-level usability score from the SUS with a rich, granular profile of the user experience, the User Experience Questionnaire (UEQ) was deployed. The UEQ is a carefully validated tool designed to efficiently capture the holistic impression of an interactive product. It goes beyond pure usability to measure both the pragmatic (task-oriented) and hedonic (human-oriented) qualities of an experience [9].

Participants rate 26 items on a 7-point semantic differential scale between contrasting adjective pairs (e.g., "annoying/enjoyable," "creative/dull," "easy/complicated"). The analysis distils these ratings into six well-defined scales: **Attractiveness**, **Perspicuity** (ease of getting familiar with the system), **Efficiency**, **Dependability**, **Stimulation**, and **Novelty**. The results can be visually plotted against a large benchmark dataset containing scores from hundreds of software products, web applications, and other interactive systems. This allows for an immediate visual diagnosis of the Motivate XR experience's relative strengths (e.g., high Novelty) and weaknesses (e.g., lower-than-average Efficiency), providing direct, actionable guidance for the user-cantered refinement of the XR interface and interaction design.

TABLE 3 - USER EXPERIENCE QUESTIONNAIRE (UEQ)

		1 - 2 - 3 - 4 - 5 - 6 - 7	
1	annoying	○ ○ ○ ○ ○ ○ ○	enjoyable
2	not understandable	○ ○ ○ ○ ○ ○ ○	understandable
3	creative	○ ○ ○ ○ ○ ○ ○	dull
4	easy to learn	○ ○ ○ ○ ○ ○ ○	difficult to learn
5	valuable	○ ○ ○ ○ ○ ○ ○	inferior
6	boring	○ ○ ○ ○ ○ ○ ○	exciting
7	not interesting	○ ○ ○ ○ ○ ○ ○	interesting
8	unpredictable	○ ○ ○ ○ ○ ○ ○	predictable
9	fast	○ ○ ○ ○ ○ ○ ○	slow
10	inventive	○ ○ ○ ○ ○ ○ ○	conventional
11	obstructive	○ ○ ○ ○ ○ ○ ○	supportive
12	good	○ ○ ○ ○ ○ ○ ○	bad
13	complicated	○ ○ ○ ○ ○ ○ ○	easy
14	unlikable	○ ○ ○ ○ ○ ○ ○	pleasing
15	usual	○ ○ ○ ○ ○ ○ ○	leading edge
16	unpleasant	○ ○ ○ ○ ○ ○ ○	pleasant
17	secure	○ ○ ○ ○ ○ ○ ○	not secure
18	motivating	○ ○ ○ ○ ○ ○ ○	demotivating
19	meets expectations	○ ○ ○ ○ ○ ○ ○	does not meet expectations
20	inefficient	○ ○ ○ ○ ○ ○ ○	efficient
21	clear	○ ○ ○ ○ ○ ○ ○	confusing
22	impractical	○ ○ ○ ○ ○ ○ ○	practical
23	organized	○ ○ ○ ○ ○ ○ ○	cluttered
24	attractive	○ ○ ○ ○ ○ ○ ○	unattractive
25	friendly	○ ○ ○ ○ ○ ○ ○	unfriendly
26	conservative	○ ○ ○ ○ ○ ○ ○	innovative

4 CROSS-PILOT RESULTS AND ANALYSIS

This section presents the consolidated findings from the evaluation of the Motivate XR beta phase across all five industrial pilots. It synthesizes quantitative data and qualitative insights collected through the standardized framework described in Section 3, transforming raw evidence into a coherent, comparative analysis of platform performance, user acceptance, and operational impact.

The findings presented here form the empirical foundation for the conclusions, recommendations, and action plan detailed in the subsequent chapters of this report.

