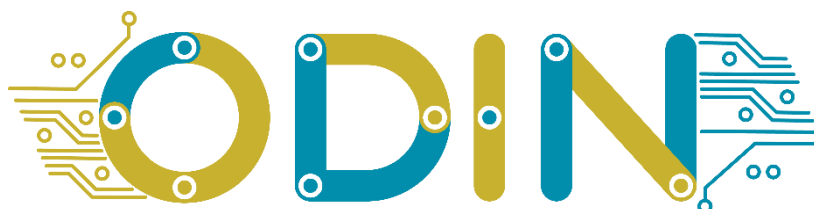


Open-Digital-Industrial and Networking pilot lines using modular components for scalable production

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Summary:

The purpose of this document is to describe the final version of the ODIN Industrial Large-Scale pilots but also their performance assessment and validation.

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1. EXECUTIVE SUMMARY

This document shows the final version of Industrial Component for large pilot lines developed in ODIN project. It presents the final version of ODIN full-scale pilot demonstrators at end users' premises for integrating hardware and software modules and validating their operation under actual production environments. ODIN pilots' integration in the end users' factories has been evaluated thanks to the Key Performance Indicators defined during the first period of the project. During the final period of the project, special efforts have been made to have industrial pilots characterized by: Industrial level robustness, industrial grade performance and industrial safety.

This deliverable focuses on presenting the integration of the pre-industrial demonstrators as presented in D5.4 at the end users' premises. In more detail, the following ODIN results' integration at the industrial level will be presented in this document.

- ODIN Open Component (WP2)
- ODIN Digital Component (WP3)
- ODIN Networked Component (WP4)
- Safety Concept (WP5)

The main objectives of the ODIN Industrial Component are the following:

- Implementation of Automotive pilot demonstrator at STELLANTIS premises.
- Implementation of White goods pilot demonstrator at BEKO premises.
- Implementation of the Aeronautics pilot demonstrator at AEROTECNIC premises.
- Assess the performance of ODIN industrial pilots.

Further information about ODIN demonstrators' final version integration at the corresponding industrial environments is provided in the following sections:

- Section 1: Provides an executive summary of the document.
- Section 2: Provides an introduction of ODIN Industrial Component final version deliverable.
- Section 3: Provides a description of ODIN Automotive pilot demonstrator.
- Section 4: Provides a description of ODIN Aeronautics pilot demonstrator
- Section 5: Provides a description of ODIN White Goods pilot demonstrator.

Finally, different results are presented including the following:

- ✓ Full scales pilot demonstrators at their final status.
- ✓ Safety assessment of the full-scale demonstrators.
- ✓ All ODIN modules integrated in full scales pilot demonstrators.
- ✓ ODIN Components were completed as they have initially been scheduled.

LEGAL DISCLAIMER

The ODIN project is co-funded by the European Union's Horizon 2020 research and innovation programme under the Grant Agreement No 101017141. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the granting authority can be held responsible for them.

2. INTRODUCTION

ODIN WP5 has been centralized on the Industrial Component for robust large scale pilot lines. The main objectives for this WP are:

- The deployment of the full-scale demonstrators in different production sectors to serve as a token of the industrial grade performance of the ODIN production systems. A full-scale instance of the pilot, integrating hardware (HW) and software (SW) modules from the Open and Digital components and operating under an actual production environment.
- The validation of demonstrators' performance for the integrated solution and its interoperability.
- Implementation of three full scales pilots' demonstrators in three different industries: Automotive, Aeronautics and White and Goods.

This deliverable provides evidence on how the core technical Work Packages of ODIN (WP2, WP3, WP4) have been successfully integrated in the full scales pilot lines and combined also with the safety concept implementation, on each of each full scale pilot.

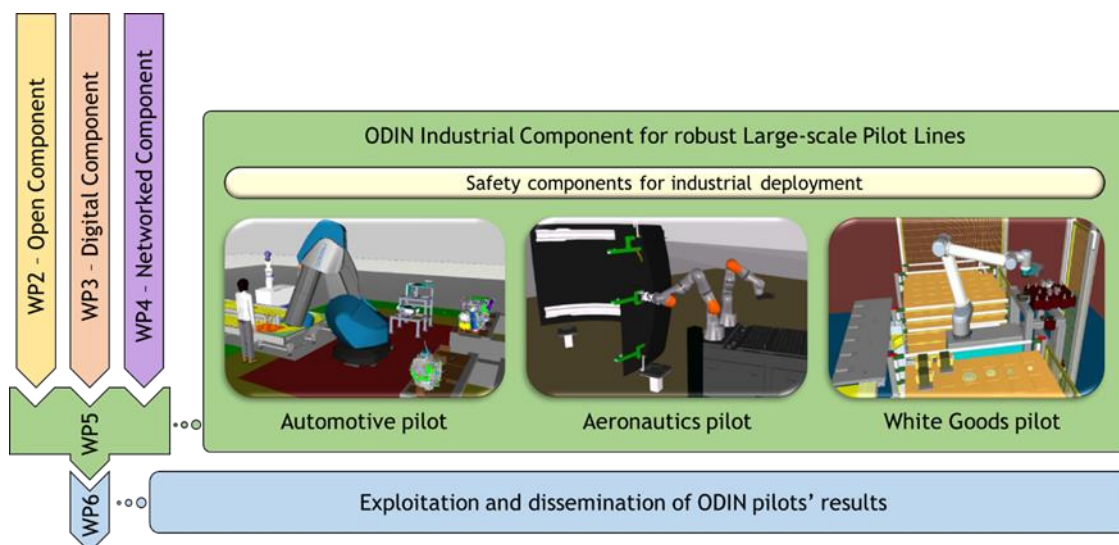


Figure 1: Large-scale Pilot Lines of Industrial Component – connection with other ODIN Components

3. ODIN AUTOMOTIVE PILOT DEMONSTRATOR

3.1. Overview

As already mentioned in previously submitted deliverable D5.4, the automotive pilot of ODIN is centralized on the assembly process of a vehicle engine and a motor as well as the quality inspection of the assembled parts (screws, connectors etc.). During the last period of the project, ODIN partners prepared the final demonstrator layout at STELLANTIS premises in order to integrate the required ODIN components for assembly process validation. The layout of the final automotive pilot demonstrator is presented in the following figure.

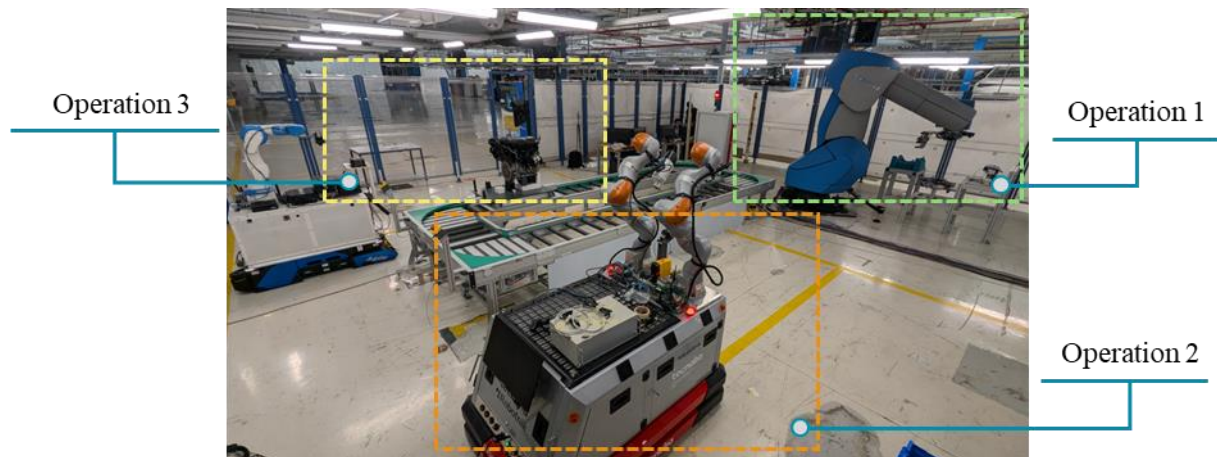


Figure 2: Automotive pilot demonstrator layout at STELLANTIS premises

3.2. Automotive pilot - Industrial demonstrator

The automotive pilot demonstrator consists of the execution of three different operations.

- Operation 1: Motor & gearbox assembly

This operation is centralized on the assembly of a motor and a gearbox part by a COMAU AURA collaborative robot [1] with the support of a human operator for the final connection using manual guidance techniques. For the realization of the specific operation, a set of alluminum tables for parts' storage have been designed by LMS. Additionally, a tool stand has been constructed by LMS for the execution of the tool exchange process by the AURA robot.



Figure 3: Execution of operation 1 at STELLANTIS premises

- Operation 2: Additional parts assembly on the motor and gearbox assembly.

The second operation of the automotive pilot is centralized on the screwing of additional parts on the motor and gearbox assembly. This execution takes place during conveyor's movement thanks to TECNALIA robot's ability for autonomous navigation as presented also in deliverable D5.4.

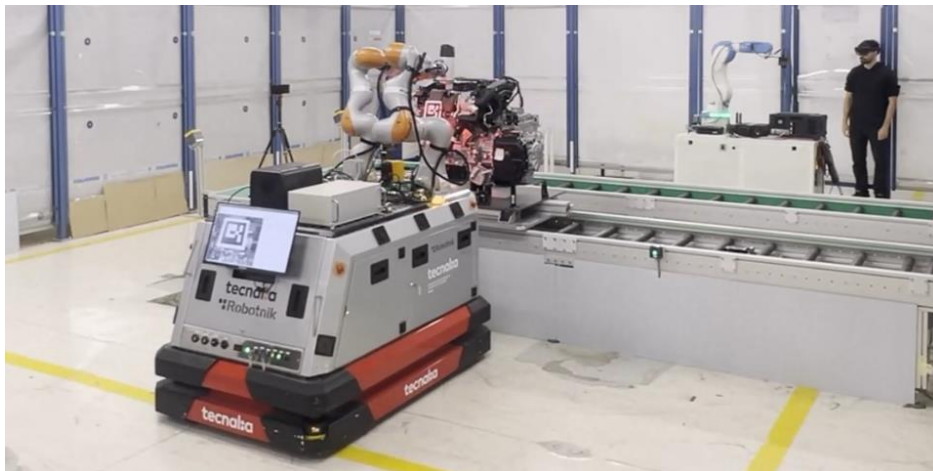


Figure 4: Execution of operation 2 at STELLANTIS premises

- Operation 3: Quality check of installed parts on the motor and gearbox assembly.

This operation is focused on the quality inspection of the installed parts on the motor and gearbox assembly. It is based on the automated inspection of parts (screws, connectors etc) by the mobile robot of COMAU using a RC_Visard 65 camera sensor [2] for the execution of the quality inspection module. Human operator's intervention is required in case of faulty inspected parts to perform any corrective actions.



Figure 5: Execution of operation 3 at STELLANTIS premises

An important key factor for the realization of the Automotive pilot at STELLANTIS premises was the installation of the movable conveyor by DGH.



Figure 6: Installation of movable conveyor at STELLANTIS premises

During the final period of the project, several updates took place inside the safety PLC of the conveyor for its connection with OpenFlow and the three robots of the industrial pilot.

3.2.1. Integration of Open Component with automotive industrial pilot

All the required modules of the Open Component for required assembly execution have been integrated in the Automotive industrial demonstrator of ODIN at STELLANTIS premises. The integration of the Open Component modules in the industrial pilot of the Automotive use case is presented in the following subsections.

3.2.1.1. Autonomous mobile manipulators

Two autonomous mobile manipulators for screwing while moving operation on moving engines and quality inspection of the assembled parts on the motor and gearbox assembly have been investigated inside the Automotive pilot of ODIN. These two operations take place side by side in the industrial pilot of STELLANTIS after the gearbox assembly on the engine's main body. The next sections describe both operations involving autonomous mobile manipulators.

TECNALIA Autonomous mobile manipulator for screw fastening on moving engines

The screws' fastening on moving motor and gearbox assemblies is based on the integration of different modules and developments of ODIN Open Component. The hardware and software solutions required for the execution of the screwing while moving task are:



Figure 7: Autonomous mobile manipulator deployed at STELLANTIS

- The autonomous mobile manipulator of TECNALIA with navigation and manipulation capabilities able navigate inside the Automotive pilot shopfloor and manipulate elements in the assembly line. The mobile manipulator of TECNALIA is equipped with the following hardware:
 - Vision system including an IDS UI-5240CP monochrome camera [3] with a resolution of 1280×1024 and a frequency of up to 50 fps and an LED lighting system.

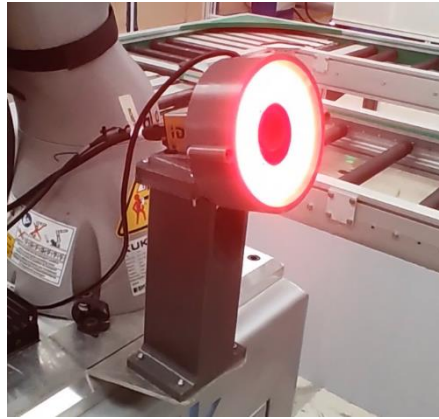


Figure 8: Vision and illumination system for mobile visual servoing

- OnRobot multifunctional screwdriver [4], which incorporates torque control as well as intelligent error detection for the management of the screwing process.



Figure 9: OnRobot automatic screwdriver used for screw fastening

- One Bridge E wireless safety system from R3 Solutions [5] for the connection of the autonomous platform's safety system with the general safety system of the robot cell.



Figure 10: Wireless safety bridge to communicate with the cell's safety manager

- Mobile Visual Servoing module, developed under task T2.3 of ODIN able to carry out the real-time control of the mobile manipulator based on visual feedback to track and perform precise operations like screw fastening on moving objects without any prior knowledge of the movement direction. This module includes a state machine able to manage the different phases of this kind of operation, setting the appropriate speed and compliance parameters based on the state of the process.
- Finally, the autonomous mobile manipulator includes the skill system developed under task T2.4 of the project offering different functionalities (e.g. screw fastening) to the high-level process orchestrator software OpenFlow. This module allows the integration of the mobile manipulator with external systems that manage the whole production.

Regarding the demonstrator deployed at STELLANTIS plant of Mirafiori, the complete screw fastening operation was divided into several steps as presented below:

1. Initial approach of the TECNALIA robot from the robot station which is located outside of the working area of the conveyor belt, to the engine assembly area using autonomous navigation techniques.



Figure 11: TECNALIA mobile robot navigation to the motor and gearbox assembly area

2. Collaborative robots' initialization, positioning the manipulator on the initial pose and setup the Visual Servoing controllers.



Figure 12: Initialization of TECNALIA mobile robot for screwing while moving task's execution

3. Mobile Visual Servoing where the module waits for the first detection of the engine to initialize the servo control loop and performs the screw fastening operation on the moving target.



Figure 13: TECNALIA robot performing the screwing while moving task

4. Once all the screws are fastened, collaborative robotic arms of the mobile robot are retracted to their navigation poses and the mobile unit navigates back to the robot station.



Figure 14: TECNALIA robot navigation to its robot station

5. Based on the previously presented hardware and software setup, the autonomous mobile manipulator of TECNALIA is deployed on the Automotive pilot case performing the screw fastening operation.

COMAU Autonomous mobile manipulator quality inspection tasks' execution

The COMAU mobile robot has been shipped to the STELLANTIS premises in Torino, Italy, at the Mirafiori plant, and its integration into the industrial cell has been completed successfully. This robot focuses on the realization of the quality inspection process for the automotive pilot's motor and gearbox assembly. As presented in D2.4, the COMAU mobile robot is capable of autonomously navigating within the industrial cell layout and docking in the required positions using feedback from its laser sensors.

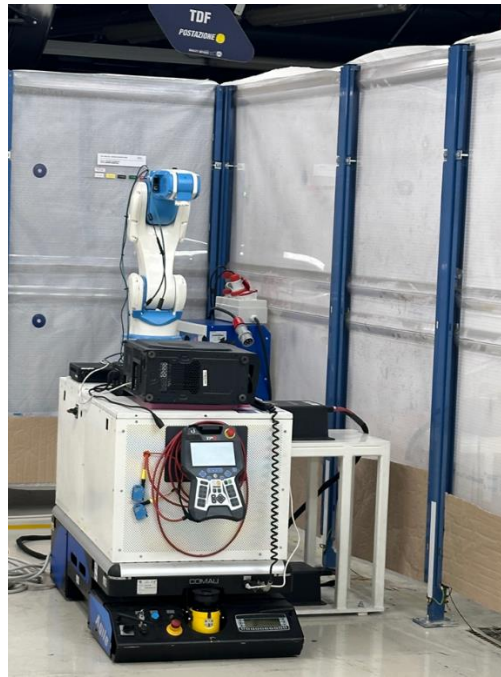


Figure 15: COMAU mobile robot installation at STELLANTIS premises

As presented in D5.4 through the Automotive small-scale pilot of LMS, the docking of the mobile robot is based on a set of reflective tapes installed on the conveyor belt. Utilizing the reflective tapes, the robot is able to navigate along the conveyor to the quality inspection position.

3.2.1.2. Reconfigurable robot tooling

As presented also in deliverable D5.4, the execution of the required robot tasks in the Automotive pilot is based on a set of reconfigurable robot tools which can be used by AURA robot for the manipulation of high payload parts like the motor and the gearbox variants [6]. This final version of the AURA grippers have also been successfully integrated in the industrial pilot of STELLANTIS.

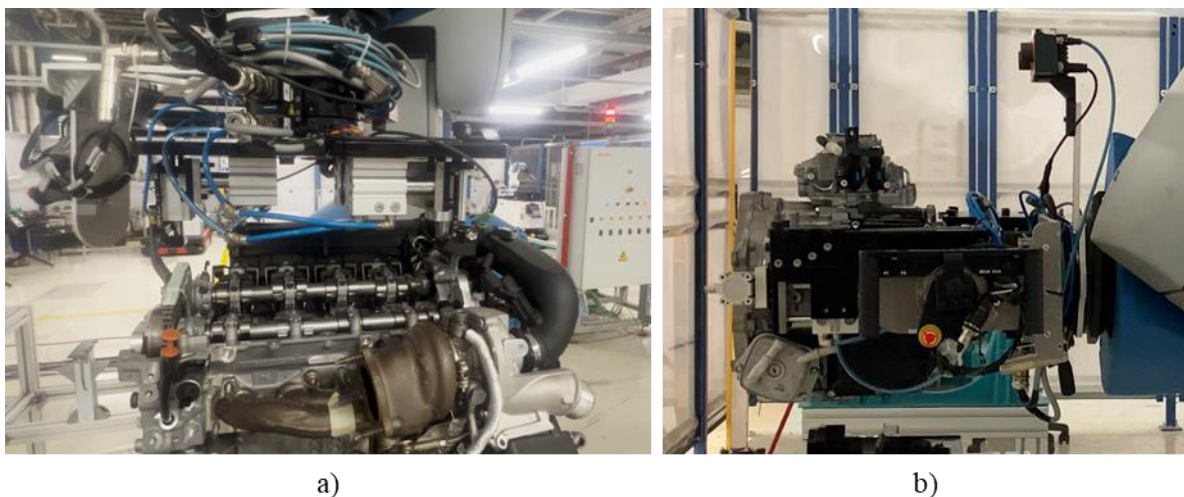


Figure 16: Integration of a) motor and b) gearbox grippers in the industrial demonstrator of STELLANTIS

Using the motor and gearbox grippers, the AURA robot was able to pick and place the required parts on the conveyor towards their connection by the human operator.

3.2.1.3. Robotic perception for the process, the human and the environment

The automotive demonstrator utilizes a set of robotic perception modules for the successful execution of the required robot tasks. These modules' integration under the industrial demonstrator of STELLANTIS is detailed below.

- Object pose estimation

As presented in the pre-industrial demonstrator of LMS (see D5.4), using the detection module of ROBOCEPTION, the AURA robot is able to grasp successfully the motor and gearbox parts. The object pose estimation module within the automotive pilot is based on a CAD template for each part to be detected. For the motor's detection, a CAD of the motor's head without the valve cover was used, utilizing the RC_Visard 160 camera [7] which is mounted on the AURA robot. This template is an updated version of the solution presented in D5.4 because during the last period the top cover of the motor needed to be removed for the sequential execution of all automotive operations. The integration of this pose estimation operation in the industrial demonstrator of STELLANTIS is presented in the following figure.

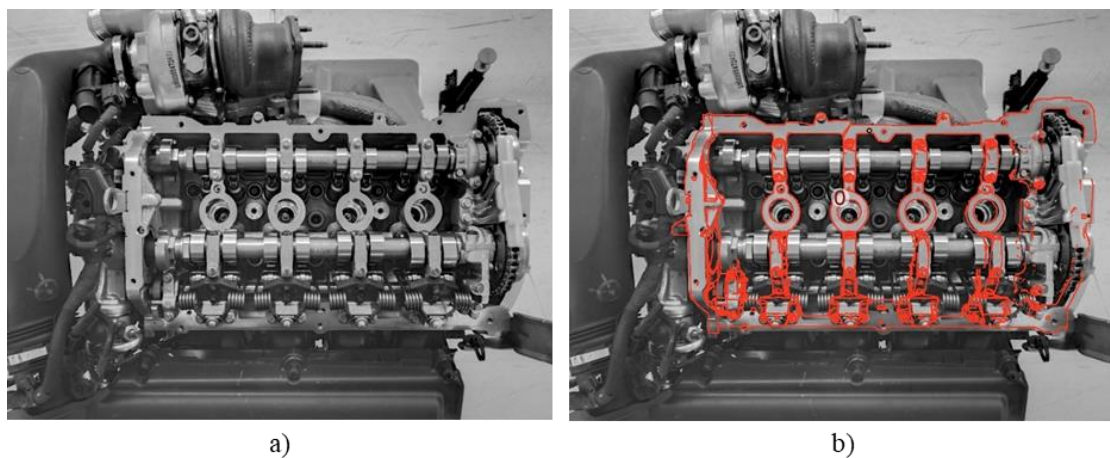


Figure 17: a) Motor part, b) Motor part pose estimation using CADMatch technique

Using the same methodology as for the motor part detection, in order to identify the entire gearbox component and establish the required grasping point, the CADMatch technique is employed using the RC_Visard 160 camera sensor. This sensor is connected to an rc_cube S [8], which is responsible for providing the necessary detection template and the execution of both motor and gearbox detection processes.

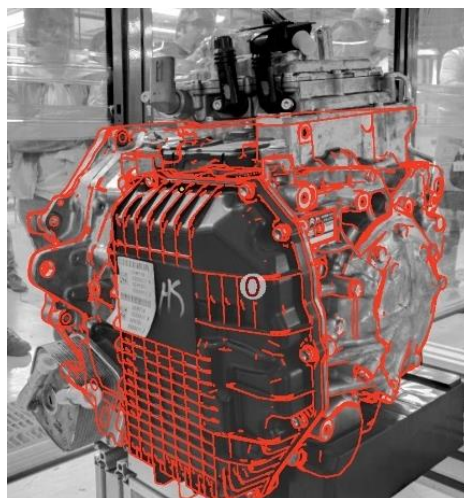


Figure 18: Motor part pose estimation using CADMatch technique

As documented in D5.4, the connection of the motor and gearbox parts under Automotive pilot Operation 1 is contingent upon the spatial object detection module of LMS. The final position of the motor placement on the assembly table is determined using this module. The spatial object detection results are handled by a ROS server, which detects the central axle of the motor and creates a frame that corresponds to the correct alignment position for the gearbox and motor. D2.4 provides a comprehensive explanation of the CNN-based approach employed by this spatial object module.

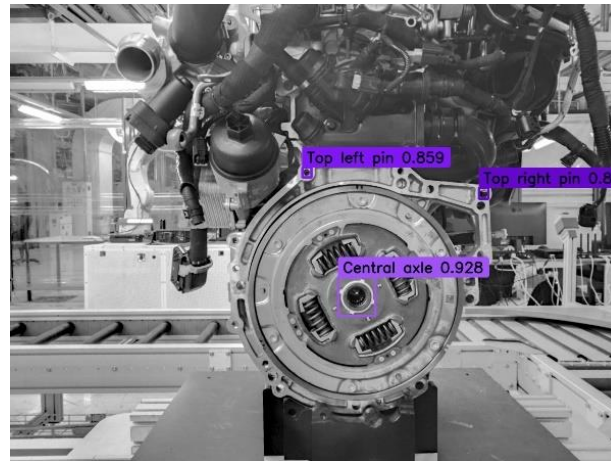


Figure 19: Alignment positions by spatial object detection module

- Quality inspection

The third operation of the Automotive pilot is centralized on the quality inspection of the assembled parts on the motor and gearbox assembly using the RC_Visard 65 camera sensor of the COMAU mobile robot as well as the corresponding software module of ROBOCEPTION. The motor and gearbox assembly is inspected for faulty installation of connectors, strap holders, screws, and valve pipes as presented also in the pre-industrial demonstrator of LMS in deliverable D5.4.

The module initially performs a CADMatch of the assembled motor to figure out the exact position of the motor. Then, using the pose of the motor, the module is able to create the ROIs dynamically for each part to be inspected. The classification of the inspected parts as either 'OK' or 'NOK' is established through the quality check service, a deep learning approach developed by ROBOCEPTION. The implemented quality check service, which incorporates updated models for these objects' inspection (i.e., electrical connectors, strap holders, screws and valve pipes). The results of this module's integration in the Automotive demonstrator of STELLANTIS are presented in the following figure.

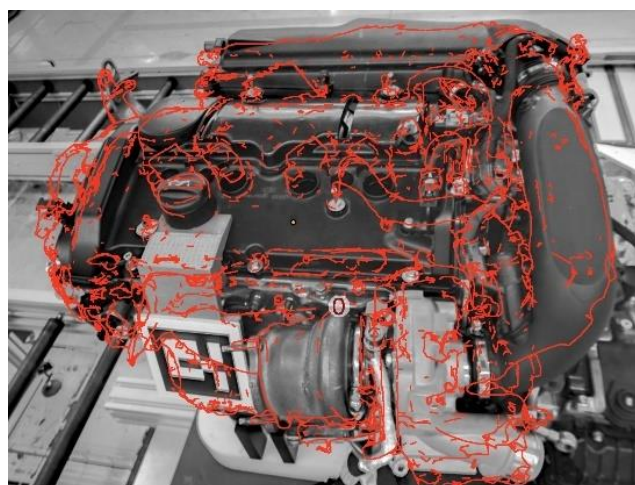


Figure 20: Assembled motor CADMatch

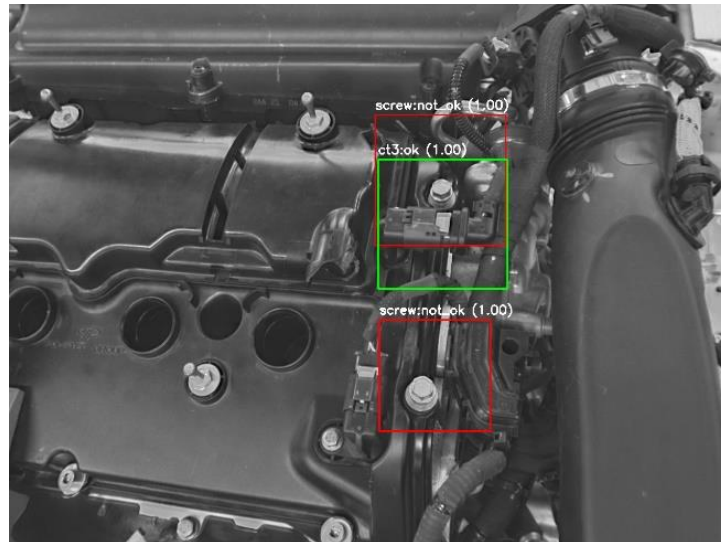


Figure 21: Quality inspection on the assembly

3.2.1.4. User friendly robot programming interfaces

To assist operators and programmers in adding new engine references, the autonomous mobile manipulator includes a programming tool to teach the screw positions onsite, facilitating the deployment. Specifically, the programming interface includes the following elements:

- Tablet and 6D joystick to interface both the user interface and robot.

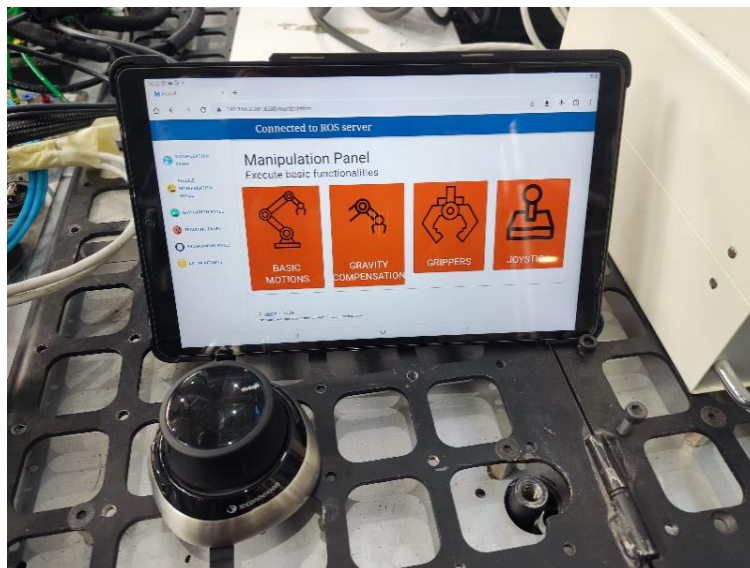


Figure 22: Tablet and 6D joystick for teaching

- Joystick application that allows moving the manipulator, adding extra features such as speed regulation and axis blocking.

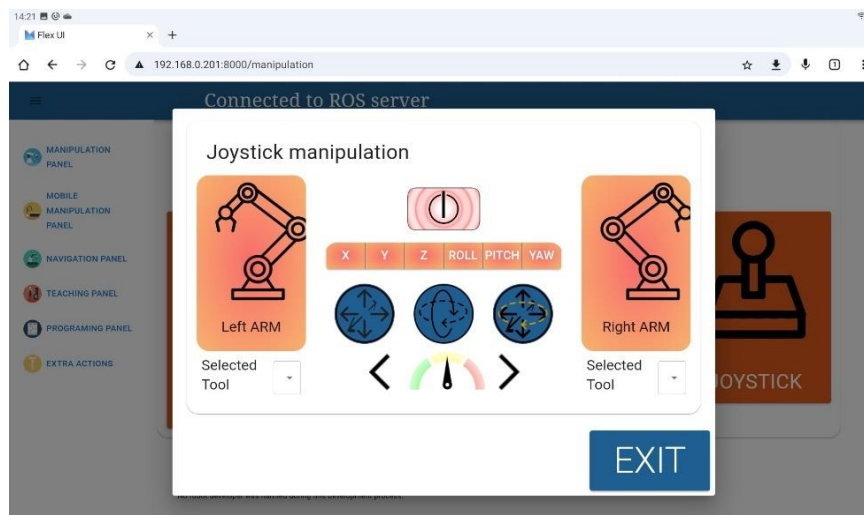


Figure 23: User Interface of the joystick application

- Teaching interface that allows adding new references. The user is able to record new manipulation poses and define the final manipulation pose (retract maneuver), as well as the final platform pose. Additionally, the user can also specify the tag of the new reference to be stored in the robot's database.

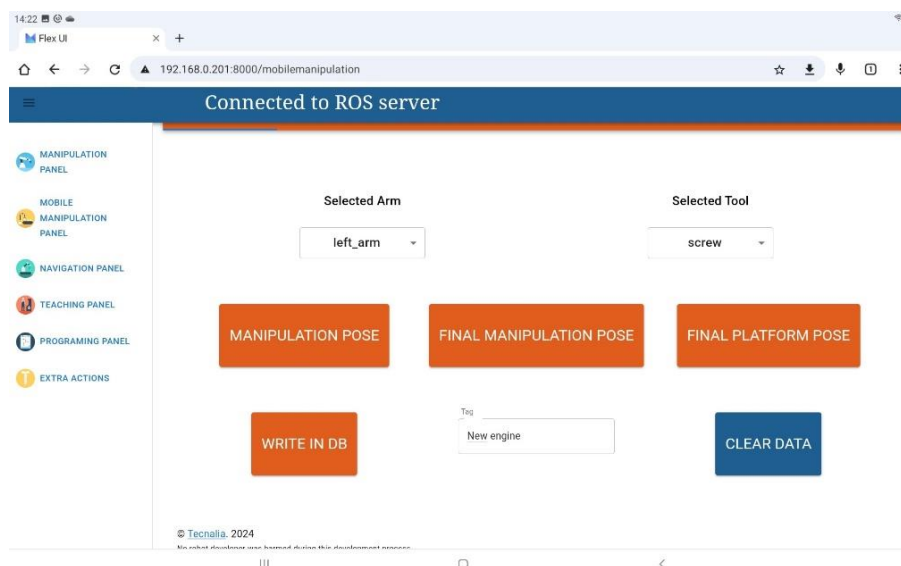


Figure 24: User Interface of the Visual Servoing Teaching application

The aforementioned user interface allows an easy and intuitive way to program new references and adjust the poses without programming any code, allowing a simple onsite deployment of the solution.

3.2.1.5. Smart human side interfaces

The operators of the automotive demonstrator use the AR application of ODIN in order to successfully execute the required assembly and corrective actions on faulty inspected parts. During the final period of the project, the AR application has been successfully integrated inside the industrial pilot layout of STELLANTIS. As presented also in D5.4, the AR application of ODIN developed by LMS consists of several interfaces for connection with other ODIN modules, and features human operators in terms of:

- Assembly guidance provision,
- Controlling of mobile and static robots,
- Production system security breach notifications provision,
- Assembled products quality inspection results provision,
- Resilience of the production system in case of unexpected events,
- Safety awareness for the operators.

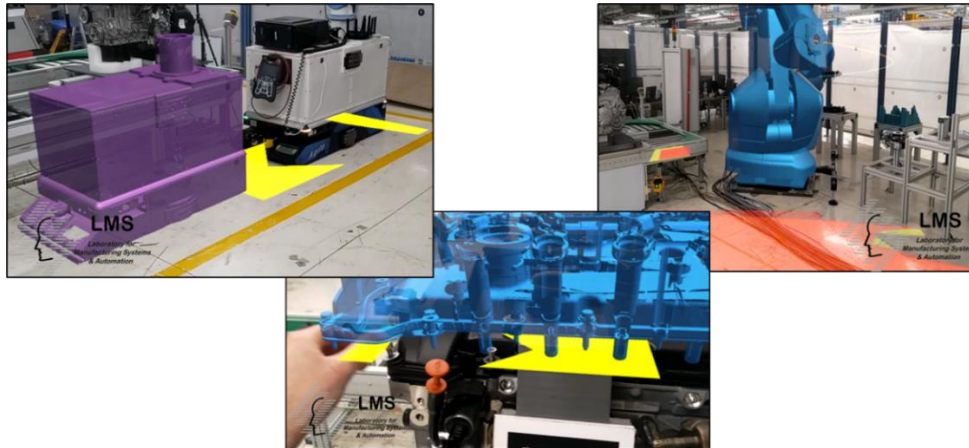


Figure 25: AR application usage in Automotive demonstrator

3.2.2. Integration of Digital Component with automotive industrial pilot

All the Digital Component modules have been integrated and validated in the industrial demonstrator of the automotive pilot at STELLANTIS premises.

3.2.2.1. Digital Simulation

During the final period of the project, the final version of the Automotive pilot simulation has been delivered by LMS. This simulation is centralized on the execution of the assembly operation utilizing the required robotic and human resources. An updated version of the Automotive pilot layout has been designed for the installation of the pilot at STELLANTIS premises based on corresponding robots' reachability and components (conveyor, cabinets, safety barriers etc.) dimensions and installation location. The updated version of the simulation presented in deliverable D5.4, includes the final version of the Automotive pilot simulation and the required resources' movements.

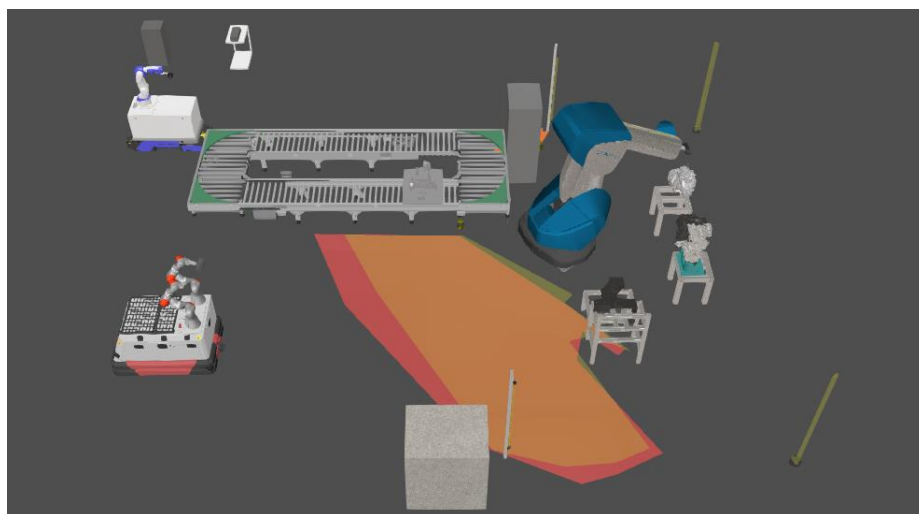


Figure 26: Automotive demonstrator simulation layout

3.2.2.2. Digital Twin

As presented in the previous deliverable D5.4, the Digital Twin of ODIN provides visualization and connectivity features through the Visual Components software demonstrated with ODIN static and mobile robots, laser scanners' and vision sensors' real-time data integration. During the last period of the project, the final version of the DT module has been successfully integrated in the industrial pilot at STELLANTIS premises. In its final version, the Digital Twin includes the following information:

- COMAU Aura and mobile robot

As presented also in deliverable D5.4, the actions of COMAU AURA and mobile robots' can be visualized inside the Digital Twin of the Automotive pilot thanks to this module's connection with OpenFlow.

- TECNALIA mobile robot

Thanks to Digital Twin module's connection with OpenFlow, the navigation of TECNALIA mobile robot's and its arms' movements can be visualized also inside the Visual Component software dynamically using data from the physical robot received during the assembly process execution.

- Conveyor

The automotive pilot's conveyor has been modelled inside the Visual Component by LMS. In the final version of the Automotive pilot, this VC model is connected with OpenFlow in order to visualize dynamically the start-stop actions and speed adjustments of the real conveyor.

- Laser scanners

As presented in deliverable D5.4, the ODIN Digital Twin includes the safety laser scanners of PILZ and their functionality to change the emergency and warning scanning areas on demand based on AURA robot's configuration (pose). During the installation of the Automotive pilot at STELLANTIS premises, three new zone sets designed by LMS and PILZ. This zone sets have added inside the software of each laser scanner of operation 1 and the corresponding simulated models inside the Digital Twin. Using real-time data received by the OpenFlow, the scanning areas inside the Digital Twin was up-to-date based on the scanning areas of the physical laser scanners as defined by the safety concept of the pilot.

- Object detection module's results

The results of the object detection module are visualized inside the Visual Component software.

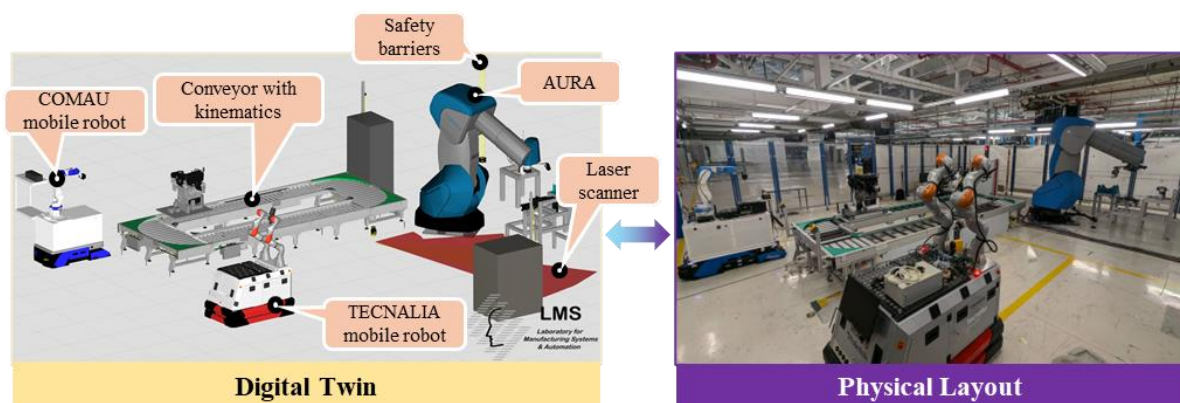


Figure 27: Integration of Digital Twin module at STELLANTIS industrial demonstrator

3.2.2.3. AI Task Planner

The AI Task Planner was a critical factor for the validation of the ODIN solution at STELLANTIS premises. In its final version, the database of the AI Task Planner has been updated in order to include all the required resources for assembly tasks' allocation and execution. Additionally, a tasks' flow rearrangement took place for the sequentially execution of all automotive pilot's operations. The final

version of this module’s User Interface including all modelled resources is visualized in the following figure.

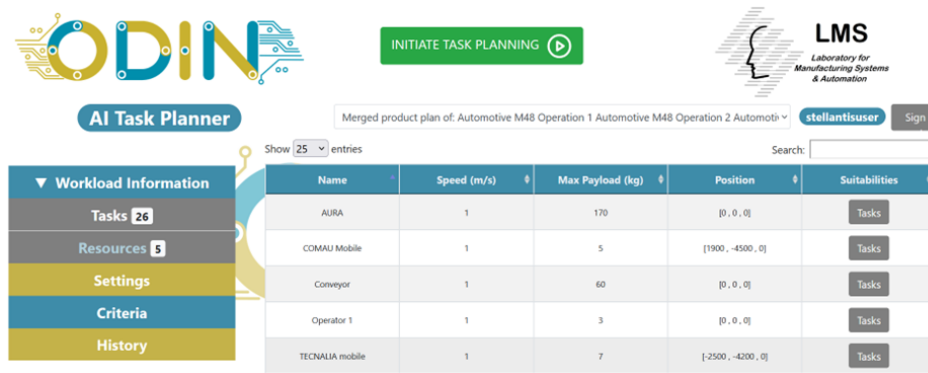


Figure 28: Integration of ODIN AI Task Planner with the Automotive demonstrator at STELLANTIS

3.2.2.4. Virtual Commissioning

As presented in deliverable D5.4, the virtual commissioning module is based on the usage of Visual Component software and its functionality to generate executable programs for COMAU and Universal Robot controllers. The final version of the Virtual Commissioning module has been validated in the Automotive pilot demonstrator at STELLANTIS premises.

As already presented, the Automotive pilot focuses on the assembly of motor and gearbox parts and the quality inspection of connectors, screws and strap holders on the final product. The Virtual Commissioning module evaluated as a very important one for production when changes on the assembly process are required. More specifically, the Virtual Commissioning module has been evaluated at STELLANTIS premises when a new inspection action was required in the last operation of the assembly process. The production manager was able to program a new robot program in the Visual Components software and using the latest version of the Virtual Commissioning module transfer the generated robot trajectory in the Visual Components.

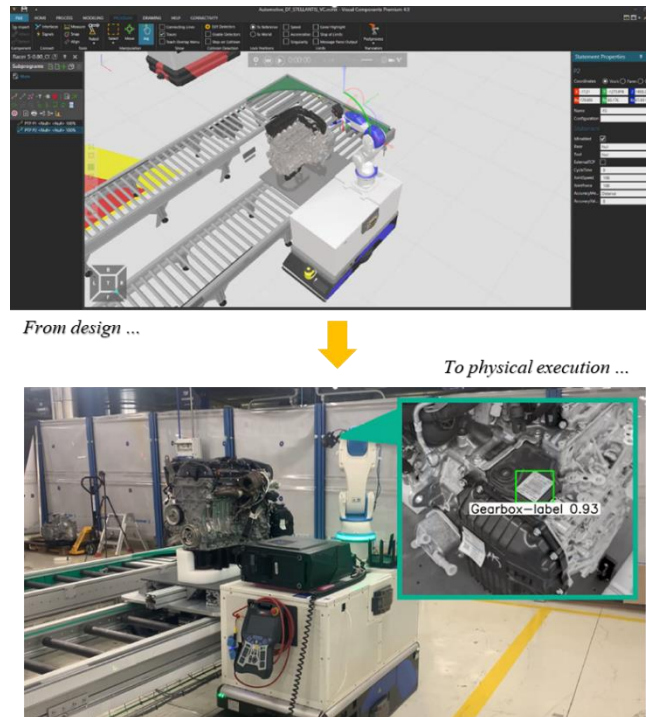


Figure 29: Integration of Virtual Commissioning module at STELLANTIS

3.2.3. Integration of Networked Component with automotive industrial pilot

3.2.3.1. OpenFlow

The Automotive demonstrator at Stellantis premises has been integrated with the final version of ODIN OpenFlow. The OpenFlow orchestrator is connected to all other ODIN modules that are necessary for the assembly process in its final form. In D5.4, the final version of OpenFlow and its integration with other ODIN modules are demonstrated.

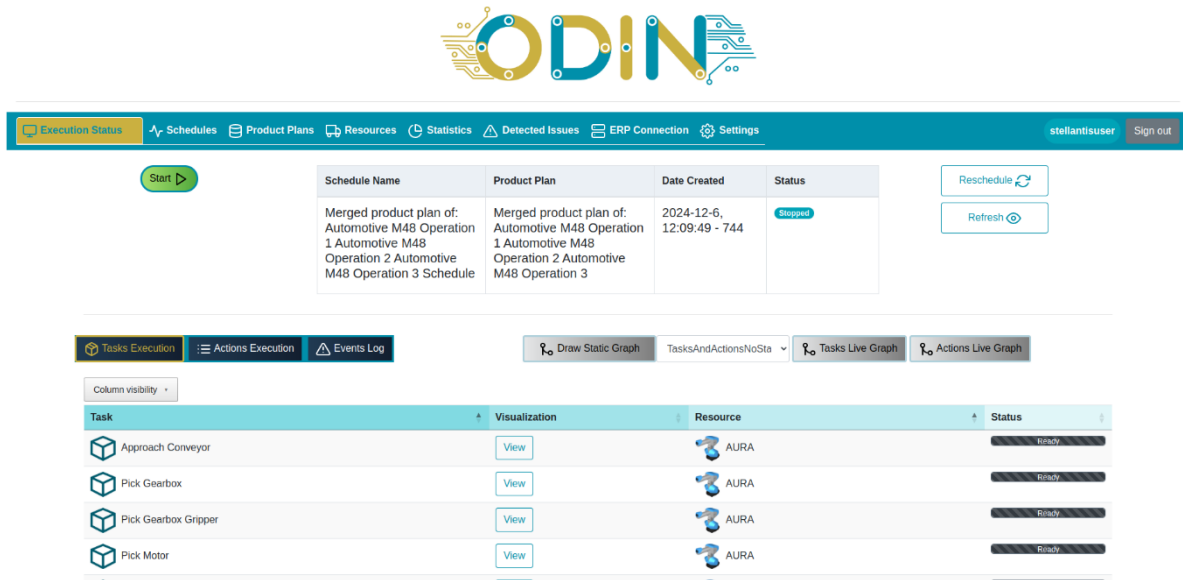


Figure 30: Integration of OpenFlow in the automotive pilot demonstrator

The execution schedule of the Automotive pilot has been updated to encompass all operations' tasks assigned to both robots and human operators. The OpenFlow module has been modified to execute all three operations sequentially, including the actions of Operation 2. Notably, for Operation 2, OpenFlow only sent the next task, while the individual actions were handled internally. Additionally, the system was integrated with the ERP for the incoming orders from Stellantis internal system. A dockerized version of OpenFlow, prepared by INTRA, is running on a high-performance PC at STELLANTIS premises. The required actions performed by robotic and human resources are managed through a set of ROS Action and Services servers which interface with the various hardware and software components of the Automotive demonstrator.

Table 1: ROS action servers for final Automotive pilot execution

ROS Action Servers	Description
Move Cartesian Action Server	Action server for the planning and execution of robot motions using Cartesian space goals.
Move Joint Action Server	Action server for the planning and execution of robot motions using Joint space goals.
Configure Payload Execution Service Server	Service server for robot's payload reconfiguration based on the payload of grasped parts (motor/gearbox/grippers).
Configure TCP Action Server	Action server for updating the robot's end effector when robot carries parts (motor/gearbox/grippers).
Detection Action Server	Action server for the detection of parts to be manipulated by the robot using CADMatch with pose estimation technique.

ROS Action Servers	Description
Assembly Detection Action Server	Action server for the execution of the assembly detection process.
Safety Action Server	Action server to communicate the safety status of the cell with OpenFlow module.
Execute Human Task Action Server	Action server for the connection of AR operator support application with OpenFlow.
Control Gripper Action Server	Action server for enabling / disabling robot's grippers.
Mobile Control Action Server	Action server for mobile robot's navigation.
Quality Inspection Action Server	Action server for the execution of the quality inspection algorithm.
Quality Inspection Detection Action Server	Action server for the detection of the assembled motor for the dynamic generation of the ROIs using CADMatch with pose estimation technique.
Skill Execution Action Server	Action server responsible to sending the next action of the Operation 2
Conveyor Control Action server	Action server for the actuation of the conveyor belt.

The connection of the OpenFlow module with the previously mentioned ROS Action and Service servers, along with the necessary ROS controllers and hardware/software components, is presented in the following figure.