4.1 TECHNOLOGY READINESS LEVEL (TRL) BASELINE ASSESSMENT

This section presents the baseline TRL assessment conducted across all MOTIVATE XR pilots during the Beta phase. The TRL framework provides a structured methodology to evaluate the maturity of each pilot's technological components—namely the authoring tools, experiencing platforms, device integration, and analytics capabilities. The assessments were performed collaboratively between Pilot Owners (who deploy the technology in operational contexts) and Technology Providers (who developed the underlying systems). This dual-perspective approach ensures that the TRL scores reflect not only the intrinsic technical maturity but also the practical readiness and adaptability of the technology within each pilot's specific use case. The resulting baseline establishes a clear benchmark for tracking technological progression, identifying areas requiring refinement, and informing the iterative development cycles outlined in the Motivate XR Evaluation and Iteration Plan.

4.1.1 COMPARATIVE TRL SCORES ACROSS PILOTS

The TRL assessments yielded the following readiness levels for each pilot, as summarised in following table. These scores represent the consolidated view of technological maturity at the beginning of the Beta phase, prior to the commencement of the structured training and evaluation activities.

Table 4 - TECHNOLOGY READYNESS LEVELS PER PILOT

Pilot	TRL	Technology Development Stage	Description of TRL Level
1	6	Pilot and Demonstration	System/process prototype demonstrated in a simulated environment.
2	7	Early Adoption	Prototype system ready (form, fit, function) demonstrated in an operational environment under limited conditions.

3	6	Pilot and Demonstration	System/process prototype demonstrated in a simulated environment.
4	7	Early Adoption	Prototype system ready (form, fit, function) demonstrated in an operational environment under limited conditions.
5	6	Pilot and Demonstration	System/process prototype demonstrated in a simulated environment.

4.1.2 ANALYSIS OF IMPLEMENTATION MATURITY AND DISCREPANCIES

The observed TRL ratings show a moderate variation across the pilots, with two pilots assessed at TRL 7 and three at TRL 6. This one-level difference does not represent a significant disparity in overall readiness but rather reflects contextual factors in each pilot's implementation pathway, such as the availability of real-world testing environments, the complexity of integration, and the timing of the assessment. The collaborative evaluation process, involving both pilot owners and technology providers, intentionally captures a holistic and context-aware perspective, which can introduce qualitative nuance into the TRL scoring. Importantly, all pilots reside within the Pilot and Demonstration to Early Adoption stages (TRL 6–7), confirming that the XR training technologies under evaluation are at a comparable and sufficiently mature level for the specific applications being tested in the Beta phase. This common maturity baseline ensures that the subsequent analysis of learning effectiveness, usability, and operational impact rests on a stable and equivalent technological foundation across all pilots.

4.2 TECHNOLOGY ACCEPTANCE AND ADOPTION DETERMINANTS

This section analyses the determinants of technology acceptance across the five industrial pilots, based on the TAM3 survey instruments embedded within the Ex-Ante and Ex-Post questionnaires. The analysis focuses on measurable shifts in key constructs as Computer Anxiety, Behavioural Intention, and Expected Usage, before and after hands-on experience with the Motivate XR system. Sample sizes varied across industries, with the number of respondents ranging from 8 to 25 at Ex-Ante and from 8 to 18 at Ex-Post: The Home Appliance pilot contributed the largest group, while Aerospace was the smallest. Despite these variations, the data provide a robust comparative view of acceptance dynamics across distinct operational contexts.

TABLE 5 - TECHNOLOGY ACCEPTANCE RESULTS

Industry	n_pre	n_post	Anxiety_pre	Anxiety_post	Intention_pre	Intention_post	Hours/day_pre	Hours/day_post	Days/month_pre	Days/month_post	SUS_post
Aero-space Industry	8	8	2.09	2.22	4.69	4.75	0.59	1.31	4.25	2.12	55.00
Aluminium Industry	11	10	1.70	2.02	4.95	5.75	1.16	1.02	7.82	4.75	68.00
Energy Distribution Industry	18	18	1.85	1.86	5.11	5.03	1.14	0.75	3.08	2.11	69.17
Home Appliance Industry	25	18	1.78	1.67	4.28	3.31	0.44	0.32	1.98	1.50	44.58
Human Robot Hybrid Manu-facturing	17	15	1.88	1.97	4.50	4.23	0.40	0.43	1.82	1.77	68.83

4.2.1 TAM3 EX-ANTE VS. EX-POST COMPARISON

The analysis focused on the construct of Computer Anxiety as a consistent baseline indicator of participants' general attitudes towards technology. This provided a clear test of whether the MOTIVATE XR training influenced this foundational aspect of acceptance. The additional focus on Behavioural Intention, Expected Usage, and ex-post usability (measured via the System Usability Scale) complements this by capturing how willingness to use the system and perceived usability evolve, while Computer Anxiety serves as a stable background construct.