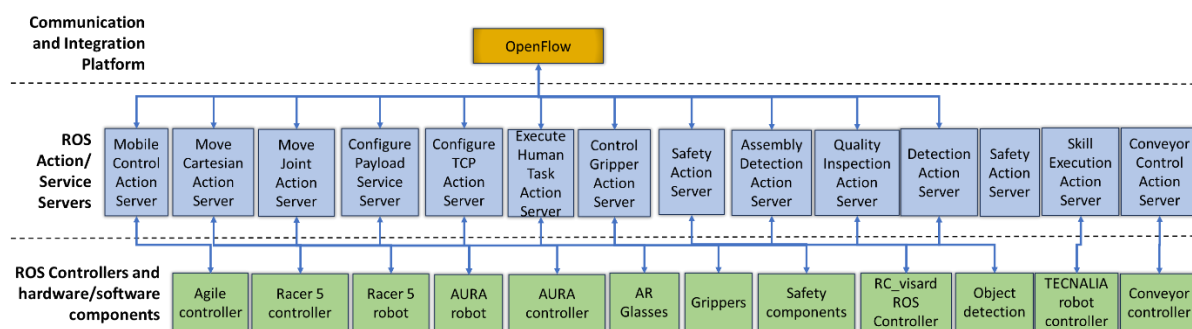


Figure 31: OpenFlow connection with ROS action servers for Automotive industrial demonstrator at Stellantis premises

3.2.3.2. Cyber Security

The industrial demonstrator at STELLANTIS facilities is equipped with the cybersecurity module of ODIN. This module is based on the interconnection of three computers, as demonstrated in D4.3. The module's functionality is primarily focused on the detection of incoming cyberattacks from outside the network, as delineated in D5.4. The module was successfully integrated at Stellantis. The Nmap scan was successfully detected by the system, and the identified attack was transmitted to the SOAR component through a direct connection to TheHive.

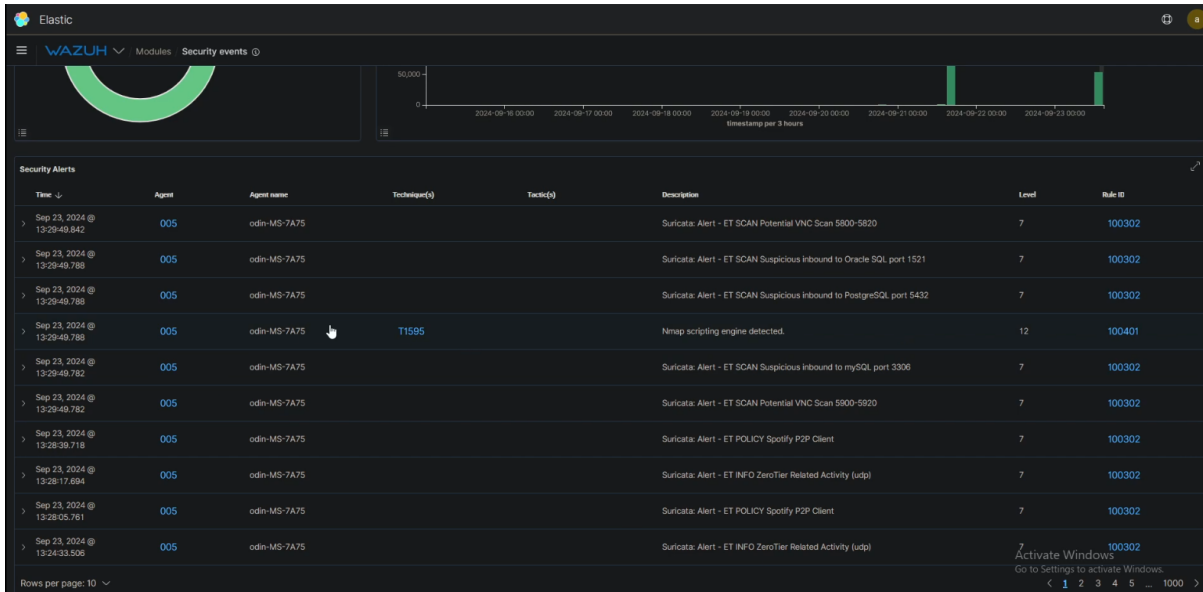


Figure 32: SIEM detection of nmap attack

Following a cyber security event detection, the assembly line turns into emergency mode, and all operations are stopped.

3.2.4. Automotive pilot safety concept integration with automotive industrial pilot

The main purpose of this section is to present the safety concept integration, and the results of the Risk Assessments conducted for the Automotive pilot at STELLANTIS premises to ensure compliance with the legal framework, related standards and best practices.

A key activity in the integration of the Automotive pilot at STELLANTIS premises was the validation of the safety concept by PILZ. This validation adhered to a set of requirements specified by PILZ, as documented in Annex 9.1.1. The next figure illustrates the locations of the safety devices within the final layout of the Automotive pilot.

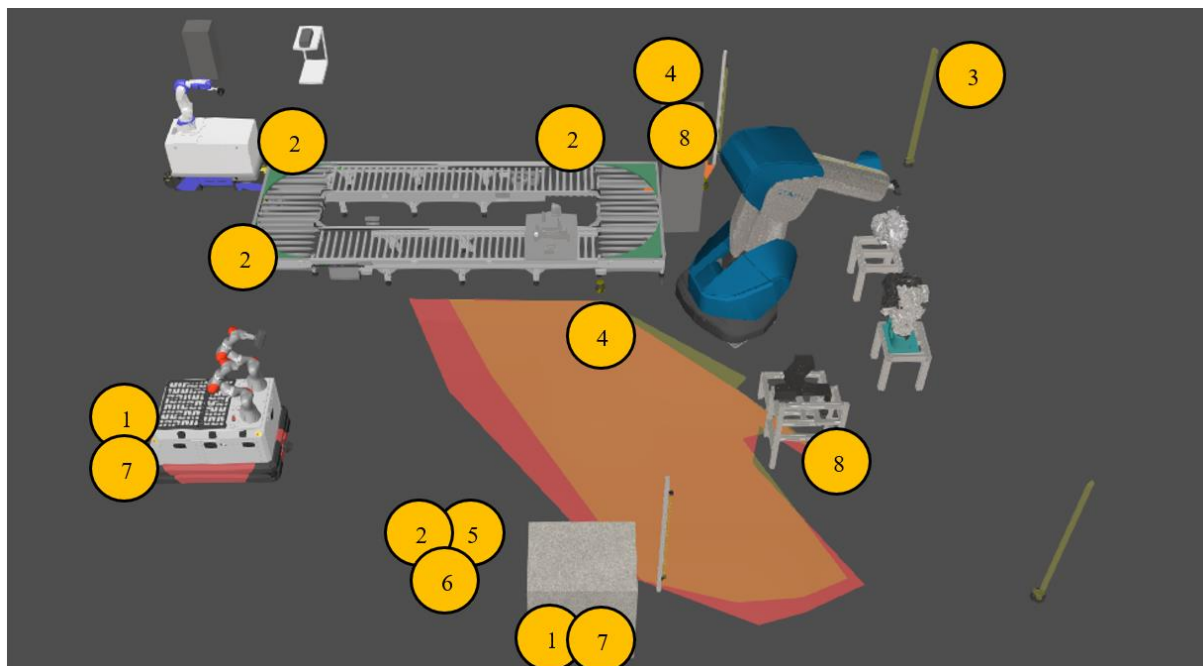


Figure 33: Automotive pilot layout Safety devices integration

Table 2: Safety equipment list

No.	Safety equipment
1	2 x Safety PLC (PAS4000) [9]
2	6 x ESTOP Push-Button (PITestop) [10]
3	1 x Light Barrier + Mirror (PSENopt) [11]
4	2 x Safety scanner (PSEnscan) [12]
5	1 x Mode Selector + 2x Keys (PITreader) [13]
6	1 x Reset Push-Buttons
7	2 x Ethernet Bridge (R3 EchoRing) [5]
8	2 x Light and Sound Beacon

In order to better understand the safety concept of the overall pilot, the integration of the safety devices will be presented in different subsections per each operation.

3.2.4.1. Motor & gearbox assembly

- Safety light barrier

The safety concept for the AURA robot system was designed around the installation of one safety light barrier, complemented by two strategically placed mirrors to ensure comprehensive coverage of the robot's operational perimeter (Figure 34). The placement of the light barrier and mirrors was determined in accordance with the safety formula based on ISO standards. However, due to the space constraints of the cell, the installation distances of the barriers had to be adapted. As a result, for this pilot implementation, the installation distances did not fully comply with the previously specified requirements. The safety light barrier is capable of detecting the presence of human operators and will automatically stop the assembly process if an operator enters the detection zone, ensuring a safe working environment.



Figure 34: Safety light barriers and mirrors

- Safety laser scanners

Two laser scanner devices have been strategically installed (Figure 35) within the industrial demonstrator layout to monitor the presence of human operators and automatically stop the assembly process if an operator enters a designated safety zone. The implementation of these laser scanners allows the system to reduce the AURA robot's speed when obstacles are detected within the warning area. Additionally, three distinct zone configurations have been defined for each laser scanner, with the specific zones adapted to the position of the AURA robot's base joint.



Figure 35: Safety laser scanners installation

- Emergency and reset buttons

Six emergency stop and one reset buttons have been installed within the Automotive pilot (Figure 36), providing operators with the change to perform an emergency stop of the assembly process if its required. The reset button enables operators to resume the assembly process, these buttons are integrated with the safety PLC of the demonstrator to ensure immediate response in the event of an emergency.

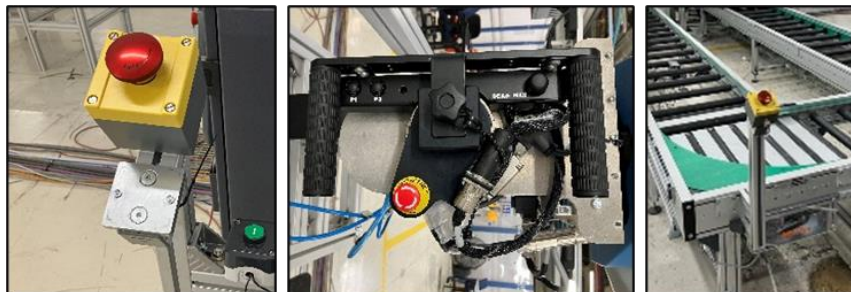


Figure 36: Emergency stop buttons in the Automotive pilot cell

- Safety PLC

As presented in deliverable D5.4, the safety PLC of the automotive pilot is fully integrated with all safety hardware devices within the robotic cell. The main safety logic is implemented within this PLC to enhance performance and ensure the reliable and consistent operation of the process. The safety PLC is placed in the main cabinet of the Automotive demonstrator (Figure 37), providing centralized control and monitoring of all safety functions.



Figure 37: Safety PLC integration

- Motor gripper sensors

As presented in deliverable D5.4, a set of position and inductive sensors (Figure 38) have been installed on the motor grippers to detect the actuation and verify the successful completion of grasping process.

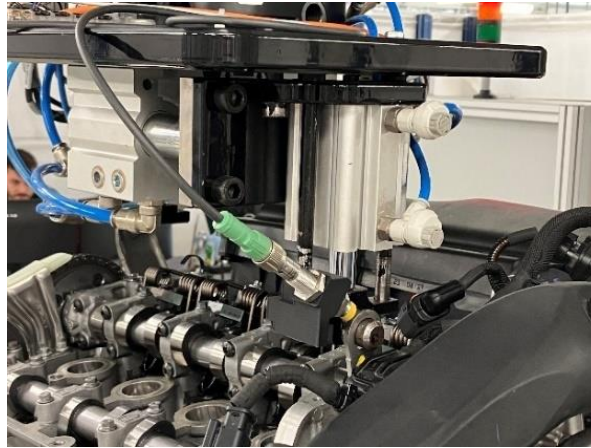


Figure 38: Inductive sensor installed in the gripper

- Mode selector

The operator is responsible for manually guiding the AURA robot during the assembly of the motor and gearbox to ensure proper alignment of the two components. As described in the D5.3, a mode selector device has been integrated (Figure 39) in order to change the safety configuration of the cell to the manual guidance operation safety requirements.



Figure 39: Mode selector integration

3.2.4.2. Additional parts assembly on the motor and gearbox assembly

- Safety synchronization between mobile platform and the rest of the cell when mobile platform is coupled to the conveyor

As described in D5.4 one of the main objectives of operation two was to expand the existing safety of the mobile platform, enabling it to synchronize effectively with the external safety of the entire cell when the mobile platform is coupled to the conveyor.

Particularly, at the beginning of the project, the mobile manipulator's internal safety system was designed to manage safety considering both arms and the mobile platform. To this end, a safety SICK PLC managed the different signals provided by the manipulators and platform, generating a unified safety output. Even so, the autonomous mobile manipulator's safety was designed to work in a standalone way, without any intercommunication with an external safety system.

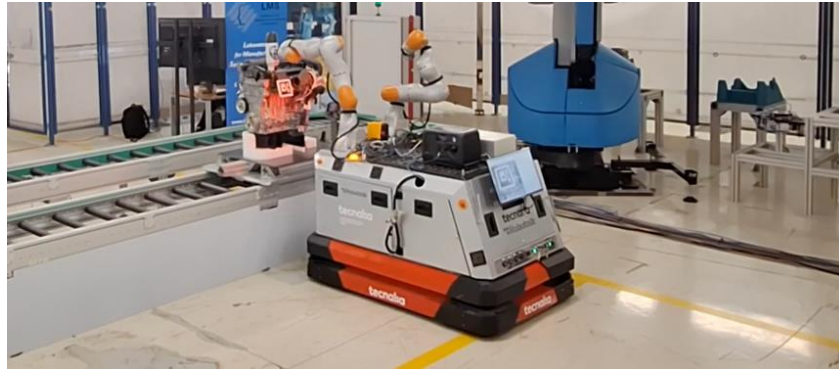


Figure 40: Mobile manipulator screwing using safe communication with the cell safety system

Therefore, the safety design of the autonomous mobile manipulator has been extended with the developments carried out on task T2.1. Particularly, several additional hardware modules were added to the original safety SICK PLC to intercommunicate with the external safety system of the complete automotive pilot. Specifically, one PILZ PLC to allow the wireless communication to the external main PLC and two additional SICK FLEXI-Soft XTIO modules [14] have been installed to incorporate extra safety digital input-outputs.



Figure 41: Safety PLC with safe IO modules

These new safe IO modules allow the introduction of new safety signals from the external safety system to stop both, the mobile platform and manipulators when a cell-level emergency is triggered. In the same way, the output signals are also used to communicate any safety issue produced in the mobile manipulator.

From the hardware point of view, the setup is completed with a Bridge E wireless Ethernet bridge from R3 Solutions, a device that ensures ultra-reliable low-latency data transmission and is used to send safety signals to the central safety system.



Figure 42: Wireless safe bridge to communicate with the external safety manager

To complete the work, the safety program managed by the safety PLC was modified to take into account the new signals and devices. Due to the general safety architecture of the cell, where the overall security is managed outside the autonomous mobile manipulator.

- Safe couple between mobile platform and conveyor

To ensure the safety signals confirm that the mobile platform is properly coupled to the conveyor and to enable synchronization between the mobile platform safety and the external safety of the cell, the contour function of the SICK safety scanners is used. This function detects a specific contour which indicates that the mobile platform is coupled to the conveyor. Figure 43 illustrates the integration of a new panel along the conveyor, where the screwing process takes place. This panel enables the contour detection function of the scanners to verify whether the mobile platform is properly attached to the conveyor while performing the screwing operation.



Figure 43: New panel integration

3.2.4.3. Quality check of installed parts on the motor and gearbox assembly

- COMAU mobile robot laser scanners

The COMAU mobile platform is equipped with two distinct laser scanners (Figure 44) designed to detect humans or objects' presence in both the front and rear areas. In the event of an infringement of the safety zones, the mobile platform stops its movement.



Figure 44: COMAU safety laser scanners

- Retroreflective sensors

As outlined in D5.4, two distinct retroreflective sensors have been installed on the COMAU mobile platform. Additionally, reflective tapes for the docking process of the mobile platform with the

conveyor have been successfully positioned on the outer area of the conveyor, as shown in the following Figure 45.

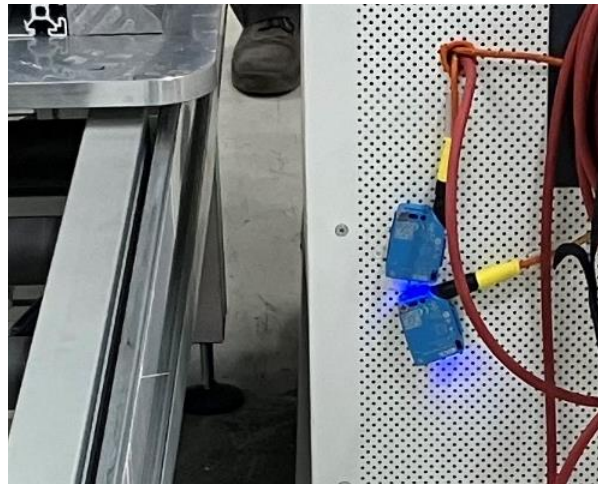


Figure 45: Retroreflective sensors

3.2.4.4. Automotive pilot risk assessment results

The following section presents a summary of the initial and final risk assessment conducted for the Automotive pilot. This analysis aims to identify, evaluate, and mitigate potential risks that could impact safety outcomes. Table 3 outlines the key risks identified.

Table 3. Automotive pilot risks identified

Priority	Hazard No	Hazard Name	PHR	Risk Level	Post PHR	Post Risk Level
1	1.2	Impact with the AURA Robot in warehouse area	781	Very High Risk	390	High Risk
2	1.10	Lack of marking of collaborative workplace	N/A	Not Acceptable	N/A	Not Acceptable
3	3.2	Inability to perform a simultaneously emergency stop between the conveyor and mobile platform	937	Very High Risk	N/A	Further Review
4	1.8	Hazards generated by the loss of end effector	781	Very High Risk	15	Very Low Risk
5	1.9	Hazards due the stability of the robot	781	Very High Risk	15	Very Low Risk
6	3.9	Unexpected movements due to mode selection	312	High Risk	12	Very Low Risk
7	3.1	Inability to perform an emergency stop	937	Very High Risk	9	Negligible Risk
8	3.3	Inability to perform a simultaneously emergency stop between the mobile platform and the robot	937	Very High Risk	9	Negligible Risk
9	1.5	Crushing during the hand guidance operation	275	High Risk	5	Negligible Risk
10	1.6	Movement of robot moving parts against a fixed part	687	Very High Risk	5	Negligible Risk
11	1.7	Robot movements beyond the expected boundaries	781	Very High Risk	5	Negligible Risk

Priority	Hazard No	Hazard Name	PHR	Risk Level	Post PHR	Post Risk Level
12	1.1	Impact with the AURA Robot in conveyor area	781	Very High Risk	4	Negligible Risk
13	1.4	Falling or ejection of the process part	390	High Risk	4	Negligible Risk
14	1.3	Impact during placement of the process parts in warehouse	625	Very High Risk	3	Negligible Risk
15	2.4	Impact hazards due to riding on the mobile platform	343	High Risk	3	Negligible Risk
16	2.6	Floor condition affecting the stopping performance	312	High Risk	3	Negligible Risk
17	2.1	Impact with the mobile platform during mobility	343	High Risk	2	Negligible Risk
18	2.2	Impact hazards due to configuration of safety scanners	343	High Risk	2	Negligible Risk
19	3.8	Unexpected movements due to new start-up	234	High Risk	2	Negligible Risk
20	2.3	Crushing between the mobile platform and the conveyor during approach	275	High Risk	1	Negligible Risk
21	2.5	Impact during movement caused by accessible parts of the machine	275	High Risk	1	Negligible Risk
22	2.7	Crushing caused by lack of foot protection	93	Significant Risk	1	Negligible Risk
23	2.8	Impact with the dual arm manipulator or tool during kitting operation	781	Very High Risk	1	Negligible Risk
24	2.9	Impact with the single arm manipulator or tool during of inspection operation	781	Very High Risk	1	Negligible Risk
25	2.10	Drawing in with the conveyor	150	Significant Risk	1	Negligible Risk
26	2.11	Falling of the process part in the conveyor	93	Significant Risk	1	Negligible Risk
27	3.4	Failure of the safety related part of control system - Robots	N/A	Further Review	N/A	Acceptable
28	3.5	Failure of the safety related part of control system - Mobile Platforms	N/A	Further Review	N/A	Acceptable
29	3.6	Failure of the safety related part of control system - End Effectors	N/A	Further Review	N/A	Acceptable
30	3.7	Failure of the safety related part of control system - Conveyor	N/A	Further Review	N/A	Acceptable
31	3.10	Inability to warn about status of Robot	N/A	Not Acceptable	N/A	Acceptable

3.2.4.5. Automotive pilot risk assessment conclusions

In the Annex 9.2.1 section, shows the body of design and on-site risk assessments of pilot, which show the correct application of the safety concepts developed during the development of the Automotive pilot. However, certain non-conformities are identified, and which should be corrected or considered in subsequent stages.

Also, in the development of the risk analysis of the pilot, outstanding aspects, documentary or technical, are mentioned, which may change depending on the final or actual service conditions.

Following the results obtained in the on-site evaluation of the implementation of the safety concepts applied for the Automotive pilot, and considering a forthcoming objective of industrializing the application by putting it into service, the following aspects should be taken into account:

- The risk assessment should be complemented and adapted to the actual operating conditions, considering the spatial limits of the target installation. Thus, the zone classification of the AMR paths or the robot workspaces could be different. Thus, variations on the safety concepts foreseen in this pilot may be necessary.
- Impact measurements for transient or quasi-static contacts should be performed again, when changing the conditions of the collaborative space and robot trajectories, with respect to the pilot.
- Similarly, as the final conditions vary from those of the pilot, it will be necessary to reconfigure and document the configurations and validations of safety equipment such as scanners.
- Final assembly should comply with good engineering practice and state of the art. For example, respecting electrical wiring or pneumatic installation techniques, which have not been the main focus in the development of this pilot.
- Complementary local regulations should be considered. E.g. lighting conditions, electrical supply system conditions (indirect contacts,...).
- At the documentary level, the technical dossier must be compiled, with the contents indicated in annex VII of 2006/42/EC, including the documents derived from this project or mentioned in it and adapted to the final application. It is essential to have the declarations of conformity and/or incorporation of the equipment constituting the application, as well as the rest of the mandatory documentation for this equipment, instruction and/or assembly manuals. The integrator must take them into consideration when preparing the technical dossier for the application.
- An important part of the technical dossier is the instruction manual. The contents of the manuals shall comply with Part 1.7.3 and 3.6 of Annex I of 2006/42/EC and the information for use found in the applicable type C standards (EN ISO 10218-2, ISO TS 15066, EN ISO 3691-4 and other relevant standards).
- It should be noted that the conditions of the applicable standards, both legal and technical, may change over time as a result of the evolution of technology and the state of the art. The machinery regulation 2023/1230 will be applicable in January 2027
- Operators must be trained and informed on the basis of the instruction manuals of the application and of the machines of which it is composed.

To summarize the above, the final application must be technically and documentarily validated, taking into account hazards beyond those specific to collaborative robotics, before it is put into service. After validation, the declaration of conformity will be issued by the integrator and the CE marking will be affixed to the assembly. Commissioning will then be carried out with guarantees of compliance with the regulations in force.

3.2.5. Identified limitations

A set of specific improvements need to take place before this solution can be deployed in the factory, integrated to the rest of the production system. The main limitation that needs to be overcome is the speed of collaborative robots. The factors that currently limit the robot's speed along with the identified next steps for overcoming these constraints are listed below:

- Next generation of safety regulations – one of main factors constraining robot's speed are the speed limits indicated by the safety related regulation (ISO/TS 15066 and ISO 12018). This raises the need for the R&D partners synergy with the safety related aspects technology providers towards producing new sensing devices as well as control software components that can contribute to the generation of enhanced safety regulations.

- 5G based networking capabilities – another important aspect that created delays in the assembly execution time is the communication related delays. In ODIN, a large amount of data needs to be captured, consumed and communicated across the involved actors. This may lead to bandwidth saturation delaying the transfer of information e.g., from OpenFlow to the robot and human operators’ interfaces.
- The OnRobot screwdriver utilized for the screwing actions of Operation 2 may not reach the tightening industrial requirements for the bolts. The required tightening is 70 Nm while the selected screwdriver is able to operate up to 10 Mm. Other industrial screwdrivers may be evaluated in the future like the ESTIC Handheld Nutrunner.
- The conveyor length limits the number of screwing actions by the TECNALIA robot during the 2nd operation.

3.2.6. Performance assessment of the automotive industrial pilot

3.2.6.1. Evaluation metrics and KPIs

On M06 of the project, a set of KPIs have been defined and documented in D1.1 for the automotive pilot’s evaluation. The list below provides the KPIs, the baseline and the target value as defined by STELLANTIS, as well as the ODIN solution achieved value for each KPI.

Table 4: Automotive pilot KPIs

KPI	Baseline	ODIN solution	Target
Number of models produced in the assembly line	2	4	4
Quality	95%	100% for Operation 1 90.0% for Operation 2 99.4% for Operation 3	99%
Production Costs	ROI < 12 months	ROI < 12 months	ROI < 12 months
Production throughput	60 vehicles / hour	41 vehicles / hour*	60 vehicles / hour
High risk workstations / operations	4	0	2

3.2.6.2. Validation process and results

The validation process for the industrial pilot and detailed presentation of the results per each KPI is presented in the following subsections.

3.2.6.2.1. Number of models produced in the assembly line

This KPI refers to the number of different parts (motor and gearboxes) that can be assembled using the ODIN solution. Using the ODIN solution, the investigated motor and gearbox parts are able to be manipulated using the AURA collaborative robot. Thanks to a pair of new motor and gearbox assembly models provided by STELLANTIS, the partners were able to validate the reconfigurability of the ODIN solution. The ability of ODIN solution to be easily adapted to new models is achieved through the following modules:

- Reconfigurable robot tooling: Reconfigurable grippers able grasp different motor/gearbox models with re-arrangement of gripper’s actuators and change of pins. The custom designed body of both motor and gearbox grippers enables the easy adaptation of the robotic tools to the investigated motor and gearbox models.
- Robotic perception for the environment, process and human: Detection algorithm able to detect multiple motor and gearbox variants using different detection templates.

- **Digital modules for AI based decision making:** The assembly sequence model of multiple motor and gearbox variants can be loaded to the AI Task Planner database for usage on demand by OpenFlow.

3.2.6.2.2. Quality

This KPI refers to the ratio of good to assembled products in terms of their connection but also evaluation of assembled screws, connectors and strap holders on the final assembly. The evaluation of this KPI is based on the calculation of the quality per each operation of the pilot as follows.

Operation 1: Success rate of gearbox and motor connection under operation 1 is 100%. In order to calculate this number, the assembly process executed up to 25 times in the industrial pilot demonstrator keeping statistics on how many times the connection of these two parts was successful.

Operation 2: Success rate of screwing operation of operation 2 is 90%. To validate the quality of the screw fastening operation on the engine that was transported in the conveyor belt, the operation was repeated onsite on STELLANTIS to verify the consistency and extract different metrics. Specifically, the validation experiment was designed with the following features:

- The engine was placed on the conveyor belt, with 4 different bolts accessible for the robot.

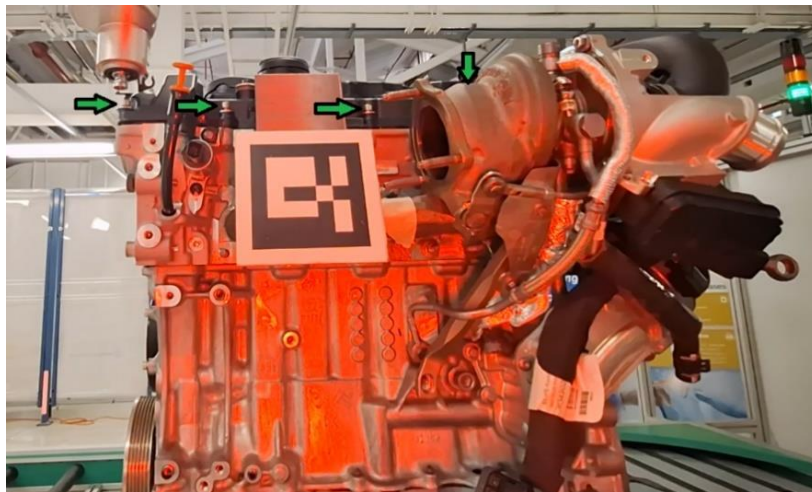


Figure 46: Screw positions on the engine

- The engine was transported thanks to the Automotive pilot's conveyor at a speed of 100mm/s.



Figure 47: Mobile manipulator fastening screws on moving engine

- Due to the positioning error of the laser-based navigation system of the mobile platform, the initial relative position between the engine and robot has a variability of up to 10cm and 5°.

Therefore, the engine was not always visible to the robot. In these cases, the start signal was triggered and the robot waited until the engine appeared on the field of view of the camera.



Figure 48: Camera view with navigation positioning error

- The screw fastening operation was repeated 25 times, including navigation to the initial screwing positions, screw fastening operation, and navigation back to the robot station area. Therefore, 100 screws were fastened in these 25 rounds.

During the validation, two metrics were recorded, the success rate and the screwing time. When the screw was not totally fastened the operation was considered a failure. The obtained results are listed below:

- 90 of the 100 screws were correctly fastened, obtaining a 90% of success rate. In all the failures, the screw was fastened to some degree although the process stopped due to some oscillations between the robot and engine.
- The mean screw fastening time (per screw) was 8'79s with a standard deviation of 0'43s. On average, 4'51s were spent approaching the screws and 4,28s fastening once the screwdriver was correctly positioned.

Operation 3: Success rate of quality inspection operation is 99.4%. In order to calculate this number, the assembly process executed up to 25 times in the industrial pilot demonstrator keeping statistics on how many parts were classified correctly. Under 4 inspection views per each run and different parts inspected per each new, only 2 parts out of 325 were classified incorrectly.

3.2.6.2.3. Production costs

This KPI refers to the relation of profits against the capital invested for deploying ODIN solution in the factory. The target from the end user side is to achieve the return of investment in less than 12 months. To measure this KPI the investment cost needs to be calculated and connected to the annual operational costs projected for the period needed to achieve the return of investment.

The payback Head To Head Point (HTHP) has been calculated for both the optimistic and pessimistic case of ODIN solution deployment and is detailly presented in the cost benefit analysis section 4.2.6.3. The optimistic case the HTHP is in 10 months, while for the pessimistic case is in 41 months.

3.2.6.2.4. Production throughput

The production throughput of the system has been measured by calculating the time needed for the production of a vehicle. In the current state of the production, 1 vehicle is produced per minute or in other words, 60 vehicles are produced within 1 hour. In the following figure, the cycle time for ODIN solution is presented, derived by the task duration analysis from the simulation of the Automotive pilot. As it is shown, the cycle time reaches up to 87 seconds that can be translated to a production throughput of 41 vehicles per hour.

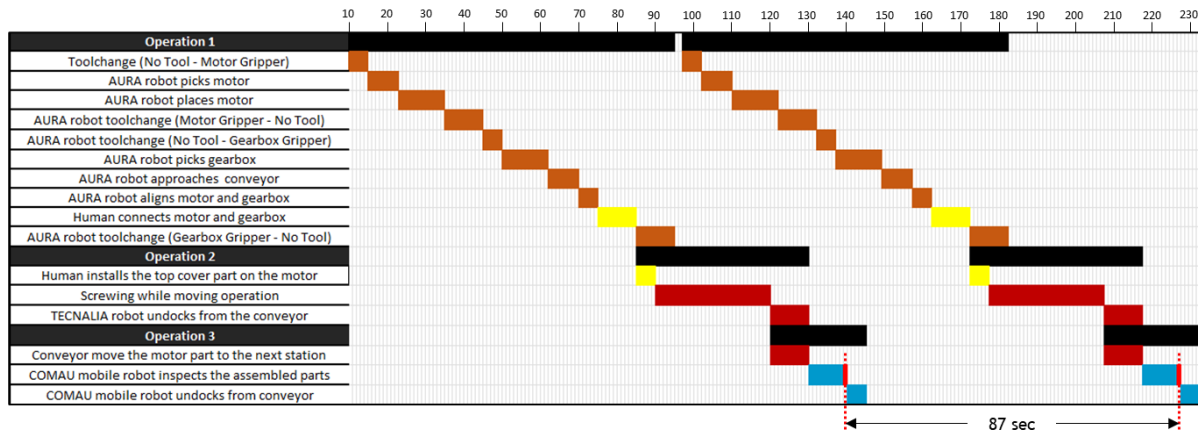


Figure 49: Production throughput of the Automotive pilot

3.2.6.2.5. High risk workstations/operations

The target for this KPI is to estimate the relative improvement in human safety. Based on the risk assessment analysis for ODIN Automotive demonstrator and the implementation of the safety concept as defined by PILZ, all the workstations of the Automotive pilot are considered as safe.

3.2.6.3. Cost benefit analysis of the automotive pilot

Concerning the economic gains, the final analysis has been performed towards the calculation of the return of investment for the current set up at STELLANTIS as well as the ODIN solution implementation case.

Two cases in terms of cost have been considered the optimistic and the pessimistic. To make a more completed analysis two group of costs have been considered for each of the cases: a) the investment cost which involves the costs for equipment acquisition and commissioning of the workstations – before starting the operation of the process and b) the operating cost which involve the annual required costs for the operation of the workstation. The following table analyses the investment cost that was required for the current set up at STELLANTIS as well as the for the two cases of ODIN solution implementation.

Table 5: Investment cost of Current STELLANTIS state vs ODIN solution (2 cases)

Cost category	Current STELLANTIS state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Equipment Cost	460.000€	598.500€ (150.000 for AURA, 8.000 for AURA installation plate, 70.000 for COMAU Mobile robot, 165.000 for TECNALIA robot, 49.000 for conveyor, 30.000 for grippers, 9.000	711.700 (170.000 for AURA, 10.000 for AURA installation plate, 90.000 for COMAU Mobile robot, 200.000 for TECNALIA robot, 52.000 for conveyor, 35.000 for grippers, 12.000

Cost category	Current STELLANTIS state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
		for screwdriver, 12.000 for tables / fixture, 9.000 tool changer, 6.000 for PLC, 4.000 for safety barriers, 500 for emergency/reset buttons, 10.000 for laser scanners, 10.000 for RC cameras, 10.000 PCs, 40.000 software licenses, 16.000 consumables and other sensors)	for screwdriver, 14.000 for tables / fixture, 11.000 tool changer, 7.000 for PLC, 5.000 for safety barriers, 700 for emergency/reset buttons, 12.000 for laser scanners, 12.000 for RC cameras, 11.000 PCs, 42.000 software licenses, 28.000 consumables and other sensors)
Commissioning labour cost	83.000€	51.500€	100.000€
Energy lines yearly cost (Electric, Pressurised air etc.)	100.000€	100.000€	120.000€
Total investment Cost (€)	643.000 €	750.000 €	931.700 €

In the following table, the operating costs of the above cases has been estimated by the consortium based on current values from the end user and experience of the technology providers and the system integrators.

Table 6: Operating cost of Current STELLANTIS state vs ODIN solution (2 cases)

	Current STELLANTIS state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Engineering cost (per year)	19.800€	10.000€	10.000 €
Maintenance cost (per year)	3.000€	6.000€	6.000 €
Electricity, pressurized air (per year)	70.000€	84.000€	84.000€
Labor cost (3 person, 2 shifts, 45k€) (per year)	270.000 €	135.000€ - (1.5 person, 2 shifts, 45k€) (per year)	180.000€ - (1.5 person, 2 shifts, 60k€) (per year)
Total running Cost (€)	362.800 €	235.000 €	280.000 €

Based on the above analysis, the payback Head To Head Point (HTHP) has been calculated for both the optimistic and pessimistic case of cell deployment. As illustrated in the following figure, in the optimistic case the HTHP is in 10 months, while for the pessimistic case is in 41 months.

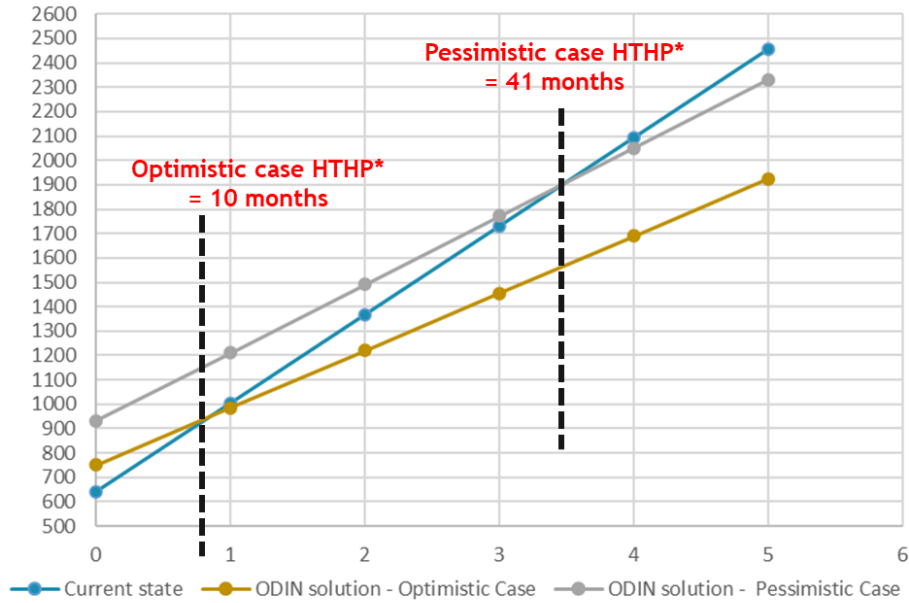


Figure 50: HTHP¹ after ODIN solution deployment

The ODIN partners estimate that the realistic case for ODIN solution is the Optimistic one with the HTHP calculated at 10 months.

3.2.7. Feedback received for ODIN solution

After the integration of ODIN solution at STELLANTIS premises, ODIN partners had the chance to organize a series of workshops with operators and managers from the STELLANTIS group in order to showcase the results of ODIN project. During these workshops, the users were able to test the Augmented Reality application of ODIN as well as perform the motor and gearbox connection using the manual guidance feature of the AURA robot.



Figure 51: Workshop organized at STELLANTIS factory

¹ Payback Head To Head Point (HTHP)

LMS in collaboration with STELLANTIS drafted a questionnaire with key questions in order to collect valuable information from the users of ODIN solution. This questionnaire included general questions regarding the flexibility and the functionality of overall ODIN solution but also technical questions more focused on the AR application, the manual guidance functionality of AURA robot and the screwing while moving operation. This questionnaire is presented in the following figure.

Figure 52: Automotive pilot questionnaire

Using the feedback from the collected questionnaires, ODIN partners were able create statistics regarding the functionality of the overall ODIN solution as well as their modules.

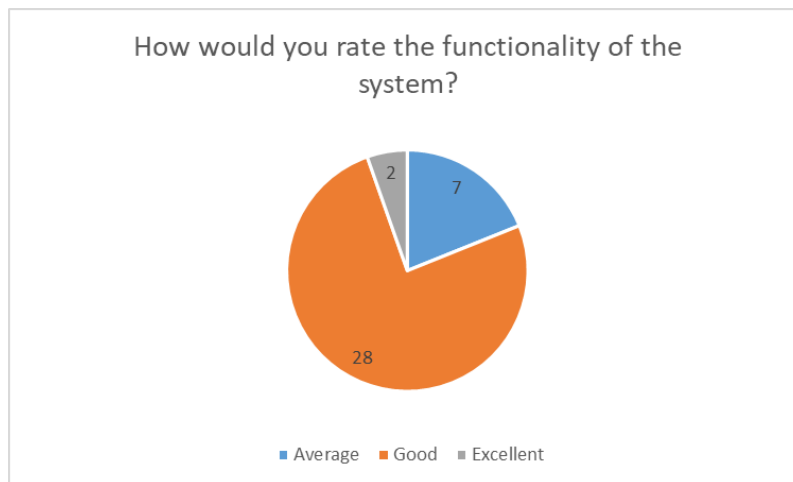


Figure 53: Evaluation of ODIN solution functionality in STELLANTIS demonstrator

Regarding the first operation of the Automotive pilot, ODIN partners were able to evaluate how comfortable do the operators feel when using ODIN solution’s modules to perform the assembly process as presented below.

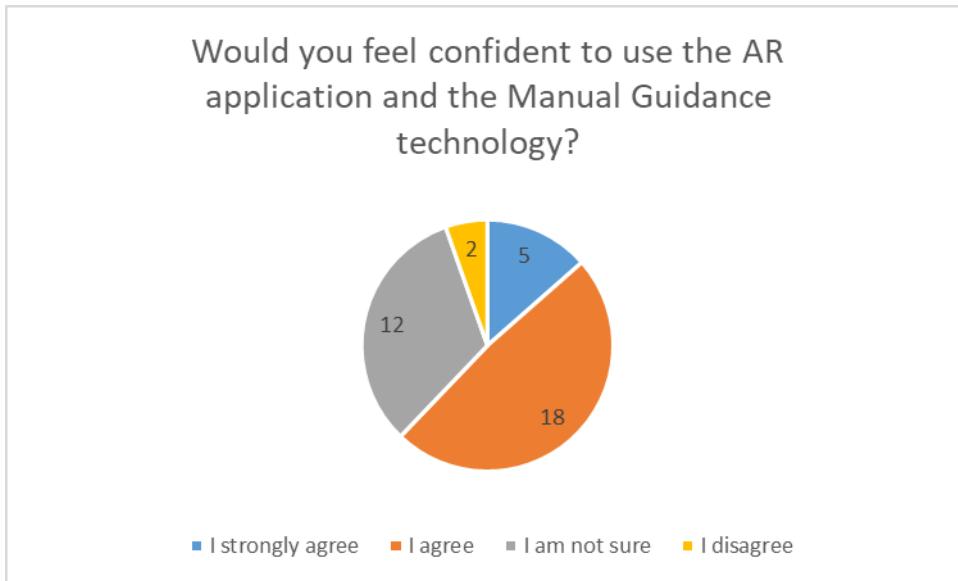


Figure 54: Evaluation of how much confident the operators are while using the ODIN AR application and MG technology

Additionally, the operators tested the ODIN solution provided valuable feedback on how much comfortable they felt while co-existing with the mobile and the AURA robots.

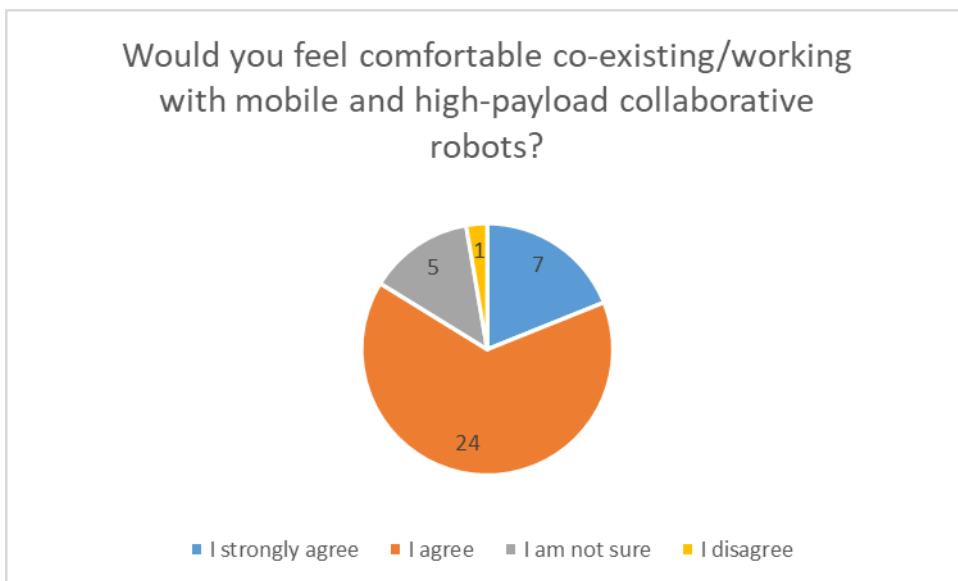


Figure 55: Evaluation of how much comfortable the operators are while using the ODIN solution

4. ODIN AERONAUTICS PILOT DEMONSTRATOR

4.1. Overview

The ODIN Aeronautics pilot demonstrator has been prepared to show the usability and flexibility of a mobile manipulator and tools in very diverse works that are involved in the manufacture of a fan cowl. This demonstrator is centered in three main steps: the fan cowl transportation, the fan cowl drilling and the fan cowl inspection.

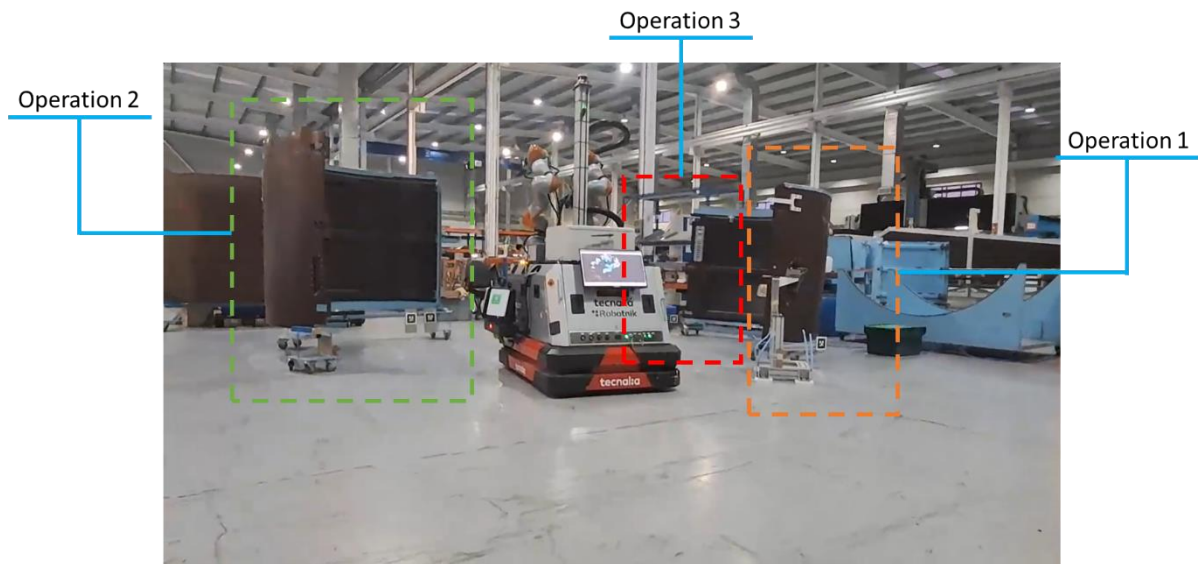


Figure 56: Aeronautic pilot demonstrator layout at AEROTECNIC premises

4.2. Aeronautics pilot - Industrial demonstrator

AEROTECNIC has provided the premises of AEROTECNIC Composites in Cadiz. There, they actively perform the required tasks to get the finished fan cowl from a simple composite part. During this process, the task of transport, drill and inspect are key for the correct manufacture of the part.

The demonstrator place at AEROTECNIC was limited to an area of 15m x 15m. There were two fan cowls prepared for the three use cases, one mounted on a transportation cart and the other was ready to perform inspection and drilling. For the transportation use case, the transportation cart was ready to work with a magnetic docking system to attach the mobile manipulator with the fan cowl. In the case of the drilling use case, near the drilling area, a fast tool exchanger was prepared. And for the case of the inspection, the mobile manipulator was equipped with two types of cameras and in the fan cowl some distinctives parts were mounted to check if all of them were in correct positions.

- Operation 1: Template base drilling

This operation is centered in the fan cowl drilling using the existing templates. For this reason, the TECNALIA mobile robot approaches the drilling station and the robot autonomously grabs the driller from the tool exchanger. With the robot correctly positioned in front of the fan cowl with the driller, the robot is able to detect the template and perform the drilling operation.



Figure 57: Execution of drilling operation at AEROTECNIC premises

- Operation 2: Fan cowl transportation

The autonomous robot of TECNALIA navigates to the station where the fan cowl is ready to be transported. There, using a designed magnetic docking, the fan cowl cart is attached to the robot. With the fan cowl in the correct position, the robot navigates along the AEROTECNIC premises to the next station where the part is required. When it arrives, the cart is detached, and the robot continues with the next task in the schedule.