Across all industries and both measurement points, Computer Anxiety was generally low. Ex-Ante mean scores ranged from 1.70 to 2.09 on a 1 to 7 scale, and Ex-Post scores ranged from 1.67 to 2.22, indicating a consistently low level of discomfort with computers and similar technologies. At the industry level, anxiety increased slightly in the Aerospace Industry (from 2.09 to 2.22) and somewhat more in the Aluminium Industry (from 1.70 to 2.02), although even these higher values remained at the low end of the scale. In the Energy Distribution Industry, anxiety was essentially stable over time (1.85 to 1.86), while in the Home Appliance Industry, it decreased marginally (from 1.78 to 1.67). In Human Robot Hybrid Manufacturing, anxiety showed a small increase (from 1.88 to 1.97). Overall, these minor fluctuations suggest that the MOTIVATE XR training did not meaningfully change general anxiety toward computers or similar technologies in any industry; participants were already relatively comfortable with technology before the intervention and remained so afterwards.

TABLE 6 - ANXIETY SCALE RESULTS PER INDUSTRY

Industry	Anxiety (Ex-Ante)	Anxiety (Ex-Post)	Δ Anxiety (Post – Pre)

Aerospace Industry	2.09	2.22	+0.12
Home Appliance Industry	1.78	1.67	-0.11
Aluminium Industry	1.70	2.02	+0.32
Energy Distribution Industry	1.85	1.86	+0.01
Human Robot Hybrid Manufacturing	1.88	1.97	+0.08

[Scale: 1–7 (higher = more anxiety). The item "Computers or similar technologies do not scare me at all" was reverse-coded.]

4.2.2 KEY DRIVERS OF ACCEPTANCE (PU, PEOU, ENJOYMENT)

The survey results indicate that differences in adoption between industries must be explained by other constructs, such as **Perceived Usefulness**, **Perceived Ease of Use**, output quality, and social influence, and by usability (as captured by the System Usability Scale), rather than by general anxiety. The strong correlation between SUS scores and changes in **Behavioural Intention** underscores that Perceived Ease of Use is a critical driver. Furthermore, qualitative feedback from logbooks consistently highlighted Perceived Usefulness, such as the value for spatial understanding and autonomous practice, and **Perceived Enjoyment**, with sessions described as "fun" and "exciting." These elements likely bolstered intention where usability was adequate and sustained engagement even where interaction was challenging.

4.2.3 CROSS-PILOT ANALYSIS OF BEHAVIOURAL INTENTION

In contrast to Computer Anxiety, **Behavioural Intention** to use the Motivate XR system showed more pronounced, industry-specific changes over time. In the Aerospace Industry, intention scores were slightly higher after the training (from 4.69 to 4.75), with both values clearly above the midpoint of the scale, indicating a generally positive and stable, if only slightly strengthened, willingness to use the system. In the Aluminium Industry, Behavioural Intention increased clearly from 4.95 to 5.75, suggesting that hands-on experience with the system substantially reinforced participants' intention to use it in the future. In the Energy Distribution Industry, intention remained very high and essentially stable (5.11 to 5.03), pointing to consistently strong acceptance of the system with only a negligible decrease over time. By contrast, in the Home Appliance Industry, intention decreased markedly from 4.28 to 3.31; whereas respondents were initially slightly positive, their intentions moved closer to neutral after training, indicating a reduced willingness to use the system. In Human Robot Hybrid Manufacturing, intention decreased moderately from 4.50 to 4.23, remaining overall positive but reflecting a certain tempering of the initial optimism following hands-on experience.