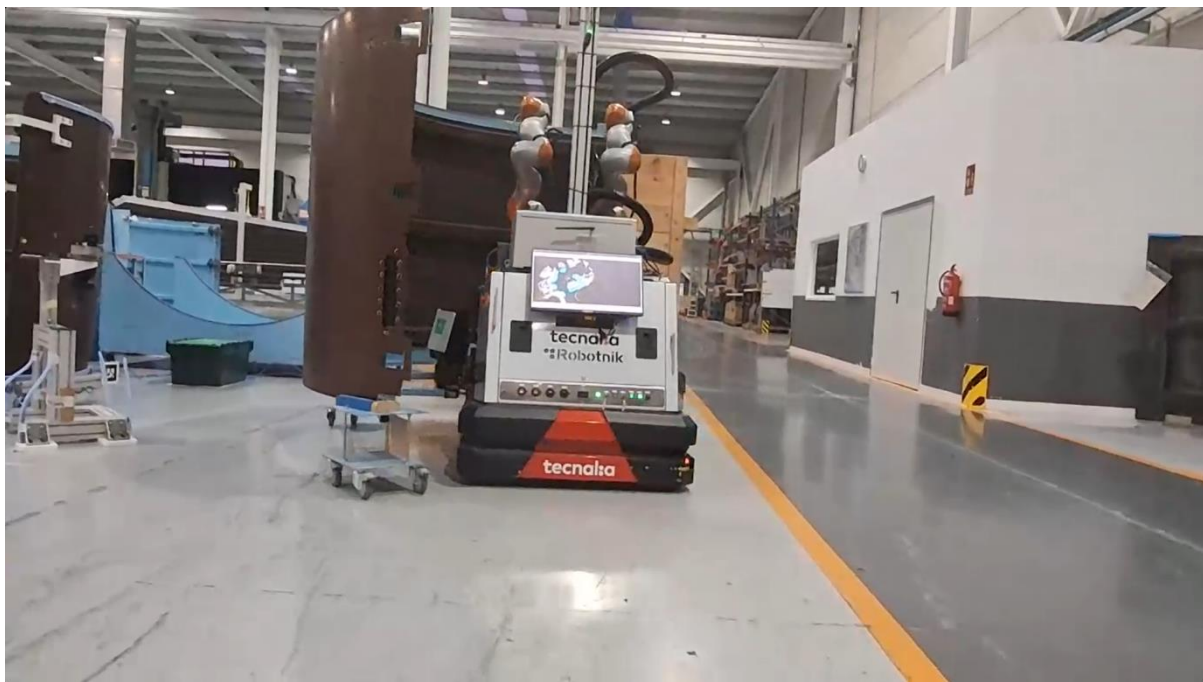


Figure 58: Execution of transportation operation at AEROTECNIC premises

- Operation 3: Quality inspection

The last operation is related to the automation of the quality inspection of the works performed in the AEROTECNIC premises. For this operation, the robot navigates autonomously to the inspection station and there it has the two inspection options. The first one, using a Photoneo 3D sensor checks the features of the scanned part and confirms if they are correctly positioned. The second option is the Keyence sensor to detect presence and absence of parts and if the mounting is correct.

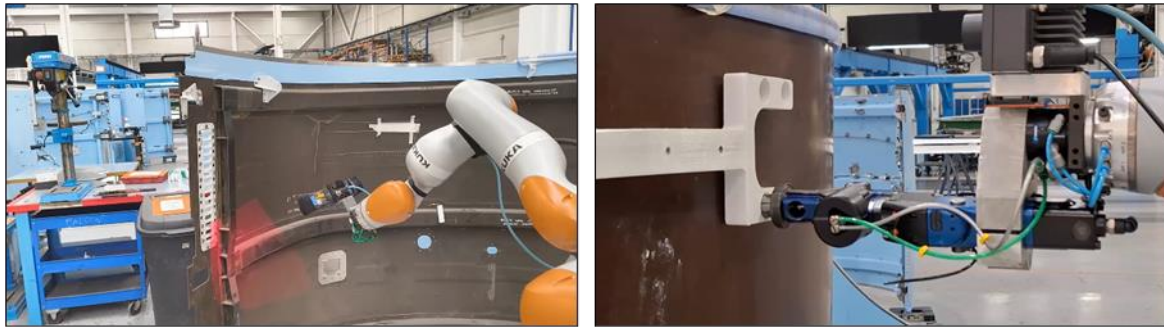


Figure 59: Execution of inspection operation at AEROTECNIC premises

4.2.1. Integration of Open Component with Aeronautics industrial pilot

The modules related to the Open Component for the drilling, transport and inspect operations have been integrated in the Aeronautic demonstrator of ODIN at AEROTECNIC premises. The integration of the Open Component modules in the industrial pilot of the Aeronautics use cases are presented in the following subsections.

4.2.1.1. Autonomous mobile manipulators

The TECNALIA autonomous mobile manipulator was prepared for the multiple use cases that have been performed in the Aeronautic pilot of ODIN. In the next sections, the improvement that have been integrated are described by use case.

- Operation 1: Template base drilling

For the use case of drilling the new version of the tool exchanger has been developed with the following considerations in mind:

- Fixed: the tool exchanger usage must be as repeatable as possible to avoid some mismatch in tool grab and release process.
- Portable: with the intention of avoiding make some work in AEROTECNIC premises, the base of the tool exchanger is composed of 4 pads generating vacuum to fix the base in ground.
- Independent: the physical connections between tool exchanger and the fan cowl stand have been eliminated.



Figure 60: Tool exchanger

To detect the drilling template, the ROBOCEPTION rc_visard 65 [2] is mounted on the left arm of the robot. Using the ROBOCEPTION cad matching technique, the template is detected in the fan cowl and then the drilling holes positions are calculated to achieve the process.



Figure 61: ROBOCEPTION camera mounted on the left arm

The selected driller for the ODIN solution is the SETITEC ST1200 [15]. This driller is pneumatic based and works automatically when the air is activated.



Figure 62: SETITEC ST1200 driller attached to the left arm

To perform the drilling operation, the deployed demonstrator was divided in the following steps:

1. The robot navigates to the drilling station autonomously.
2. The robot docks where the drilling operation must be performed.
3. The driller is grabbed from the tool exchanger.
4. The drilling template is detected and the trajectories to move into the holes are being calculated.
5. The robotic arm inserts the driller in the holes and execute the drilling.
6. When all the drills are completed, the driller is released in the tool exchanger.
7. Finally, the mobile robot undocks from the drilling station and continues with the next task in the scheduler.

- Operation 2: Fan cowl transportation

In the use case of the transportation the main efforts were dedicated to tuning the robot where the navigation includes the fan cowl. Firstly, some improvements were made in the self-detection management when the fan cowl is attached to the robot because it was made with non-rigid union. Also, it was necessary the footprint optimization, considering the balance between the navigation and the safety.



Figure 63: Magnetic docking for fan cowl transportation in the robot

This footprint's change is depending on if the robot is navigated with or without the attached fan cowl. For that reason, a dynamic reconfigure of the footprint was deployed that can change between different states using the signals from the safety module.

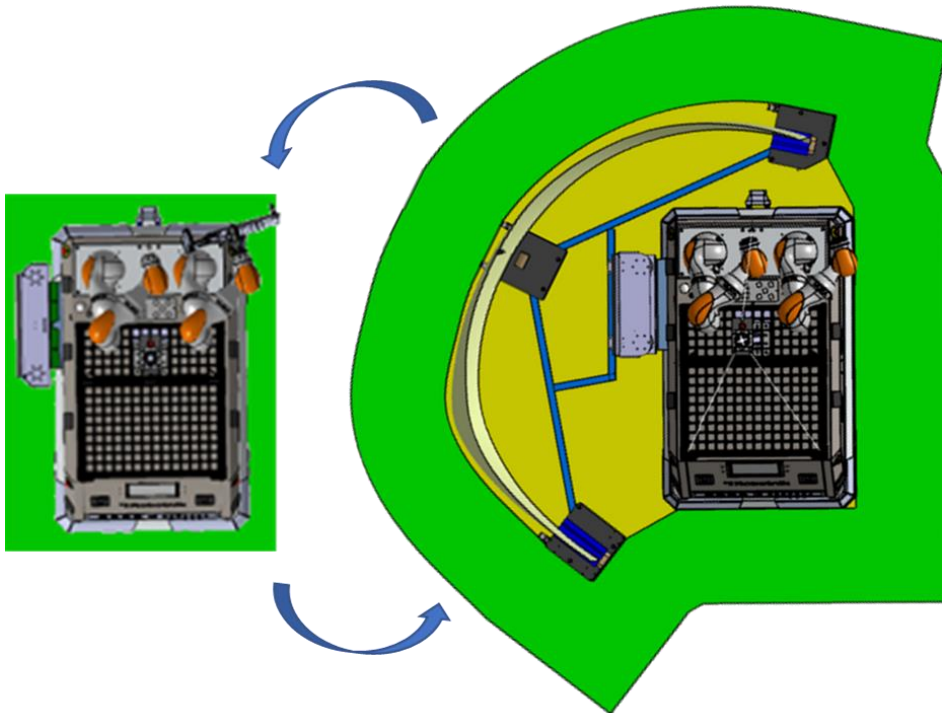


Figure 64: Footprint reconfigure with and without fan cowl attached

To attach and detach the fan cowl cart and the robot a magnetic docking was designed by AEROTECNIC. This device is connected to the SICK Flexisoft [14] safety signals to change between different states and control the connection in a safe and robust way.



Figure 65: Magnetic docking designed by AEROTECNIC

To perform the fan cowl transportation, the deployed demonstrator was divided in the following steps:

1. The robot navigates to the transportation station autonomously.
2. The robot docks in the transportation cart position in 2 steps, front approach and lateral docking
3. The magnetic docking device capture the fan cowl cart.
4. The robot navigates with the fan cowl attached where the part is required for the next step.
5. The magnetic docking device release the fan cowl cart.
6. The robot undocks from the cart in 2 steps, first lateral undocking and then go back to complete the separation. When the undocking is completed, the robot continues with the next task in the scheduler.

- Operation 3: Quality inspection

Finally, for the quality inspection operation, the following features have been implemented and integrated. The Photoneo MotionCam-3D [16] ROS driver has been improved to add support to work in continuous acquisition mode. An eye-in-hand calibration pattern based on RGB pattern and Ceres is now ready to get more precise results. To create more accurate scanning trajectories, the teaching-based methodologies have been improved, avoiding the configuration changes and the appearance of singularities.



Figure 66: Photoneo MotionCam-3D mouter on right arm

Also, a new Keyence sensor has been integrated for 2D inspections. This new sensor is used to detect the presence or absence of the components of the fan cowl. Checks if the rivet installation and control the distance measurements to assure if all the assemblies are correctly made.

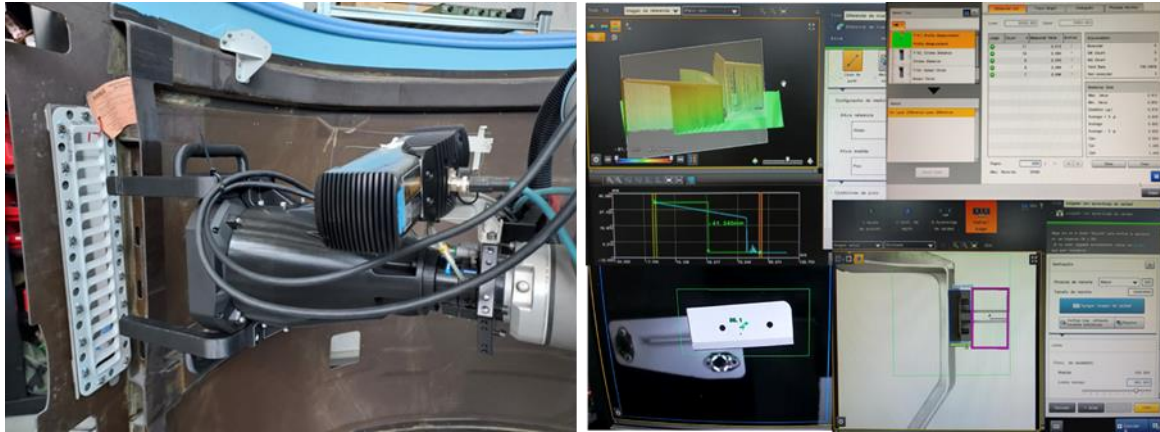


Figure 67: Keyence camera mounted on right arm and recovered data

The following steps are required to complete the execution of the quality inspection operation:

1. The robot navigates to the inspection station autonomously.
2. The robot docks where the inspection operation must be performed.
3. The sensor is activated, and the right arm move following the taught trajectory to complete the scan.
4. The scan data is stored and analysed to find any defect that was produced in the part assembly process.
5. When the inspection is completed, the robot undocks the station and continues with the next task.

In the case of the two sensors the execution flow is the same, the differences come from how they work. The photoneo sensor get continuous information and compare with a valid part. The Keyence gets discrete photos and analyses if the data is under the required validation parameters.

4.2.1.2. Robotic perception for the process, the human and the environment

The preparation phase begins with the operator using a teaching system to program the robot's scanning trajectories. This process leverages a 6D joystick, allowing the operator to physically guide the robot along the surface of the component that needs to be inspected. The teaching system provides an intuitive and straightforward way to define paths for the robot.

The teaching system is basically what has been already introduced in Subsection 3.2.1.4, although some minor modifications had to be introduced due to the specific requirements of the scanning process, which are described in Subsection 3.2.1.3.

This approach is particularly advantageous because it allows operators to easily adapt the scanning trajectories for components of varying shapes and sizes. Unlike rigid pre-programmed methods, this flexibility ensures that the system remains versatile and responsive to different inspection requirements. In order to be able to have a successful reconstruction the scanning process has to guarantee that the inspected part is within the depth limits of the sensor; the operator can visualize the real-time depth map while performing the trajectory, and adapt the movements to ensure that this is fulfilled. The teaching procedure also allows the operator to adapt to the complexity of the part, spending more time in those more populated areas or that needs to be reconstructed in more detail.

The scanning process is initiated from a docking position to guarantee the highest level of precision. The docking position serves as a reference point, ensuring that all subsequent movements and measurements maintain their accuracy relative to the component.

The execution phase is where the robot performs the inspection process, translating the preparation into precise and efficient operation. This phase begins with the robot docking itself to the component being inspected. To achieve this, the robot uses a marker attached to the component as a reference point, ensuring accurate alignment and calibration. The docking process establishes a reliable starting position,

crucial for maintaining precision throughout the inspection (a detailed explanation of the docking mechanism is provided in another section of this document).

Once docking is complete, the robot prepares for the scanning process by retracting its right arm. This movement is designed to prevent any potential collisions with the left arm, which will be actively engaged in scanning the component (see Figure 68). Ensuring that the arms operate independently without interference is essential for maintaining smooth operation and avoiding any interruptions during the scan.



Figure 68: Robot configuration with the right arm retracted prior to scan

With the scanning area secured, the robot begins executing the trajectories defined during the preparation phase (see Figure 69 for a snapshot during a scan trajectory). These pre-determined paths guide the scanning equipment systematically over the surface of the component, ensuring comprehensive coverage. As the robot progresses through the trajectory, it collects high-density point clouds using the Photoneo MotionCam-3D camera, which represent precise measurements of the component's geometry. These individual datasets are not used and processed in isolation; instead, they are seamlessly fused in real-time into a single, unified reconstruction. This integration process ensures that the final 3D model of the component is both consistent and accurate, providing a complete representation of its surface geometry.



Figure 69: Running a scan and reconstruct process

In comparison with previous implementations reported in previous deliverables, the pointcloud fusion algorithm which was previously Voxblox [17] has been substituted by VDBFusion [18]. Both VDBFusion and Voxblox are advanced volumetric mapping systems that use Truncated Signed Distance Fields (TSDFs) to represent 3D environments. Despite their shared foundation, VDBFusion introduces significant improvements over Voxblox in multiple areas, including data structure, flexibility, performance, map accuracy, and storage capabilities.

One of the key differences lies in their underlying data structures. VDBFusion utilizes the OpenVDB library, which is based on a hierarchical structure that is both scalable and memory-efficient. This design contrasts with Voxblox's voxel hashing approach, which is less optimal for large-scale environments. The hierarchical nature of VDBFusion's data structure allows for faster voxel access and more efficient memory use, leading to better performance, particularly when mapping complex or expansive environments.

When it comes to performance, VDBFusion demonstrates notable efficiency. This computational efficiency is complemented by better memory management, resulting in lower memory consumption and the production of smaller, more compact map files. These characteristics make VDBFusion particularly advantageous for applications with stringent hardware limitations or where resource efficiency is critical.

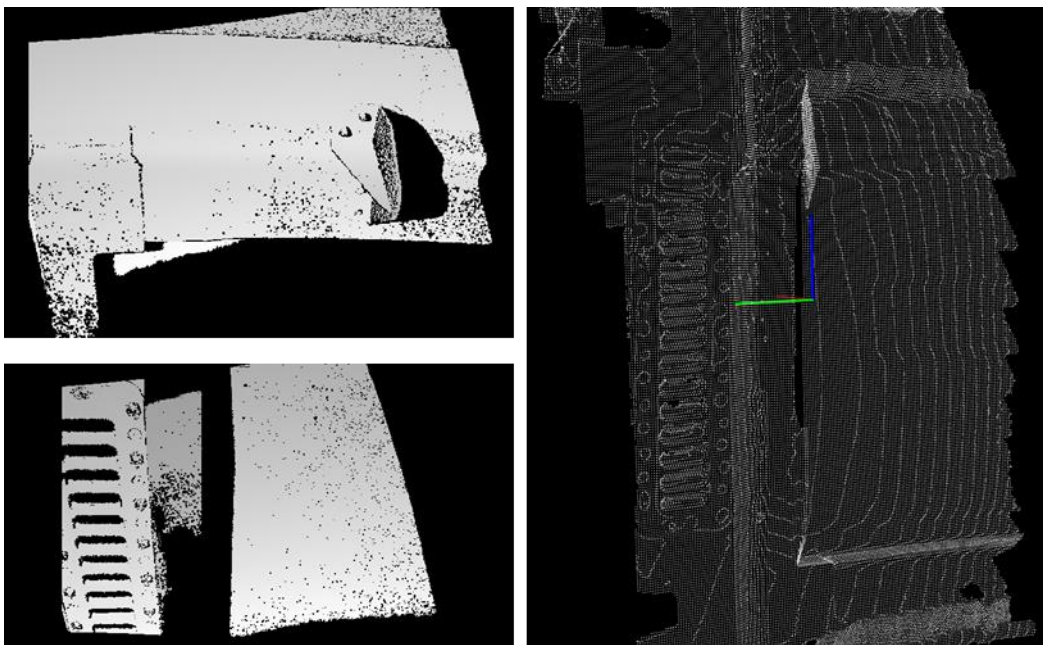


Figure 70: View of two example input pointclouds (depthmaps) and the resulting pointcloud reconstruction

The maps generated by VDBFusion are more accurate than those produced by Voxblox, as evidenced by comparative experiments on multiple datasets. This higher level of precision is partially attributed to the advanced VDB data structure, which reduces projection errors and enables more precise surface reconstructions. Moreover, VDBFusion incorporates a space carving feature, which allows for the removal of dynamic objects from the map. This capability is essential for maintaining the integrity and accuracy of the map in environments with moving obstacles or other sources of noise.

Figure 70 shows an example of the reconstruction generated along with two sample depthmaps generated by the 3D sensor during the scanning procedure.

4.2.1.3. User friendly robot programming interfaces

The teaching mechanism used in this process is the same as described in Subsection 3.2.1.4. This system is designed for simplicity and efficiency, enabling the operator to define new scan trajectories with ease

and adapt to different part references without significant effort. While the mechanism provides flexibility, the scanning process itself introduces specific challenges that require adjustments.

For the reconstruction algorithm to function correctly, it relies on receiving valid point clouds. This requirement can be problematic because the sensor used for scanning operates within a limited depth range. During the teaching process, when trajectories are defined in Cartesian space, there is a risk of configuration changes occurring. Configuration changes lead to the sensor to orient toward areas outside its measurable depth range. When this happens, the reconstruction algorithm may fail to generate accurate results due to invalid or missing data. To address this issue, the teaching mechanism has been modified to store trajectories in joint space rather than Cartesian space. By doing so, configuration changes are avoided, ensuring the sensor remains within its valid measurement range throughout the scan trajectory execution process. This modification improves the reliability of the data acquisition process and reduces the likelihood of reconstruction failures.

An additional benefit of this change is the reduced sensitivity to singularities during trajectory execution. Scan trajectories typically require the robot to traverse its entire workspace, which often involves moving near or through singularities (as in Figure 71). Storing and executing trajectories in joint space inherently limits the impact of singularities on the robot's movement. This improvement is particularly significant for scanning operations, where uninterrupted and precise motion is critical to ensure comprehensive and accurate data collection.



Figure 71: Scanning close to singularity configuration

4.2.2. Integration of Digital Component with Aeronautics industrial pilot

All the Digital Component modules have been integrated and validated in the industrial demonstrator of the automotive pilot at AEROTECNIC premises as presented in the following subsections..

4.2.2.1. Digital Simulation

In the last integration of the aeronautic case, the scenario has been developed in AEROTECNIC premises after all the elements are located definitely. This simulation only takes into consideration the used involved parts in the real environment.

4.2.2.2. Digital Twin

As already documented in section 3.2.2.2, the Digital Twin of ODIN provides visualization and connectivity features through the Visual Components software. The Digital Twin of the Aeronautics pilot integrated at AEROTECNIC premises includes the following information:

- TECNALIA mobile robot.

Thanks to Digital Twin module's connection with OpenFlow, the navigation of TECNALIA mobile robot's and its arms' movements can be visualized also inside the Visual Component software dynamically using data from the physical robot received during the assembly process execution.

- One Fan cowl mounted in a cart used for the transportation operation.
- One Fan cowl with some parts to analyze in the inspection operation and the template for drilling operation.
- The tool exchanger.

Place where the driller is positioned by default in the drilling station. There the driller can be connected to the required air to be able to work and make the required holes.

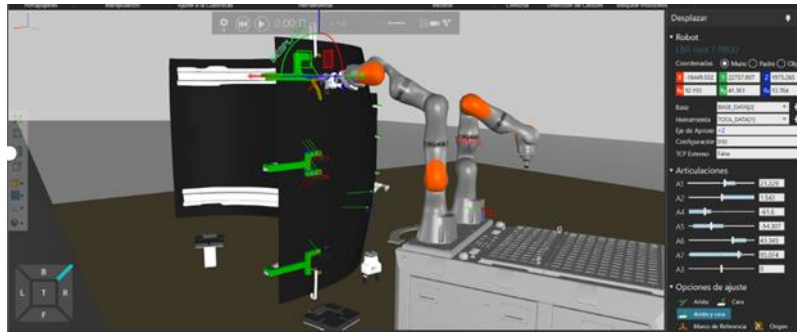


Figure 72: Aeronautic demonstrator simulation layout

The communication of the digital twin has been validated in the Automotive use case at AEROTECNIC premises in real time. Due to some issues and priorities, the aeronautics use case has been tested with some rosbags that have been recorded in real time.

4.2.3. Integration of Networked Component with Aeronautics industrial pilot

All the Networked Component modules have been integrated and validated in the industrial demonstrator of the automotive pilot at AEROTECNIC premises.

4.2.3.1. OpenFlow

The aeronautics pilot case, located at AEROTECNIC premises, has been deployed to manage the correct flow of the different operations that have been integrated. It coordinates the execution of the tasks that are scheduled through the internet portal and command it to the robot where the skill engine acts as the main controller. As the progress of the process is completed, the monitor checks the status, and the system continues with the following tasks.

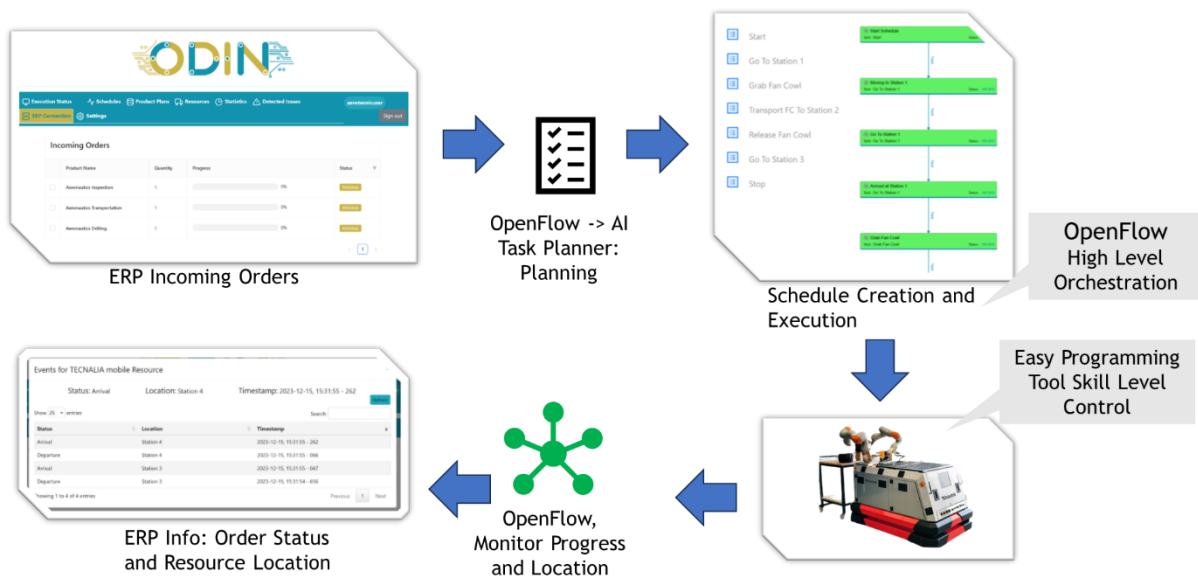


Figure 73: OpenFlow process cycle for aeronautic pilot site

4.2.3.2. Cyber Security

The final version of the cyber security module has been integrated in the Aeronautics case pilot demonstrator at AEROTECNIC for the detection of cyber security threats in the local network of the robots. As presented in D4.3, this module is based on the connection of three different computers. As it can be seen in Figure 74, the cybersecurity module is in charge of the detection of cybersecurity events in the monitored endpoint. The monitored endpoint is the computer where the OpenFlow component is installed. The detected cybersecurity incidents are sent to the SIEM in alert format, that is in the S21Sec cloud. This component is in charge of the normalization and initial analysis of the alerts, and it is also in charge of the selection of alerts that should be further analyzed. These alerts are sent to the SOAR. The SOAR is in charge of analyzing these alerts and implementing the necessary responses. In order to notify the cybersecurity issues to the operator in order to implement actions in the robotic system, the Alert checker component has been developed and deployed in the Monitored endpoint (in AEROTECNIC premises). This component oversees collecting the representative alerts from the SOAR and writing them in a ROS topic. Analyzing this topic, the robot operator can implement actions in the environment, avoiding thus the problems that the detected attack might produce.

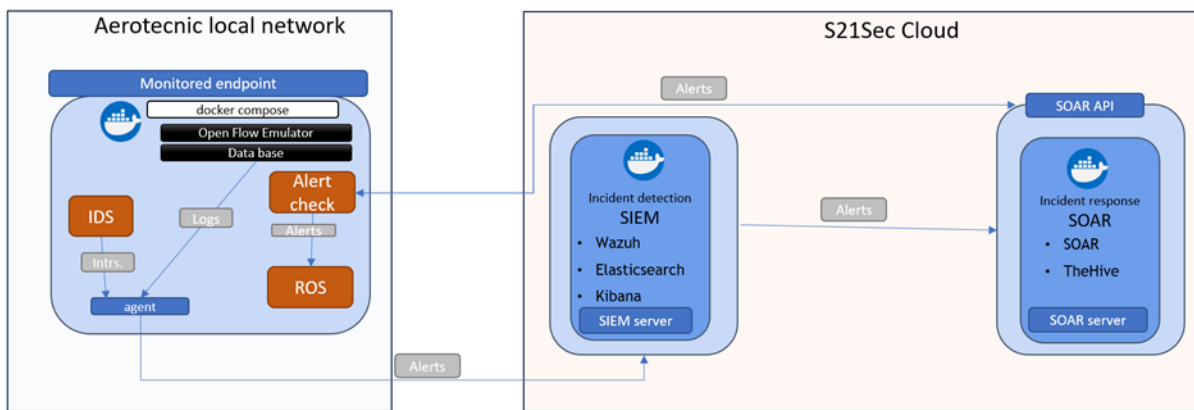


Figure 74: Cybersecurity module deployment in Aeronautic pilot

In this case, the detection and response to a denial of service (DoS) attack has been tested. For this purpose, a Docker container has been deployed inside the monitored endpoint to simulate an attacker inside the network. From this container, the attack on the monitored endpoint was launched, indicating its IP address (Figure 75).

```

root@ae919816c68d: / 100x55
(root@ae919816c68d)-[/]
# hping3 10.108.43.250 -q -n -d 120 -S -p 80 --flood
HPING 10.108.43.250 (eth0 10.108.43.250): S set, 40 headers + 120 data bytes
hping in flood mode, no replies will be shown
^C
--- 10.108.43.250 hping statistic ---
393691 packets transmitted, 0 packets received, 100% packet loss
round-trip min/avg/max = 0.0/0.0/0.0 ms
    
```

Figure 75: DoS attack to the monitored endpoint

As soon as the attack has been launched, the intrusion detector (IDS) has detected the attack as shown in Figure 76 and reported it to the Wazuh agent to send it to the SIEM.

```

12/10/2024-09:51:06.678141  [**] [1:5:0] LOCAL DOS SYN packet flood inbound, Potential DOS [**] [Classification: Misc activity] [Priority: 3] {TCP} 172.18.0.2:6631 -> 10.108.43.250:80
12/10/2024-09:51:06.678141  [**] [1:6:0] LOCAL DOS SYN packet flood outbound, Potential DOS [**] [Classification: Misc activity] [Priority: 3] {TCP} 172.18.0.2:6631 -> 10.108.43.250:80
    
```

Figure 76: Detection of DoS by IDS

Figure 77 shows the alert in the SIEM where enriched information has been added from the external, such as the Mitre technique code (T1498).

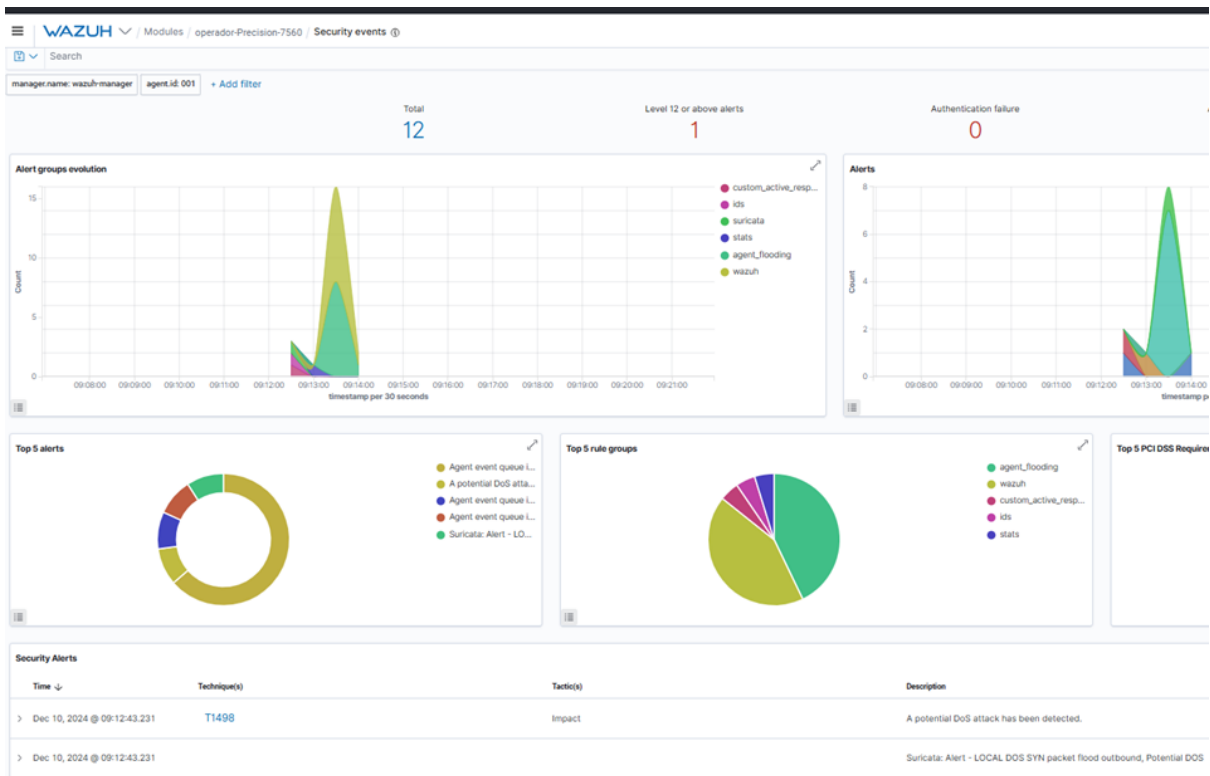


Figure 77: DoS attack detection in the SIEM

Because this alert is critical, it has a level of 12 and is sent to SOAR. Figure 78 shows this alert in the SOAR. Details of the alert in the SOAR is presented in Figure 79.

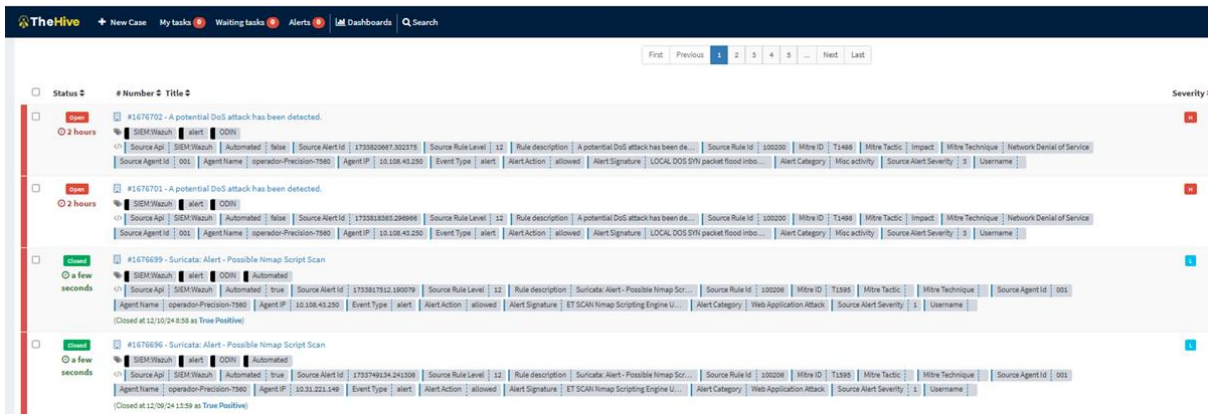


Figure 78: DoS alert in SOAR

The screenshot displays the SOAR interface for a specific alert. At the top, the navigation bar includes 'TheHive', '+ New Case', 'My tasks', 'Waiting tasks', 'Alerts', 'Dashboards', and 'Search'. The main content area shows the alert details for case # 1676702. The alert title is 'A potential DoS attack has been detected.' and its severity is 'H'. The TLP is 'TLP:RED' and the PAP is 'PAP:AMBER'. The assignee is 'Wazuh TH integration OdinTecnalia' and the date is '12/10/24 9:51'. The alert has 8 cases and 1 alert. The tags are 'SIEM:Wazuh', 'alert', and 'ODIN'. The additional information table includes fields like Source Api, Source Rule Level, Mitre ID, Source Agent Id, Event Type, Alert Category, Automated, Rule description, Mitre Tactic, Agent Name, Alert Action, and Source Alert Severity.

Basic Information	
Title	A potential DoS attack has been detected.
Severity	H
TLP	TLP:RED
PAP	PAP:AMBER
Assignee	Wazuh TH integration OdinTecnalia
Date	12/10/24 9:51
Tags	SIEM:Wazuh alert ODIN

Additional information			
Source Api	SIEM:Wazuh	Automated	False
Source Rule Level	12	Rule description	A potential DoS attack has been detected.
Mitre ID	T1498	Mitre Tactic	Impact
Source Agent Id	001	Agent Name	operador-Precision-7560
Event Type	alert	Alert Action	allowed
Alert Category	Misc activity	Source Alert Severity	3

Figure 79: DoS alert detail in SOAR

The Alert collector component collects this alert from the SOAR by making an API call, transforms the alert and writes it to the corresponding ROS topic in the monitored endpoint. This alert in ROS allows different options, but in this case, due to the severity of the detected attack, it has been decided to stop the process of the robots.

4.2.4. Aeronautics pilot safety concept integration with aeronautics industrial pilot

This section aims to detail the integration of the safety concept and the outcomes of the Risk Assessments performed for the Aeronautics pilot at AEROTECNIC premises.

4.2.4.1. Aeronautics pilot safety concept integration

The safety concept validation procedure conducted at AEROTECNIC premises was based on a set of requirements outlined in the document provided in **Annex 9.1.2**.

To enhance understanding of the overall pilot safety concept, the integration of safety devices will be detailed in separate subsections for each operation.

4.2.4.1.1. Operation 1: Template base drilling

- Safety zones of the scanners adjusted when the mobile platform is in drilling position

The main objective concerning the safety of the drilling operation was to adapt the safety zones of the scanners throughout the entire sequence of the operation. As the mobile platform approaches the drilling position (Figure 80), the scanner safety areas are adjusted and adapted in compliance with the standard mentioned in D5.4. By using the contour detection safety function of SICK scanners, it is ensured that the several key points are detected, confirming that the mobile platform has arrived to the drilling position and ready to begin the operation process safely.



Figure 80: Mobile platform in drilling position

Once the robot arms begin the drilling operation, the scanner safety zones of the mobile platform are further adjusted to extend the safety areas, ensuring comprehensive coverage of key areas where potential hazards may arise if an operator enters (Figure 81). If any of the safety zones are triggered, all components performing the drilling operation are immediately stop.



Figure 81: Safety areas distance verifications

4.2.4.1.2. Operation 2: Fan cowl transportation

- Adaptation of the safety zones of the scanners when the fan cowl is coupled to the mobile platform

The adaptation of the scanner safety zones when the mobile platform is coupled to the fan cowl was a critical verification step in the safety process. The adjustment ensures that the safety zones are

appropriately configures to account for the new configuration of the mobile platform transporting the fan cowl, maintaining optimal detection capabilities and hazard prevention in accordance with D5.4.

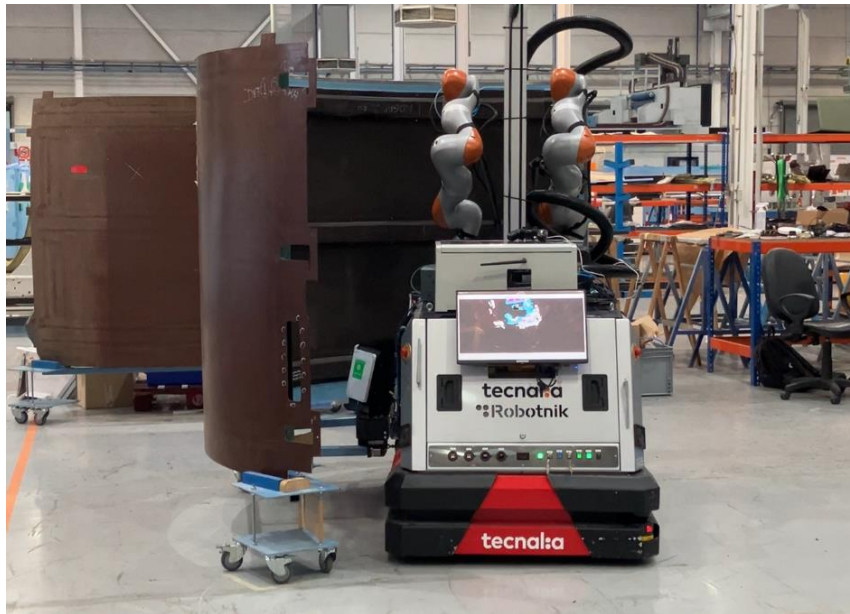


Figure 82: Mobile robot's coupling with fan cowl

- Safety stop activation in the event of decoupling between the mobile platform and the fan cowl

For the transportation operation, a safety magnetic sensor was integrated to ensure secure coupling between the mobile platform and the fan cowl, as described in D5.4. This sensor verifies that the coupling process is completed accurately, offering real-time feedback to the system on the status of the connection. By continuously monitoring alignment and coupling integrity, the sensor significantly enhances safety, ensuring reliable and secure operation throughout the transportation process.



Figure 83: Magnetic sensor used for attaching the fan cowl to the mobile platform

An emergency stop is activated if the safety magnetic sensor detects that the mobile platform is not properly attached to the fan cowl or if it becomes detached during the transportation operation. The following figure illustrates the activation of an emergency stop during the transportation operation, triggered by the detachment of the safety magnetic sensor.



Figure 84: Emergency stop due the detachment of the safety magnetic sensor

4.2.4.1.3. Operation 3: Quality inspection

- Adaptation of the scanner safety zones when the mobile platform is in the inspection position

Similar to drilling operation, during inspection operation, as the mobile platform approaches the inspection position, the scanner safety zones are adjusted in accordance with safety standards described in D5.4. By using the contour detection functionality of the SICK safety scanners, the system can confirm that the mobile platform is in the inspection position using several reference points detected, this ensures that the mobile platform is accurately positioned in the inspection area and is ready to begin the inspection process. Additionally, the safety zones of the scanners are adapted to monitor critical areas, ensuring that if an operator enters the hazard zone, all components involved in the inspection operation are immediately stopped. Figure 85 illustrates the verifications conducted to confirm this functionality.



Figure 85: Safety verifications during inspection operation

4.2.4.2. Aeronautic pilot risk assessment results

The following section presents a summary of the initial and final risk assessment conducted for the Aeronautic pilot. This analysis aims to identify, evaluate, and mitigate potential risks that could impact safety outcomes. Table 7 outlines the key risks identified.

Table 7: Aeronautic pilot risks identified

Priority	Hazard No	Hazard Name	PHR	Risk Level	Post PHR	Post Risk Level
1	1.14	Lack of marking of robot Collaborative workplace and Operating Zone	N/A	Not Acceptable	N/A	Not Acceptable
2	2.11	Lack of marking of robot Collaborative workplace and Operating Zone	N/A	Not Acceptable	N/A	Not Acceptable
3	3.10	Lack of marking of robot Collaborative workplace and Operating Zone	N/A	Not Acceptable	N/A	Not Acceptable
4	1.13	Hazards generated by foreseeable misuse due to lack of technical documentation	N/A	Not Acceptable	N/A	Further Review
5	2.10	Hazards generated by foreseeable misuse due to lack of technical documentation	N/A	Not Acceptable	N/A	Further Review
6	3.9	Hazards generated by foreseeable misuse due to lack of technical documentation	N/A	Not Acceptable	N/A	Further Review
7	1.11	Failure of the safety related part of control system	625	Very High Risk	15	Very Low Risk
8	1.15	Hazards generated by electrical components and electromagnetic radiation	390	High Risk	15	Very Low Risk
9	2.5	Failure of the safety related part of control system	625	Very High Risk	15	Very Low Risk
10	2.6	Unexpected movements due to new start-up	500	High Risk	15	Very Low Risk
11	2.12	Hazards generated by electrical components and electromagnetic radiation	390	High Risk	15	Very Low Risk
12	3.6	Failure of the safety related part of control system	625	Very High Risk	15	Very Low Risk
13	3.11	Hazards generated by electrical components and electromagnetic radiation	390	High Risk	15	Very Low Risk
14	1.10	Inability to perform an emergency stop	750	Very High Risk	9	Negligible Risk
15	2.9	Inability to perform an emergency stop	750	Very High Risk	9	Negligible Risk
16	3.5	Inability to perform an emergency stop	750	Very High Risk	9	Negligible Risk

Priority	Hazard No	Hazard Name	PHR	Risk Level	Post PHR	Post Risk Level
17	1.4	Loss of stability during co-transport by manual guiding	312	High Risk	6	Negligible Risk
18	1.6	Falling or ejection of assembly part during normal operation	156	Significant Risk	6	Negligible Risk
19	1.12	Hazards generated from operation by unauthorized personnel	250	High Risk	6	Negligible Risk
20	3.7	Falling or ejection of assembly part during normal operation	156	Significant Risk	6	Negligible Risk
21	3.8	Hazards generated from operation by unauthorized personnel	250	High Risk	6	Negligible Risk
22	3.1	Unexpected contact between robot and operator parts during hand-guiding	1500	Very High Risk	5	Negligible Risk
23	1.7	Loss of the end effector	117	Significant Risk	4	Negligible Risk
24	1.9	Loss of stability of the manipulator	117	Significant Risk	4	Negligible Risk
25	3.2	Loss of the end effector	117	Significant Risk	4	Negligible Risk
26	3.4	Loss of stability of the manipulator	117	Significant Risk	4	Negligible Risk
27	1.1	Quasi-static contact between manipulator and fixed structures	1250	Very High Risk	3	Negligible Risk
28	1.2	Quasi-static contact with end effector against personnel	1250	Very High Risk	3	Negligible Risk
29	1.3	Impact of mobile manipulator/part against personnel during co-manipulation	1250	Very High Risk	3	Negligible Risk
30	1.5	Transient contact with end effector against personnel	1250	Very High Risk	3	Negligible Risk
31	2.4	Remote access for manual intervention	500	High Risk	3	Negligible Risk
32	3.3	Contact during teaching/manual mode of robotic arms (T1/T2) mode	250	High Risk	3	Negligible Risk
33	2.2	Clamping between the mobile manipulator/part and fixed structures	125	Significant Risk	2	Negligible Risk

Priority	Hazard No	Hazard Name	PHR	Risk Level	Post PHR	Post Risk Level
34	2.3	Contact during teaching/manual mode of robotic arms (T1/T2) mode	250	High Risk	2	Negligible Risk
35	1.8	Contact during teaching/manual mode of robotic arms (T1/T2) mode	250	High Risk	1	Negligible Risk
36	2.1	Impact between mobile manipulator/part and operator during autonomous navigation	1250	Very High Risk	1	Negligible Risk
37	2.8	Hazards generated from operation by unauthorized personnel	250	High Risk	1	Negligible Risk
38	2.7	Inability to warn about status of Robot system - Inadequate design of interface Human-machine	N/A	Not Acceptable	N/A	Acceptable

4.2.4.3. Aeronautic pilot risk assessment conclusions

Annex 9.2.2 shows the body of design and on-site risk assessments of pilot, which show the correct application of the safety concepts developed during the development of the Aeronautic pilot. However, certain non-conformities are identified, which could be considered as minor, and which should be corrected or considered in subsequent stages.

Also, in the development of the risk analysis of the pilot, outstanding aspects, documentary or technical, are mentioned, which may change depending on the final or actual service conditions.

Following the results obtained in the on-site evaluation of the implementation of the safety concepts applied for the Aeronautic pilot, and considering a forthcoming objective of industrializing the application by putting it into service, the following aspects should be taken into account:

- The risk assessment should be complemented and adapted to the actual operating conditions, considering the spatial limits of the target installation. Thus, the zone classification of the AMR paths or the robot workspaces could be different. Thus, variations on the safety concepts foreseen in this pilot may be necessary.
- Impact measurements for transient or quasi-static contacts should be performed again, when changing the conditions of the collaborative space and robot trajectories, with respect to the pilot.
- Similarly, as the final conditions vary from those of the pilot, it will be necessary to reconfigure and document the configurations and validations of safety equipment such as scanners.
- Final assembly should comply with good engineering practice and state of the art. For example, respecting electrical wiring or pneumatic installation techniques, which have not been the main focus in the development of this pilot.
- Complementary local regulations should be considered. E.g. lighting conditions, electrical supply system conditions (indirect contacts,...).
- At the documentary level, the technical dossier must be compiled, with the contents indicated in annex VII of 2006/42/EC, including the documents derived from this project or mentioned in it and adapted to the final application. It is essential to have the declarations of conformity and/or incorporation of the equipment constituting the application, as well as the rest of the mandatory documentation for this equipment, instruction and/or assembly manuals. The

integrator must take them into consideration when preparing the technical dossier for the application.

- An important part of the technical dossier is the instruction manual. The contents of the manuals shall comply with Part 1.7.3 and 3.6 of Annex I of 2006/42/EC and the information for use found in the applicable type C standards (EN ISO 10218-2, ISO TS 15066, EN ISO 3691-4 and other relevant standards).
- It should be noted that the conditions of the applicable standards, both legal and technical, may change over time as a result of the evolution of technology and the state of the art. The machinery regulation 2023/1230 will be applicable in January 2027.
- Operators must be trained and informed on the basis of the instruction manuals of the application and of the machines of which it is composed.

To summarize the above, the final application must be technically and documentarily validated, taking into account hazards beyond those specific to collaborative robotics, before it is put into service. After validation, the declaration of conformity will be issued by the integrator and the CE marking will be affixed to the assembly. Commissioning will then be carried out with guarantees of compliance with the regulations in force.

4.2.5. Identified limitations

The main limitation that has been encountered in the integration of the aeronautic pilot site, mostly of them are related to the drilling use case. Other limitations were found on the moving of the robot in the transportation when a wide range of rotation is produced, generating a lot of inertia on the transportation cart and producing some disconnections on the sensor of the docking system.

The driller collet was not able to enter into the regular template used by AEROTECNIC to perform the drillings in the fan cow. Efforts have been made on getting one of the correct size, but unfortunately the supplier was not able to provide us in time the required for this purpose. Due this problem, the template was redesigned to be usable with the driller, losing the ability to drill two holes out of the six that were required.

Continuing with the driller, the drill bit equipped was not able to drill correctly the carbon fiber, destroying the piece at the same time that the drill bit breaks. Even this, because the template is printed in plastic, when the driller starts, expands the collet and it breaks the template.

4.2.6. Performance assessment of the aeronautics industrial pilot

4.2.6.1. Evaluation metrics and KPIs

The aeronautics pilot case checked five KPIs to evaluate the quality of the applied ODIN solution. These KPIs aboard the three main cases integrated un in AEROTECNIC premises. The following list describes each KPI.

- KPI 1 Automation of template base drilling: ODIN solution involves the integration of autonomous navigation, reconfigurable robot tooling, robotic perception and user-friendly robot programming interfaces towards the automation of the omegas drilling for antipeeling riveting.
- KPI 2 Reduce number of operations involved in non-ergonomic transportation tasks: ODIN solution provides 3D autonomous navigation for transporting safely and autonomously aeronautic big parts (fan cowls).
- KPI 3 Traceability afterward for unforeseen defect: ODIN solution, thanks to the combination of autonomous navigation, multiple sensor equipment, and user-friendly interfaces, enables generating a digital 3D reconstruction of the assembly, giving the possibility of having traceability afterwards for unforeseen defects.
- KPI 4 Time needed for adding new steps to the inspection procedures: ODIN solution provides user-friendly interfaces on top of skill-based programming approach which allows easily integrating new steps to inspection procedures.
- KPI 5 Time needed for quality inspection: ODIN solution aims to reduce the time needed for the quality inspection procedures.