TABLE 7 - INTENTION TO USE PER INDUSTRY

Industry	Intention (Ex-Ante)	Intention (Ex-Post)	Δ Intention (Post – Pre)
Aerospace Industry	4.69	4.75	+0.06
Home Appliance Industry	4.28	3.31	-0.97
Aluminium Industry	4.95	5.75	+0.80
Energy Distribution Industry	5.11	5.03	-0.08
Human Robot Hybrid Manufacturing	4.50	4.23	-0.27

[Scale: 1–7 (higher = stronger intention to use)]

Concerning expected hours of XR use per day, average values were relatively modest across all industries (well below two hours per day at both time points), but again, the direction and magnitude of change varied by context. In the Aerospace Industry, expected daily usage more than doubled from 0.59 to 1.31 hours, indicating that participants anticipated fewer but more intensive XR sessions after having experienced the system. In the Aluminium Industry, expected hours per day decreased slightly from 1.16 to 1.02, suggesting that, despite the strong increase in Behavioural Intention, users did not expect to spend more time per day with the system. In the Energy Distribution Industry, expected daily usage decreased from 1.14 to 0.75 hours, implying that participants still intended to use XR, but envisioned shorter sessions than initially assumed. In the Home Appliance Industry, expected hours per day decreased modestly from 0.44 to 0.32, a pattern that is consistent with the observed decline in Behavioural Intention. Finally, in Human Robot Hybrid Manufacturing, expected hours per day remained virtually stable (0.40 to 0.43), indicating that XR occupies a consistently small but steady proportion of daily work time in this context.

A similar picture emerges when looking at expected days of use per month: all industries revised their expectations downward after the training. In the Aerospace Industry, expected days of use decreased from 4.25 to 2.12 days per month, while in the Aluminium Industry they dropped from 7.82 to 4.75 days, representing one of the strongest downward adjustments. In the Energy Distribution Industry, expectations fell from 3.08 to 2.11 days per month, and in the Home Appliance Industry from 1.98 to 1.50 days per month. In Human Robot Hybrid Manufacturing, expected days of use remained almost unchanged, decreasing only slightly from 1.82 to 1.77 days. Overall, after actual exposure to the Motivate XR system, participants in most industries expected to use it less frequently than originally anticipated, with the most pronounced revisions occurring in the Aluminium and Aerospace industries.

TABLE 8 - EXPECTED DAILY USAGE PER INDUSTRY

Industry	Hours/Day (Ex-Ante)	Hours/Day (Ex-Post)	Days/Month (Ex-Ante)	Days/Month (Ex-Post)	Δ Hours/Day	Δ Days/Month
Aerospace Industry	0.59	1.31	4.25	2.12	+0.72	-2.12
Home Appliance Industry	0.44	0.32	1.98	1.50	-0.12	-0.48
Aluminium Industry	1.16	1.02	8.09	4.75	-0.13	-3.34
Energy Distribution Industry	1.14	0.75	3.08	2.11	-0.39	-0.97
Human Robot Hybrid Manufacturing	0.40	0.43	1.82	1.77	+0.04	-0.06

[Expected daily usage was converted to approximate hours; expected monthly usage to approximate days.]

4.3 USABILITY AND USER EXPERIENCE

This section presents the evaluation of the platform's usability and the overall user experience during the beta phase. The analysis integrates the quantitative results from the **System Usability Scale (SUS)** with qualitative insights from the **User Experience Questionnaire (UEQ)** framework and detailed facilitator observations. Together, these data paint a comprehensive picture of how intuitive, efficient, and engaging the Motivate XR system was for trainees across the five industrial pilots, revealing both strengths in design appeal and critical challenges in interaction and comfort.