Table 8: Aeronautics pilot KPIs values

KPI	Baseline	ODIN solution – Current state of validation	Target
KPI1 Automation of template base drillings (reachability, tool equip, detection, easy programming)	0%	75% Drilling machine issues do not allow actual drilling	100%
KPI2 Reduce number of operators involved in non-ergonomic transportation tasks	2 operators	0 operators	0 operators
KPI3 Traceability afterward for unforeseen defects	Laser tracker probe based geometrical inspection, inspections done by a certified verifier	Digital 3D reconstruction of the assembly	Digital 3D reconstruction of the assembly
KPI4 Time needed for adding new steps to the inspection procedures	40h (including training and follow-up)	8h (30 mins data acquisition + 1.5h online testing + 6h offline)	8h (15 mins data acquisition + 1h 45mins online testing / 6h offline)
KPI5 Time needed for quality inspection	100%	34%	34%

4.2.6.2. Validation process and results

In the case of the aeronautics pilot site, since the site is composed of three different use cases, the validation has been performed in these three processes: drilling, transportation and inspection. The KPI 1 is related to the drilling, the KPI 2 is related to the transportation and the KPI 3, 4 and 5 are used for inspection case validation. In some cases, the transportation has been tested also during the drilling and inspection, but these tests are not considered for the KPI validation results.

4.2.6.2.1. KPI 1 Automation of template base drilling (Automation, tool equip, detection, easy programming)

To evaluate the KPI 1 related with the automation of the drilling task in the aeronautics use case, the operation was performed in AEROTECNIC premises several times to check the stability, the repeatability and the correctness of the process. In this process the following subtasks have been considered:

- The ability of the Mobile robotic platform to move autonomously and safely along the premises between the different drilling stations.
- Due to the requirements of the driller an easily adaptable tool warehouse has been implemented for quick and automatic driller exchange.
- The detection of drilling template is made using the ROBOCEPTION CADMatch module. This allows us to perform the drilling operation with the mobile platform and can adapt quickly to new references if necessary.
- And the usage of user-friendly robot programming interfaces based on 3D joystick and manual guidance to have an easy adaptation of the working places.

Table 9: Aeronautics pilot KPI1

KPI	Baseline	ODIN solution – Current state of validation	Target
KPI1 - Automation of template base drillings (reachability, tool equip, detection, easy programming)	0%	75% Drilling machine issues do not allow actual drilling	100%

In the evaluation the ODIN solution checked the possibility of the making the drilling automated without the requirements of any operators. The process of automated drilling includes the correct positioning of the mobile platform, the ability of attach the driller, the detection of the drilling template and the drilling task itself. Due to issues with the drilling machine, that is not valid for the real template, some modifications were done. With these modifications the template loses two holes and, at the same time the drilling machine was not able to perform correctly the drills in the fan cowl which is not the same as the one used in AEROTECNIC facilities.

4.2.6.2.2. KPI 2 Reduce number of operators involved in non-ergonomic transportation tasks

The KPI 2 related with the transportation of the fan cowl task in the aeronautics use case, the operation has been tested in AEROTENIC premises where this activity is one of the most used to move between different stations. To complete this KPI the following parts have been integrated:

- The mobile platform has been prepared to move autonomously and safely around the designated working area to transport the fan cowls from one station to another one.
- To perform the correct transportation of the fan cowl, an automatic docking mechanism has been implemented that allows attaching slightly modified part transporting carts.

Table 10: Aeronautics pilot KPI2

KPI	Baseline	ODIN solution – Current state of validation	Target
KPI2 - Reduce number of operators involved in non-ergonomic transportation tasks	2 operators	0 operators	0 operators

The evaluation achieves the estimated target that reduce the requirements of the physical operators from 2 to 0 operators. Out of the main tests in controlled area, more tests were realized trying to move along all the premises with successful results.

4.2.6.2.3. KPI 3 Traceability afterward for unforeseen defects

ODIN solution, thanks to the combination of autonomous navigation, multiple sensor equipment, and user-friendly interfaces, enables generating a digital 3D reconstruction of the assembly, giving the possibility of having traceability afterwards for unforeseen defects. To complete this KPI the following parts has been integrated:

- The mobile robotic platform can move autonomously and safely along quality inspection stations.
- An easily adaptable tool warehouse has been implemented for quick and automatic vision sensor exchanging
- Sensor for 3D reconstruction and meshing based on 3D pointcloud fusion.
- A user-friendly joystick and manual guidance tools that allow easy creation and adaptation of the scanning trajectories.

Table 11: Aeronautics pilot KPI3

KPI	Baseline	ODIN solution – Current state of validation	Target
KPI3 - Traceability afterward for unforeseen defects	Laser tracker probe based geometrical inspection, inspections done by a certified verifier	Digital 3D reconstruction of the assembly	Digital 3D reconstruction of the assembly

The evaluation completes with the acceptance of the ODIN solution, based on the usage of a digital 3D reconstruction of the assembly instead of the baseline where a laser tracker and certified verifier was used.

4.2.6.2.4. KPI 4 Time needed for adding new steps to the inspection procedures

ODIN solution provides user-friendly interfaces on top of skill-based programming approach which allows easily integrating new steps to inspection procedures. This reduces the required time when new steps are required for the inspection, like when new fan cowl specifications come. To complete this KPI the following parts has been integrated:

- Mobile robotic platform able to move autonomously and safely along quality inspection stations
- An easily adaptable tool warehouse has been implemented for quick and automatic vision sensor exchanging
- Sensor for 3D reconstruction and meshing based on 3D pointcloud fusion.
- A 6DoF Pose estimation based on synthetic data generated from CAD models.
- Sensor for 2D quality inspection operations.
- A user-friendly joystick and manual guidance tools that allow easy creation and adaptation of the scanning trajectories.

Table 12: Aeronautics pilot KPI4

KPI	Baseline	ODIN solution – Current state of validation	Target
KPI4 - Time needed for adding new steps to the inspection procedures	40h (including training and follow-up)	8h (30 mins data acquisition + 1.5h online testing + 6h offline)	8h (15 mins data acquisition + 1h 45mins online testing / 6h offline)

In the evaluation it was able to achieve the ability to change easily the inspection method between the two different sensors used. This was mostly assured due to the need of the change that must made to use the sensors in the same arm.

4.2.6.2.5. KPI 5 Time needed for quality inspection

ODIN solution aims to reduce the time needed for the quality inspection procedures. The integration of different elements and the usage of it reduces the total time of the inspection process. To complete this KPI the following parts have been integrated:

- Mobile robotic platform able to move autonomously and safely along quality inspection stations
- An easily adaptable tool warehouse has been implemented for quick and automatic vision sensor exchanging
- Sensor for 3D reconstruction and meshing based on 3D pointcloud fusion.
- A 6DoF Pose estimation based on synthetic data generated from CAD models.

- Sensor for 2D quality inspection operations.
- A user-friendly joystick and manual guidance tools that allow easy creation and adaptation of the scanning trajectories.

Table 13: Aeronautics pilot KPI5

KPI	Baseline	ODIN solution – Current state of validation	Target
KPI5 - Time needed for quality inspection	100%	34%	34%

The test made in the AEROTECNIC premises show a time reduction to 34% of the baseline time. This accelerates the production of the fan cowl process where the inspection is a key part and takes a lot of time in multiple steps on the production line.

4.2.6.3. Cost benefit analysis of the aeronautics pilot

The cost benefit analysis of the aeronautics pilot is divided into three different pilot lines: drilling pilot line, transport pilot line and inspection pilot line. This final analysis has been performed calculating the current set up at AEROTECNIC vs ODIN solution.

Two different cases in terms of cost have been calculated, optimistic and pessimistic. Following the same methodology presented in section 3.2.6.3 for the Automotive pilot, two group of costs have been considered for each of the cases: a) the investment cost which involves the costs for equipment acquisition and commissioning of the workstations – before starting the operation of the process and b) the operating cost which involve the annual required costs for the operation of the workstation.

The investment cost that was required in drilling pilot for the current set up at AEROTECNIC as well as the for the two cases of ODIN solution implementation are presented in the following table.

Cost category	Current Drilling Pilot Line state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Equipment Cost	<ul style="list-style-type: none"> - 3.000€ drilling equipment - 12.000€ for templates - 3.000€ installation 	165.000€ (single-arm mobile platform) <ul style="list-style-type: none"> - 2.000€ for grippers and tool fixtures - 20.000€ for drilling machine - 12.000€ for templates - 3.000€ installation - 3.000€ sensors 	165.000€ (single-arm mobile platform) <ul style="list-style-type: none"> - 3.000€ for grippers and tool fixtures - 30.000€ for drilling machine - 12.000€ for templates - 8.000€ installation - 3.000€ sensors
Commissioning labour cost	16.000€	16.000€	24.000€
Energy lines (Electric, Pressurised air etc.)	5.000€	4.000€	6.000€
Total investment Cost (€)	39.000 €	225.000 €	251.000 €

In the following table, the operating costs of the drilling line above cases has been estimated by the consortium based on current values from the end user and experience of the technology providers and the system integrators.

Cost category	Current drilling pilot line state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Engineering cost (per year)	1.000€	1.200€	2.400 €
Maintenance cost (per year)	1.000€	4.800€	9.600 €

Cost category	Current drilling pilot line state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Operation cost - Electricity, pressurized air (per year)	1.000€	900€	1.200€
Labor cost (1 person, 2 shifts, 220 days) (per year)	80.000 €	20.000 € (operator attending the machine ¼ of the time)	40.000€ (operator attending the machine half of the time)
Cost for quality defects (per year)	15.000€	0€	0€
Cost due to MDS* (per year)	3.240€	650€	650€
Total running Cost (€)	101.240 €	27.550 €	53.850 €

Based on the above analysis, the payback Head To Head Point (HTHP) has been calculated for both the optimistic and pessimistic case of cell deployment. As illustrated in the following figure, in the drilling line optimistic case the HTHP is in 31 months, while for the pessimistic case is in 54 months.

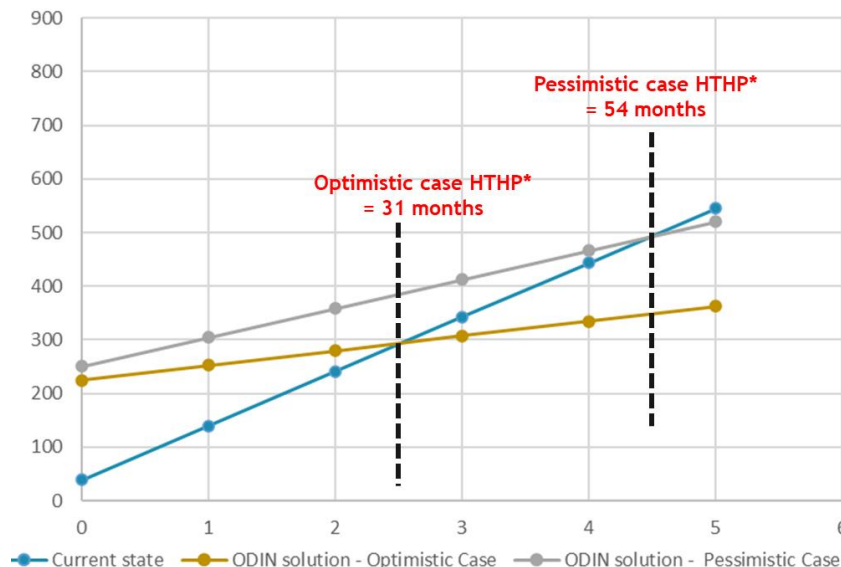


Figure 86: HTHP after ODIN solution for drilling operation

The investment cost that was required in transport pilot for the current set up at AEROTECNIC as well as the for the two cases of ODIN solution implementation are presented in the following table.

Cost category	Current transport pilot line state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Equipment Cost	1.100€ x 20 = 22.000 € for carts	- 100.000 € (mobile platform) - 3.500 € for robot docking mechanism - 1.700 € x 24 = 34.000 € for carts with docking mechanism	- 100.000 € (mobile platform) - 5.000 € for robot docking mechanism - 36.000 € for carts with docking mechanism

Cost category	Current transport pilot line state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Commissioning labour cost	4.000€	18.000€	24.000€
Energy lines yearly cost (Electric, Pressurised air etc.)	0	2.000€	4.000€
Total investment Cost (€)	26.000 €	157.500 €	169.000 €

In the following table, the operating costs of the transport line above cases has been estimated by the consortium based on current values from the end user and experience of the technology providers and the system integrators.

Cost category	Current Transport Pilot state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Engineering cost (per year)	0€	1.200€	2.400 €
Maintenance cost (per year)	1.100€	4.800€	9.600 €
Operation cost - Electricity, pressurized air (per year)	0€	900€	1.200€
Labor cost (2 person, 2 shifts, 220 days) (per year)	160.000€	60.000€	120.000€
Cost for quality defects (per year)	3.000€	1.000€	2.000 €
Cost due to MSD* (per year)	4.000€	-	-
Total running Cost (€)	168.100€	67.900€	135.200 €

Based on the above analysis, the payback Head To Head Point (HTHP) has been calculated for both the optimistic and pessimistic case of cell deployment. As illustrated in the following figure, in the transport line optimistic case the HTHP is in 16 months, while for the pessimistic case is in 52 months.

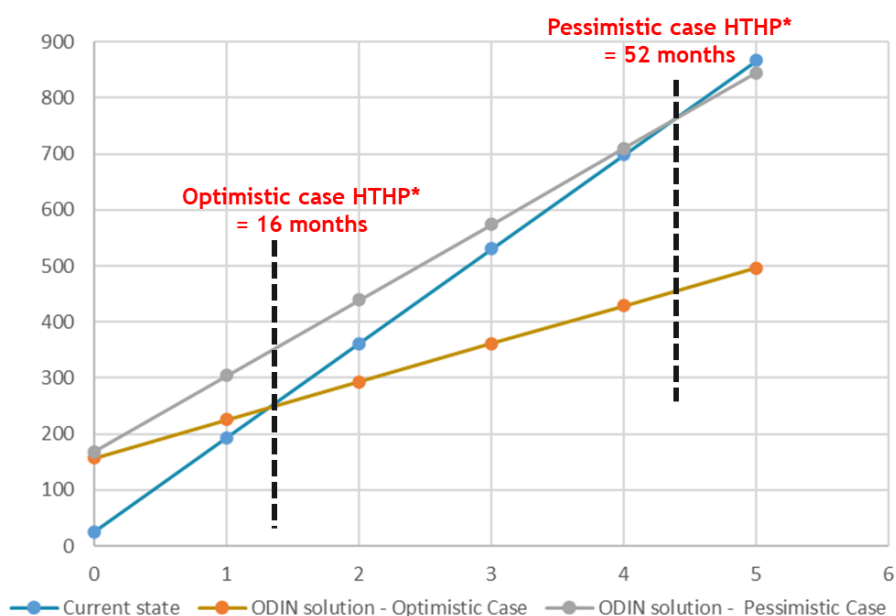


Figure 87: HTHP after ODIN solution for transporting operation

The investment cost that was required in inspection pilot for the current set up at AEROTECNIC as well as the for the two cases of ODIN solution implementation are presented in the following table.

Cost category	Current STELLANTIS state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Equipment Cost	- 2.000 € measuring and inspection equipment - 600 € tablet and software	- 165.000 € (single arm mobile platform) - 3.000 € for grippers and tool fixtures - 14.000 € for Photoneo sensor - 18.000 € Keyence sensor, illumination and controller - 2.000 € automation components	- 200.000 € (dual-arm mobile platform) - 4.000 € for grippers and tool fixtures - 16.000 € for Photoneo sensor - 18.000 € Keyence sensor, illumination and controller - 4.000 € automation components
Commissioning labour cost	40.000€	32.000€	40.000€
Energy lines yearly cost (Electric, Pressurised air etc.)	0	0	0
Total investment Cost (€)	42.600 €	234.000 €	282.000 €

In the following table, the operating costs of the inspection line above cases has been estimated by the consortium based on current values from the end user and experience of the technology providers and the system integrators.

Cost category	Current Inspection Pilot state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Engineering cost (per year)	60.000€	20.000€	40.000 €
Maintenance cost (per year)	500€	4.800€	9.600 €
Operation cost - Electricity, pressurized air (per year)	0€	900€	1.200€
Labor cost (2 person, 2 shifts, 220 days) (per year)	160.000€	60.000€	80.000 €
Cost for quality defects (per year)	10.000€	5.000€	10.000€
Total running Cost (€)	230.500€	90.700€	140.800 €

Based on the above analysis, the payback Head To Head Point (HTHP) has been calculated for both the optimistic and pessimistic case of cell deployment. As illustrated in the following figure, in the inspection line optimistic case the HTHP is in 16 months, while for the pessimistic case is in 32 months.

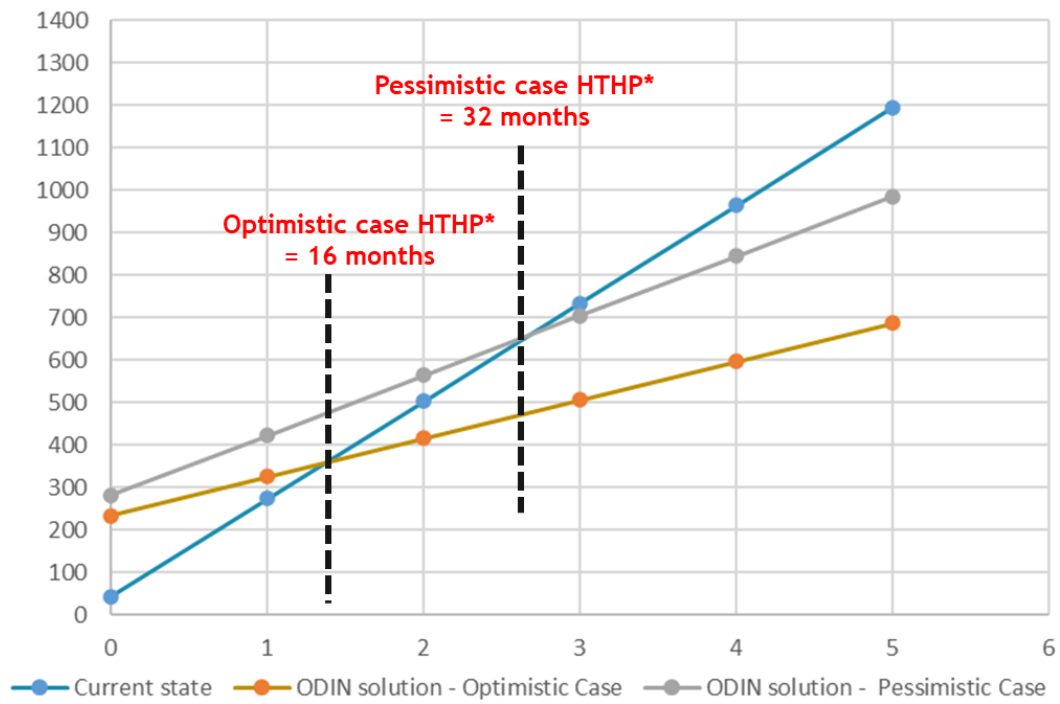


Figure 88: HTHP after ODIN solution for inspection operation

5. ODIN WHITE GOODS PILOT DEMONSTRATOR

5.1. Overview

The White Goods pilot of ODIN is centralized on the enhancement of HRC regarding productivity and safety in an industrial HRC shopfloor. During the last period of the project, ODIN partners prepared the final demonstrator layout at BEKO premises in order to integrate the required ODIN components for assembly process's validation. The layout of the final white goods pilot demonstrator is presented in the following figure.



Figure 89: White Goods pilot demonstrator layout at BEKO premises

5.2. White Goods pilot - Industrial demonstrator

All the required assembly tasks for the assembly of ovens and gas cooktop burners are executed in the final version of the White Goods demonstrator at BEKO premises. The updates of the final demonstrator contrary to the pre-industrial demonstrator of LMS presented in deliverable D5.4 are the following:

- Conveyor

In the final version of the White Goods pilot layout, the movable conveyor is connected with the central orchestrator module OpenFlow in order to bring closer the ODIN pilot to the real production conditions.

- Carts

BEKO was able to provide the exact model of carts from the real production environment in order to evaluate better the ODIN solution in terms of robot's reachability but also safety concept's implementation.

- Laser scanner sensor

A laser scanner sensor has been introduced in the final industrial pilot. This sensor has been placed on the top of the conveyor assembly self towards takt time reduction. In contrary to the safety concept of the small scale pilot, in the industrial pilot of BEKO use case the collaborative robot does not need to move always with collaborative speed when it is inside the assembly area of the conveyor. Robot's speed reduction when it is located inside the assembly shelf area is required only in case that the human presence has been detected inside this area using the laser scanner sensor.

5.2.1. Integration of Open Component with White Goods industrial pilot

The required modules of the Open Component have been integrated in the White Goods industrial demonstrator of ODIN at BEKO premises as presented in the following subsections.

5.2.1.1. Reconfigurable robot tooling

The final version of the reconfigurable robot tools for the White Goods pilot has been presented in deliverable D5.4 and no further needs to be documented in this deliverable. During the third period of the project, this module has been integrated in the industrial pilot of BEKO and used by the collaborative robot for the execution of the required manipulation tasks as presented in the following figure.



Figure 90: Integration of reconfigurable robot tools at the industrial demonstrator of BEKO

As presented also in D5.4, the following gripping tools have been integrated in the industrial pilot of BEKO:

- Magnetic gripper utilized for the manipulation of transformers and cooktops.
- Flexible gripper used for pick and place actions of knobs.
- Vacuum gripper utilized for the manipulation of cardboards and blisters.

5.2.1.2. Robotic perception for the process, the human and the environment

- Object detection

The integration of the object detection module inside the White Goods demonstrator at LMS premises has been detailly presented in D5.4. During the final period of the project, the object detection module has been successfully integrated inside the White Goods industrial demonstrator.

The blisters and detection components have now been thoroughly tested at BEKO premises, confirming their functionality in the operational environment. Both the CADMatch and SilhouetteMatch techniques have been tested to ensure accurate detection and manipulation of components.

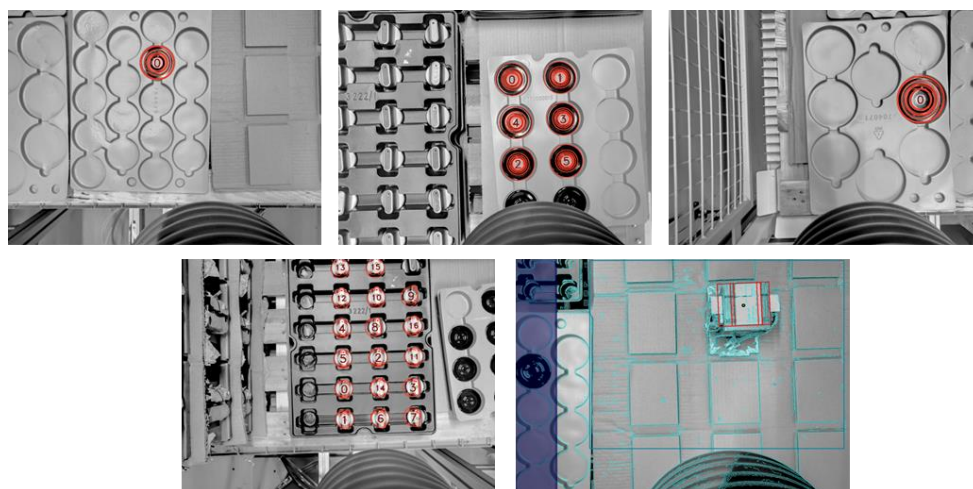


Figure 91: Detection results from all parts at White Goods industrial demonstrator

For the detection process, an RC_Visard 65 camera sensor [2] is mounted on the robot's end effector, with the detection module running on an RC_Cube S [8] device, which also supplies the necessary CAD templates. The RC_Visard 65 camera sensor has been installed on the robot end effector with a custom flange made by LMS.

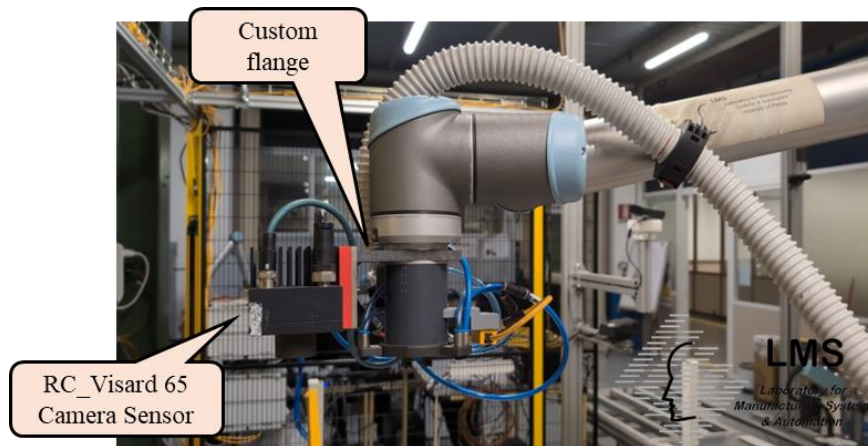


Figure 92: RC_Visard camera sensor installed in White Goods pilot demonstrator

Once detection is completed, the module's results are forwarded to OpenFlow, creating grasping points as frames within ROS's transformation tree. These frames determine the UR10 collaborative robot's target poses to grasp the required parts.