4.3.1 SYSTEM USABILITY SCALE (SUS) BENCHMARKING

The Ex-Post **System Usability Scale (SUS) scores** reveal substantial differences in perceived usability of the MOTIVATE XR pilot system across industries. The Energy Distribution Industry (69.17), Human Robot Hybrid Manufacturing (68.83), and the Aluminium Industry (68.00) all reached values around or slightly above the conventional SUS benchmark of 68, which is typically interpreted as reflecting "good" or "acceptable" usability. In contrast, the Aerospace Industry reported a SUS score of 55.00, clearly below this benchmark and indicative of notable usability issues. The lowest perceived usability was found in the Home Appliance Industry, with a SUS score of 44.58, suggesting poor usability and a likely mismatch between the system and the work context in this sector. These usability ratings provide important context for understanding the observed changes in Behavioural Intention and Expected Usage, as lower SUS scores tend to coincide with reduced willingness to use the system and downward adjustments in expected use.

TABLE 9 - SYSTEM USABILITY SCALE (SUS) SCORES

Industry	SUS (Ex-Post)
Aerospace Industry	55.00
Home Appliance Industry	44.58
Aluminium Industry	68.00
Energy Distribution Industry	69.17
Human Robot Hybrid Manufacturing	68.83

4.3.2 USER EXPERIENCE QUESTIONNAIRE (UEQ) RESULTS

While explicit **User Experience Questionnaire (UEQ) scale** scores are not provided in the consolidated dataset, the qualitative feedback from observation logbooks richly illustrates the pragmatic and hedonic dimensions of the user experience that the UEQ is designed to measure.

Pragmatic Quality (e.g., Perspicuity, Efficiency, Dependability) was frequently challenged. Users across multiple pilots reported that interactions were "not intuitive," virtual buttons were difficult to manipulate, and system stability was unreliable, evidenced by logs noting "system crashed," "FPS dropped," and "overheated." These pain points directly correlate with the lower SUS scores in Aerospace and Home Appliance and explain why Perceived Ease of Use emerged as a barrier to acceptance.

Hedonic Quality (e.g., Stimulation, Novelty) emerged as a consistent strength. Trainees described sessions as "fun," "enjoyable," and "exciting," with some noting they lost track of time, a strong indicator of engagement. Positive remarks about "good rendering," "animation quality," and the value of 3D visualization over traditional videos highlight the innovative appeal and motivational pull of the XR medium, even in pilots where usability was suboptimal.

4.3.3 SYNTHESIS OF QUALITATIVE FEEDBACK

The qualitative data from facilitator **observation logbooks** reveals a consistent, dual narrative across the beta phase, which aligns with and explains the quantitative survey results.

- **Validated Pedagogical Value and Engagement**: Trainees widely acknowledged the unique strengths of XR for spatial learning, procedural rehearsal, and engagement. Positive feedback highlighted the ability to "walk around the hologram," gain confidence through autonomous practice, and experience training as more immersive and effective than conventional methods. This correlates with the high Perceived Usefulness inferred from the survey.
- **Critical Friction Points in Interaction and Ergonomics**: Recurring and high-severity issues dominated trainee experiences and directly explain the low SUS scores in certain pilots:

1. Non-intuitive Interaction: Difficulty with virtual controls, menu navigation, and object manipulation.
2. Hardware and Physical Discomfort: Pervasive reports of dizziness, eye strain, device overheating, and poor visual clarity in see-through AR modes, particularly detrimental in pilots like Electricity Distribution where referencing physical documents was essential.
3. Software Instability: Crashes, frame rate drops, and overheating-induced interruptions undermined session flow and professional trust.
4. Missing Authoring Features: In the Aerospace authoring pilot, absent standard tools (undo, copy, preview) increased complexity and slowed content creation.

This synthesis confirms that while the core value proposition of XR training is strongly affirmed, the user journey remains obstructed by fundamental usability, comfort, and stability barriers. These experiential deficits must be addressed to unlock consistent adoption across industrial contexts.

4.4 OPERATIONAL IMPACT AND ENGAGEMENT

Building on the acceptance and usability findings, this section examines the tangible operational outcomes and user engagement levels observed during the beta training sessions. It synthesizes evidence from system logs and facilitator observations regarding task completion, error patterns, and module engagement. The analysis aims to assess the immediate effectiveness of the XR training in supporting procedural learning and to understand the relationship between the experiential quality of the sessions and users' intentions for sustained use.

4.4.1 TASK COMPLETION AND ERROR ANALYSIS

The analysis offers detailed behavioural and observational insights into operational performance. **Task Completion** was successfully achieved in many sessions, with trainees often completing assemblies autonomously, for example, in Pilot 5 (HRC), where users assembled a component "without ever having seen it before." However, completion was frequently mediated by facilitator support, system restarts, or workarounds due to interaction difficulties, unclear instructions, or technical instability.

Error Patterns identified in the logs include:

- Interaction Errors: Accidental skipping of steps, difficulty "grabbing" virtual objects, and unintended menu selections due to non-intuitive controls.
- Instructional Ambiguity: In some cases, instructions lacked specific details (e.g., "mandatory direction" or "force to apply"), leading to hesitancy or incorrect execution.

System-Induced Disruptions: Software crashes, freezes, or overheating warnings necessitated task restarts, directly impacting completion efficiency and trainee momentum.

4.4.2 USER ENGAGEMENT AND MODULE COMPLETION RATES

Engagement was notably high from a motivational and affective standpoint. Logbook entries consistently described sessions as "fun" and "engaging," with some users noting that "time passed without realising it." This suggests strong hedonic engagement, which can positively influence learning persistence and attitude toward the technology.

Module Completion Rates are not explicitly quantified in the dataset, but qualitative notes indicate that most scheduled training modules were completed within sessions, albeit often with interruptions or adaptations. However, the post-experience expectations for future use (Table 4) decreased across almost all pilots, particularly in terms of expected days of use per month. This indicates that while engagement during sessions was generally positive, the perceived feasibility of sustained operational integration is currently limited by the experienced friction points in usability, comfort, and system reliability.

4.5 SYNTHESIS OF CROSS-PILOT STRENGTHS AND WEAKNESSES

The consolidated results from the five industrial pilots present a coherent picture of the Motivate XR platform's performance during the beta phase. The evidence points to consistent **strengths** that affirm the project's core value, alongside a clear pattern of **challenges** that currently impact adoption potential.

A primary strength lies in the **validated pedagogical value** and **high user engagement**. Trainees across sectors reported that the XR training enhanced spatial understanding, procedural accuracy, and confidence. The system's ability to make complex tasks more intuitive was frequently highlighted, with users describing sessions as engaging and immersive. This strong resonance with **Perceived Usefulness** and **Perceived Enjoyment** provides a solid foundation for acceptance, particularly evident in the Aluminium and Energy Distribution pilots where Behavioural Intention remained strong or increased after training. Furthermore, the TRL assessment confirms a robust technological base, with all pilots operating at TRL 6 or 7, demonstrating a functional ecosystem ready for further development.

However, these strengths are balanced by challenges that emerged across contexts. A key area for improvement is **usability**, which presents a potential gatekeeper for adoption. While three pilots reported acceptable **SUS scores**, two pilots scored notably lower, linked to interaction complexity and a steeper learning curve. In these contexts, usability challenges tempered the system's perceived usefulness.

Related **hardware and ergonomic factors** were also reported. Observations noted instances of physical discomfort, such as dizziness and eye strain, and device overheating in certain conditions. These factors can influence session duration and user comfort, particularly in applications requiring extended use or clear see-through functionality.

Software stability and **feature completeness** were also identified as areas needing attention. Occasional system interruptions and the absence of some expected authoring tools, like undo and copy functions, impacted the user experience. Finally, a common trend was a downward adjustment in expected usage frequency after hands-on experience, suggesting users recalibrated their expectations toward more realistic integration into daily workflows.

This synthesis confirms that the beta phase successfully validated the core concept of XR for industrial training. The immediate priority is to enhance the **user experience** by addressing the identified points of friction in **usability**, **hardware comfort**, and s**oftware robustness**.

4.6 CROSS-PILOT GOOD PRACTICES AND COMMON PATTERNS

The findings from the cross-pilot evaluation carry direct implications for the **iterative refinement** of the Motivate XR platform and for planning the final validation phase. The evidence suggests that improvements should address the integrated user experience across hardware, interaction design, and content clarity.

In line with the Mid-term focus outlined in D7.1, the immediate priority is to address the refinement backlog based on the beta evidence. Key actions should focus on enhancing Perceived Ease of Use through interface refinements, mitigating ergonomic concerns, and ensuring greater software stability. The addition of core authoring features will also support content creator efficiency.

The variation in **TAM3** and **SUS** outcomes across pilots indicates a need for contextual adaptation. Pilots with higher acceptance can inform implementation guidelines, while specific challenges in other sectors may require tailored adjustments to scenarios and interactions.

For the Final Phase, the evaluation strategy should evolve from the pragmatic evidence collection of the beta window to the **KPI-level validation** defined in D7.1. Preparation should include establishing automated assessment checkpoints, longitudinal measures of learning retention, and rigorous tracking of operational impact against project KPIs.

The beta-phase instruments (TRL, TAM3, SUS, and UEQ) will remain foundational and should be supplemented with deeper analytics to capture the impact of the refined platform. In summary, the beta phase has provided a robust diagnostic of the platform's current state. The focus for the mid-term period is on targeted improvements to ensure the platform is prepared for the summative KPI validation of the final phase.

5 CONCLUSIONS, DISCUSSION & ITERATION PLAN

This section synthesises the evidence gathered during this beta phase, interprets the key findings, acknowledges the evaluation's limitations, and translates these insights into actionable recommendations and a concrete plan for the mid-term iteration cycle.

5.1 INTERPRETATION OF KEY FINDINGS

The cross-pilot analysis reveals that **the Motivate XR platform successfully validates its core pedagogical value proposition**. Users across diverse industrial contexts recognised its effectiveness for spatial learning, procedural training, and engagement, as reflected in strong **Perceived Usefulness** and **Perceived Enjoyment**. This is a foundational success for the project.

However, the primary factor influencing the Behavioural Intention to adopt the technology was Perceived Ease of Use, closely linked to System Usability Scale (SUS) scores. Pilots with acceptable usability (Aluminium, Energy Distribution, Human-Robot Collaboration) maintained or increased their intention to use the system. In contrast, pilots where users faced significant interaction complexity (Home Appliance, Aerospace) saw intention drop or expectations shift toward more limited, intensive use cases. This pattern confirms that **usability is the critical mediator between the platform's proven value and its operational adoption**.

Furthermore, the evaluation highlights that technological maturity (TRL 6-7) does not guarantee a seamless user experience. While the system is functionally demonstrable, recurring reports of hardware discomfort (e.g., eye strain, overheating) and software instability point to significant friction in the integrated hardware-software-user loop. These ergonomic and reliability issues directly challenge the feasibility of prolonged use and professional integration.

Finally, the universal downward revision of **expected usage frequency** after hands-on experience indicates that initial expectations were optimistic. This recalibration toward more realistic integration scenarios is a valuable outcome, setting a pragmatic baseline for planning the platform's role in organisational training ecosystems.

5.2 LIMITATIONS OF THE BETA EVALUATION

The findings of this report are constrained by the scope and context of the beta-phase implementation. The evaluation window was limited to a short-term, first-use experience, capturing immediate reactions and initial performance but not **long-term learning retention** or sustained adoption patterns. The sample sizes, while sufficient for identifying clear trends, varied across pilots and were not statistically powered for definitive subgroup analyses.

Data collection relied partially on **self-reported measures** (e.g., TAM3, SUS) and facilitator observations, which are subject to perceptual bias. While supplemented by system logs, the analysis lacked granular, automated analytics on specific error types and cognitive load, which will be crucial for deeper diagnostic iteration.

Furthermore, the evaluation focused on assessing the platform's performance within pre-defined training scenarios. It did not measure the broader **operational impact** on organisational workflow efficiency, training cost reduction, or safety compliance at scale, objectives reserved for the final validation phase.

5.3 RECOMMENDATIONS FOR IMPROVEMENT

Based on the synthesis of strengths and weaknesses, the following recommendations are prioritised for the mid-term iteration cycle:

- **Prioritise Usability and Interaction Design**: Redirect development focus to substantially improve Perceived Ease of Use. This includes simplifying control schemes, standardising interaction patterns, and implementing an in-XR guidance system to reduce the initial learning curve. The interface should be iteratively tested against the System Usability Scale (SUS) benchmark.
- **Address Hardware and Ergonomic Friction**: Collaborate with device providers to establish and disseminate best practices for mitigating physical discomfort. This includes optimising device settings for see-through clarity, defining recommended session durations, and exploring accessory solutions to improve fit and thermal management for prolonged use.
- **Stabilise the Software Core and Complete Authoring Features**: Resolve the identified issues of system crashes and performance instability as a non-negotiable prerequisite for professional use. Concurrently, implement the missing core authoring features (e.g., undo, copy, preview) to empower content creators and improve the efficiency of curriculum development.
- **Develop Contextual Implementation Guides**: Create pilot-specific deployment guidelines that account for the varying acceptance drivers and workflow constraints observed. Successful pilots (Aluminium, Energy) should be documented as reference cases, while guidance for challenged pilots should include tailored scenario adjustments and support protocols.

5.4 ACTION PLAN FOR THE MID-TERM PHASE

Aligned with the Mid-term focus outlined in D7.1, the following action plan is proposed to operationalise the recommendations:

- **Activity**: Conduct focused iteration workshops (WP7 + WP leads + pilot owners) to review the cross-pilot findings, perform root-cause analysis on top usability issues, and prioritise the refinement backlog.
- **Outputs**: A prioritised refinement backlog with assigned owners and timelines for (1) UI/UX improvements, (2) stability fixes, and (3) authoring tool enhancements.
- **Timeline**: Workshops to be completed by M20. First iteration sprints on high-priority items to commence immediately and deliver testable updates by M25.

- **Success Criteria**: Measurable improvement in SUS scores and reduction in critical incident reports (crashes, overheating) in follow-up technical tests with pilot teams before the end of M31.

This plan ensures the consortium moves decisively from diagnostic evaluation to targeted enhancement, preparing a more robust and user-ready platform for the final validation phase.

6 NEXT STEPS AND FUTURE RESEARCH

This final section outlines the preparatory steps for the conclusive project phase and identifies key research avenues informed by the beta evaluation.

6.1 PREPARATION FOR FINAL PHASE VALIDATION

The immediate next step is to transition from the iterative, fix-focused mid-term period to the rigorous, **KPI-driven final validation phase** (M32–M35). Preparation must begin by updating the evaluation protocols from D7.1 to reflect the lessons learned in the beta.

This involves defining clear, automated metrics for the final project KPIs, such as the ≥20% task-time reduction and ≤10% procedural error rates. The platform's analytics capabilities must be extended to support the continuous, embedded assessment required for these measurements. Furthermore, the **final-phase training curricula** must be updated to incorporate the usability and scenario refinements developed during the mid-term iteration.

6.2 LONGITUDINAL EX-POST SURVEY AND KPI TARGETS

A critical component of the final validation will be the deployment of a **longitudinal ex-post survey.** This survey, building upon the TAM3 framework used in the beta, will be administered after a period of sustained use in the final phase. Its purpose is to measure sustained technology acceptance, long-term Perceived Usefulness, and the integration of the platform into regular training routines. This moves beyond first impressions to assess enduring adoption.

Concurrently, the consortium must establish a rigorous monitoring framework to track performance against the operational **KPI targets**. This will require baselining current performance metrics in each pilot and implementing the analytical dashboards specified in D7.1 to track progress toward the targets of significant efficiency gains and error reduction. The success of the final phase will be judged on the attainment of these concrete, measurable outcomes.

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