- Human motion intention

As presented in deliverable, D5.4, the human motion intention module uses a Kinect v2 sensor and a Neural Network model to predict the operator's actions. In D5.5, this module was tested within the BEKO White Goods industrial pilot to validate its functionality with OpenFlow, dynamically adjusting the UR10 robot's actions based on the operator's state.

In the industrial setting, the module performed as follows:

- Working State: When the operator is in a working state, the robot dynamically places the parts on the assembly table's shelf.
- Standing State: If the operator is standing, the robot provide the part directly to the operator's hand, positioning itself for easy retrieval from the robot's gripper.

The integration at BEKO premises confirmed that this dynamic interaction reduced the cycle time of the operation, by having responsive robot behaviour aligned with the operator's real-time actions.

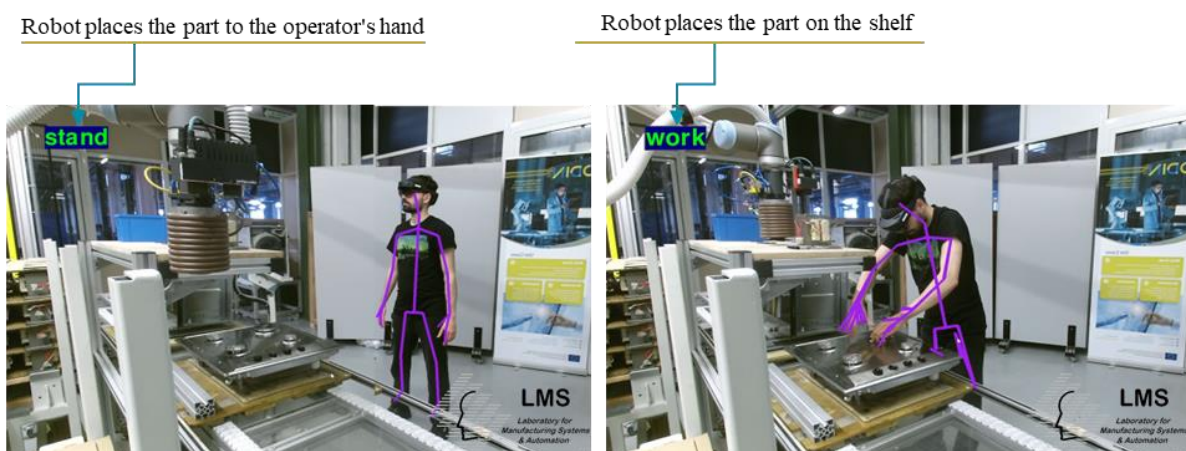


Figure 93: Human motion intention module integration in White Goods industrial demonstrator

5.2.1.3. Smart human side interfaces

In the industrial demonstrator of BEKO, three different type of human side interfaces are integrated to achieve a) the required human-robot interaction for assembly tasks' execution but also b) the safety training and familiarization of operators with HRC workstations. These interfaces' integration in the final demonstrator setup is detailedly presented in the following subsections

5.2.1.3.1. AR operator support application

The operators of the White Goods demonstrator use the AR application of ODIN in order to successfully execute the required assembly actions. Information and controls related to the execution of assembly tasks are transferred to the operator through the virtual world of the AR application. Virtual buttons with options and a virtual menu have been created to assist the operator to navigate when using the module. As presented also in D5.4, the AR application of ODIN developed by LMS consists of several interfaces for connection with other ODIN modules, and features human operators in terms of:

- Assembly guidance provision,
- Controlling of UR10 collaborative robot,
- Production system security breach notifications provision,
- Resilience of the production system in case of unexpected events,
- Safety awareness for the operators,
- Production schedule hologram-based visualization.

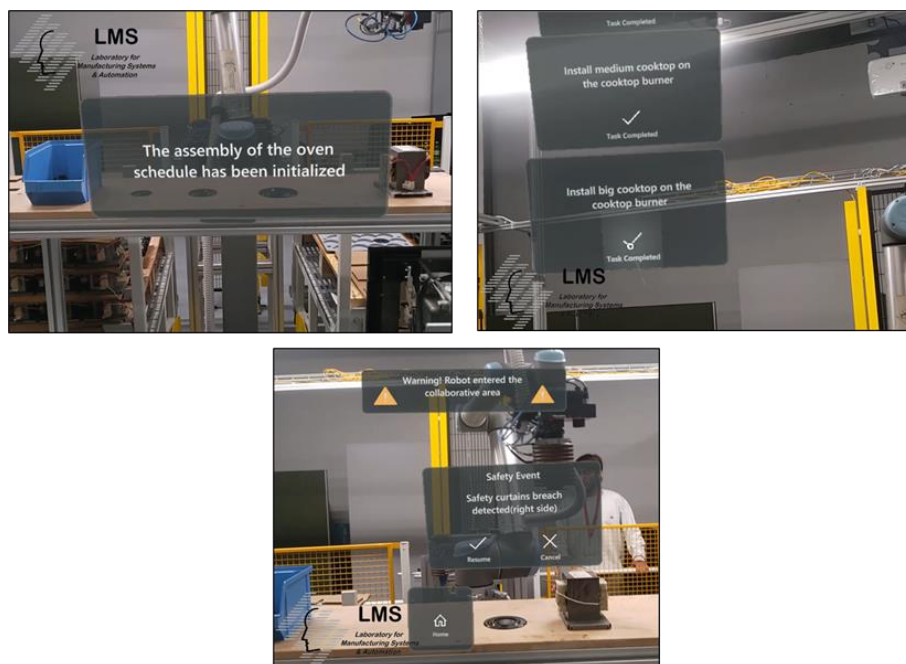


Figure 94: AR application usage in White Goods demonstrator

5.2.1.3.2. Projector-based interface

The projector-based interface of the White Goods demonstrator extends and finalises the earlier developments represented in D5.4. Two projectors are included, one at the front of the cell, one at the back. The front projector is used to display information around the parts being manipulated by operators, as well as two virtual buttons projected on a mobile table allowing to start and stop the robot actions. The back projector is used to display the state of the two safety light curtains at the back of the cell (Figure 95 a) Additionally, a Kinect Azure RGBD camera mounted on top of the cell (on the front side) monitors interactions with projected elements (Figure 95 b).

This interface is connected to OpenFlow, which can trigger the following events:

- Projection of virtual interface on top of a mobile table (Figure 96: b)
- Projection of slots and their static borders around positions where the robot places parts (Figure 96: a)
- Booking/releasing those slot borders to indicate to the operator whether to avoid a slot or interact with certain parts (Figure 96: a)
- Safety instructions based on the light curtains state (Figure 97)



Figure 95: a) Projector at the back of the work cell, b) projector and Kinect camera at the front of the work cell

For the elements to be projected correctly, the interface first needs to be calibrated. This process involves four steps as follows:

- Finding the relative position of the camera with respect to the robot base.
- Finding the parameters for forward/back projection of 3D points into 2D pixel coordinates.
- Computing the homographies for each display surface to link the image as seen from the camera and the projections onto that same surface.
- For the moving table, an Aruco marker was used, and its dimensions need to be calibrated relatively to the dimensions of the surface it represents.

The interface also keeps track of the coordinates of each display area, allowing OpenFlow to send relative coordinates for each element to be displayed. In the case of the slots being projected onto the shelf, a grid can also be created (Figure 96: a). In that case, the interface takes care of computing the size of each slot and OpenFlow only sends a position in terms of (row, column) within that grid.

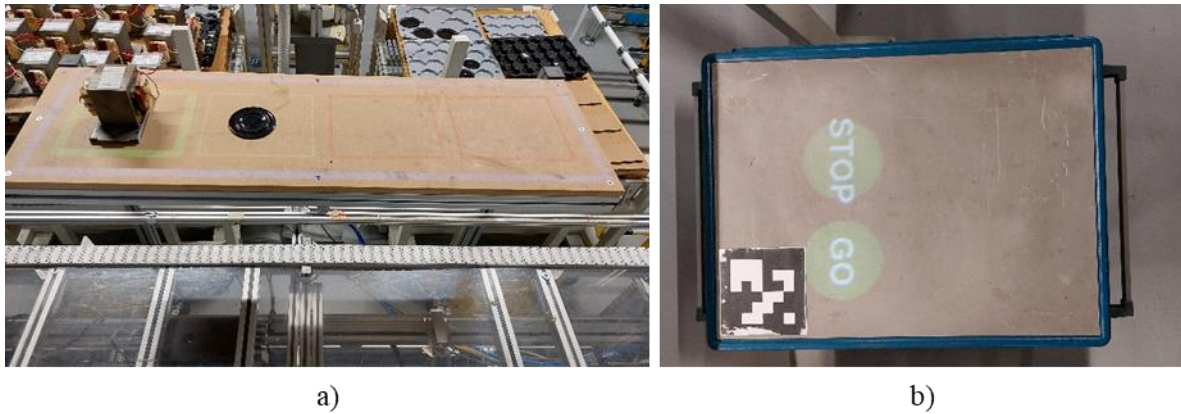


Figure 96: Front projector - a) Slots with borders on the shelf. Showing green borders for pickable objects. Red borders (two on the right) are booked by the robot and operator may not enter these slots. If violated the robot will stop, b) Mobile table with dynamic and interactive user interface. Stop and Go buttons.

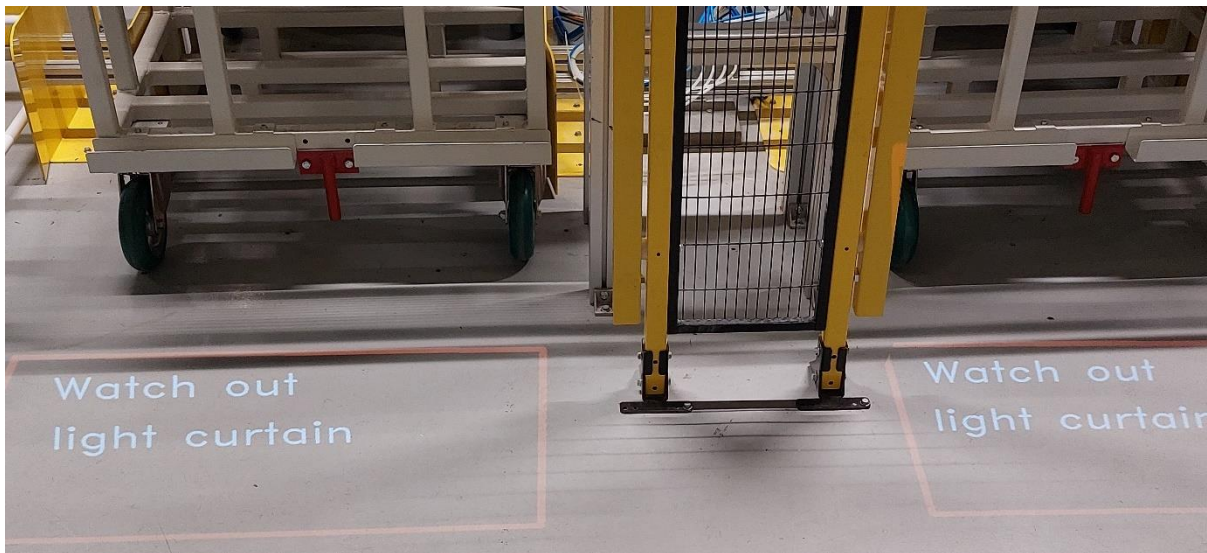


Figure 97: Back projector - safety instructions based on the light curtains state.

In return, the projected elements can send the following events back to OpenFlow:

- Start/stop button pressed on mobile table. (Figure 96: b),
- Slot border violations when operator crosses them. (Figure 96: a),
- Object presence within slot borders. (Figure 96: a),
- Indicating for the operator from which slot to pick the part and
- Releasing the slot once operator picks the part away.

To detect interactions with projected elements the system keeps track of the position of the operator's hands. This is achieved using MediaPipe Hand Landmarker, a machine learning tool by Google. The tool returns hand landmarks in 2D image coordinates which are then combined with depth information to get the 3D pose of the hand. The interface then compares that 3D pose with the position of the center of each projected element.

As for object presence within slots, it is determined in two steps. First, when creating slots, a snapshot of the depth map within each slot is taken, to serve as a baseline. Later, upon request from OpenFlow, slots are scanned again and the current depth map is compared with the baseline to detect any significant differences indicating object presence (Figure 98).

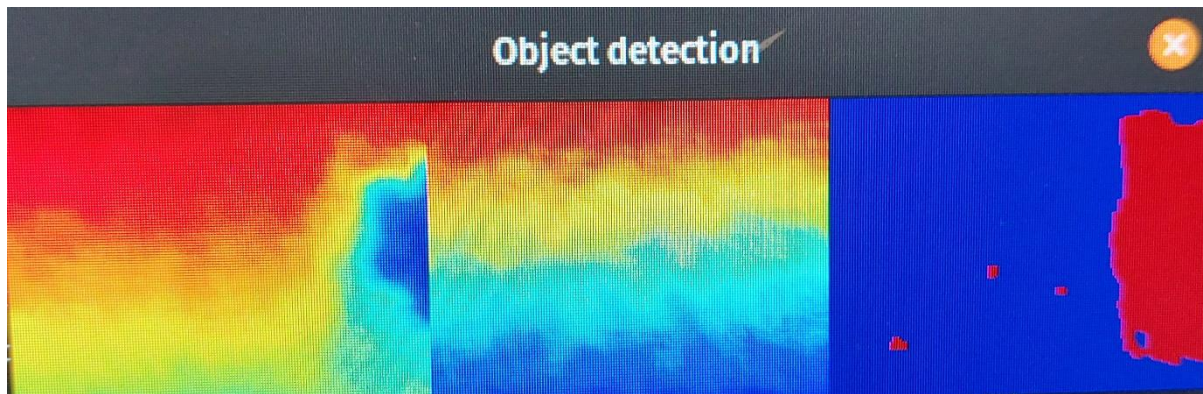


Figure 98: Comparison between baseline and current depth map within a slot to determine object presence.

5.2.1.3.3. VR safety training

During the final stage of the project, the final version of VR safety training has been presented in White Good industrial demonstrator. Two language versions of the final VR safety training was developed – one in English and another one in Italian to accommodate the familiarity and comfort of the local operators during the testing of the final demonstrator. Due to the platform used these are completely separate instances.

The VR safety training has been designed to cover the assembly of microwave and cooktops. In the last stage of the project, the complete safety procedure of the system has been created, so that it is corresponding to the implementation of the work cell real life. This includes among other the new safety design of system and safety scanner which has been integrated on top of the shelf. Regarding these developments, users can now completely perceive safety procedures, safety areas, and robot motion. Here are three stages of the VR safety training:

- Stage one:
 - User gets familiar with robot cell, regarding robot, and assembled products. User can get familiar with assembly process by observing avatar performing tasks in collaboration with robot. User required to understand:
 - Robot trajectories.
 - Process sequences.
 - Access areas at the work cell.
- Stage two:
 - Get familiar with safety devices and safety procedures existing in the work cell. These are achieved by reading text, watching a embedded video, or interactive elements such as control panel and emergency button.
 - Familiarity with invisible safety measures such as light curtain and safety scanner.
 - Perform safety procedures, and observe the response of the system meanwhile.
 - Audio cues as warning, instruction, or Andon sounds.
- Stage three:
 - Perform assembly process in VR environment by the operator, offering him/her a safe environment to learn the process.
 - Recall safety measures by checking status of system.
 - In case of hazard events perform safety procedures.

The VR safety training features have been discussed in D5.4. User can interact with emergency buttons to create a full stop for the entire work cell. Light curtains installed at the back side of the work cell are also active and influences to cell operation as in reality. In addition, full functionality of Andon panel and its process has been implemented (Figure 99). The Andon panel has yellow and red buttons to pause

the assembly line and call supervisor. The corresponding light towers will indicate the changed status and for clarity, related audio cues will be played to simulate real scenario at shop floor.

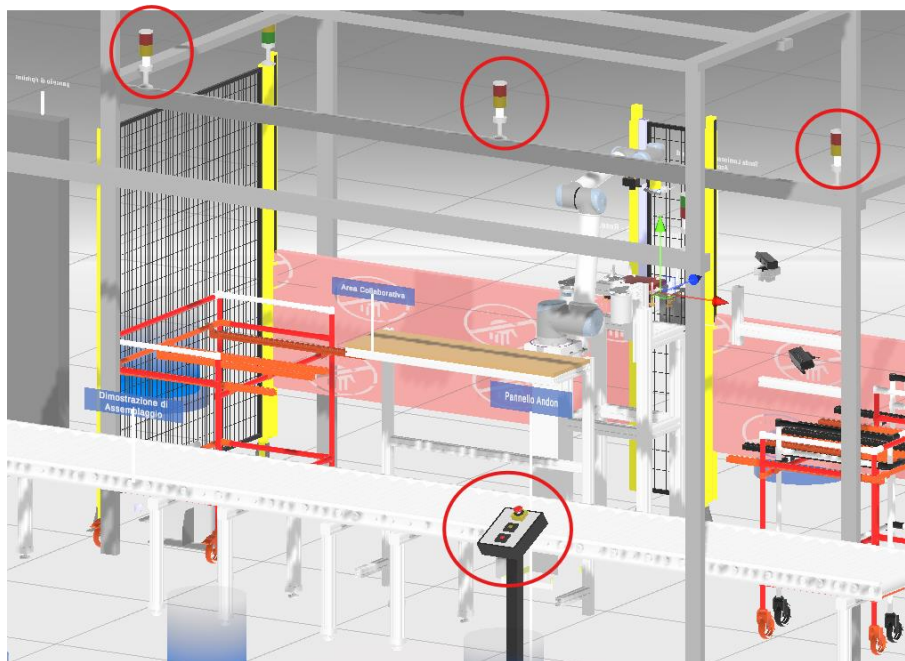


Figure 99: Andon panel and related light towers

For final demonstrator, the safety scanner has been added to the training to familiarize users regarding safety area around shelf exchanging the assembled components between the robot and operator (Figure 100). VR controller track the hand position of the user, and when it enters to the area monitored by the safety scanner, it demonstrates the violation in reduction of robot speed.

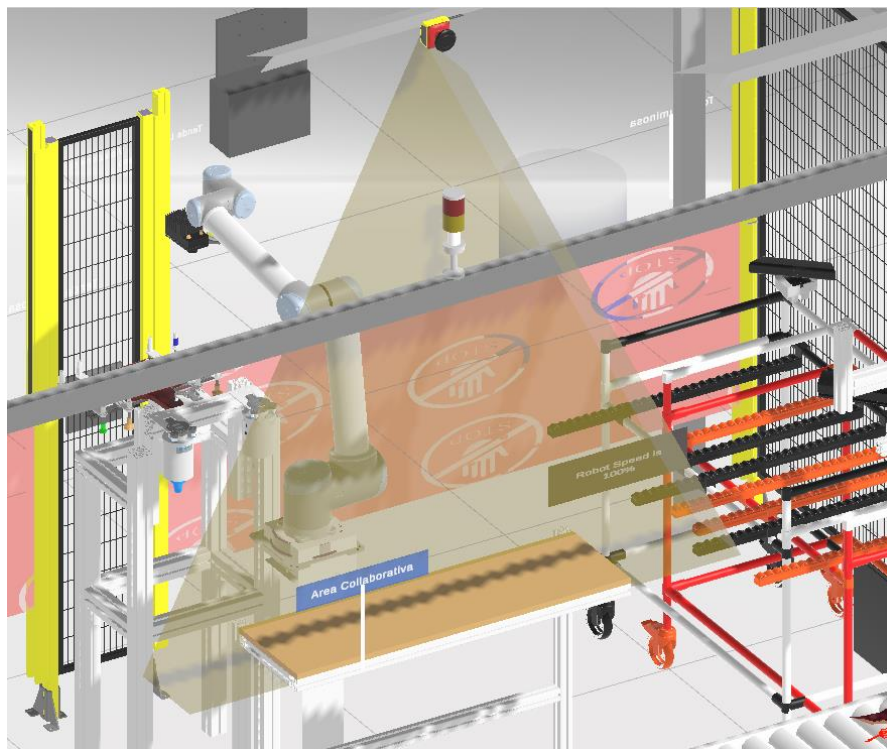


Figure 100: Integration of safety scanner at final demonstrator

It's worth mentioning that all robot trajectories during assembly stage have been integrated, so that users can recall robot movements right before assembly of products.

PLC cabinet representation has been added with the instructions and interactive buttons to let users follow process of reset of emergency state of system (Figure 101).

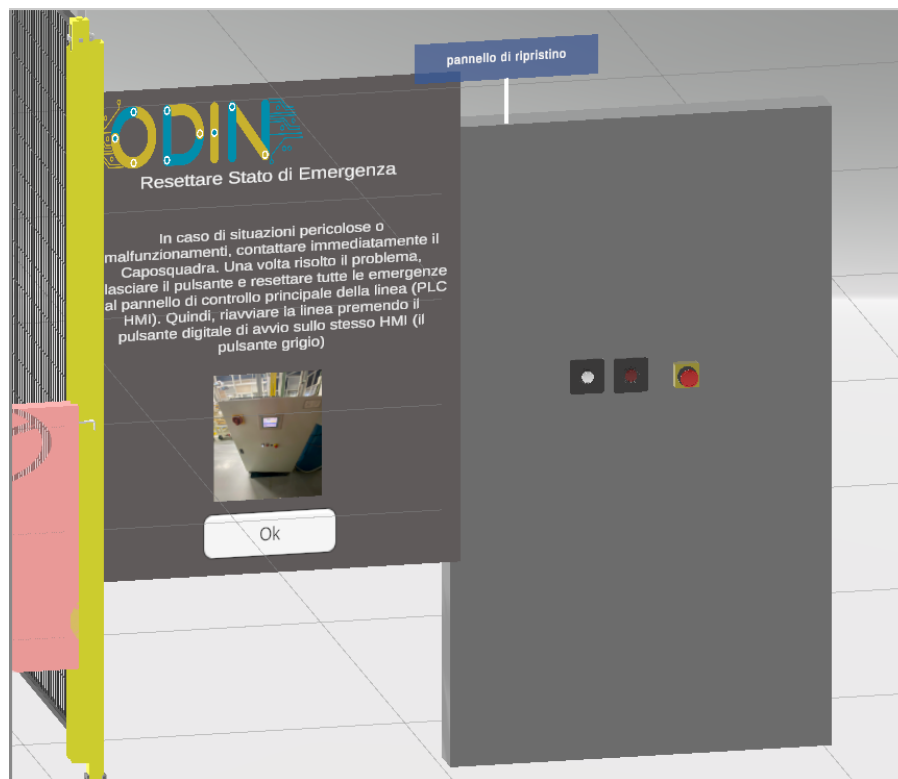


Figure 101: PLC cabinet for reset of emergency state. Showing the Italian version of VR safety training.

Finally, the video of trolley assembly has been embedded to the instruction panel inside the VR. This shows the user how to make an exchange of component supply trolley at the back side of the work cell. The procedure includes how to unlock and take out the empty trolley and how to bring the new full trolley, lock it on its place and finally how to reset the light curtains.

The main output from VR safety training modules' implementation is to utilize templates that have been developed for ODIN project. The templates aim to provide all requirements regarding safety measures to develop new VR safety training without challenges and to reduce the development costs. The template concept provides modules for VR such as robot workspace, light indicators, light curtain, hazardous border and scripts. The templates have been developed from TAU laboratories and have been tested in the industrial White Good pilot demonstrator. It has shown that fast integration is possible, and it can assist in fast prototyping. Furthermore, modules have been improved and two other modules have been added - namely interactive emergency button and LIDAR safety scanner as industrial representation of safety devices.

5.2.2. Integration of Digital Component with White Goods initial industrial pilot

All the Digital Component modules have been integrated and validated in the industrial demonstrator of the automotive pilot at BEKO premises as presented in the following subsections.

5.2.2.1. Digital resource description

The resources used in the White Goods pilot are modelled as Resource Descriptions (RDs). These descriptions are stored and made available to anyone in the Resource Catalogue Platform (RCP). The description focuses on the comprehensive representation of production modules, including their identification, capabilities/skills, interfaces, and links to documentation. Also link to the Visual

Component's VCID is provided as a foreign key providing the linkage with the resource's simulation representation in Visual Component SW.

Integration with the Open Flow has been performed. The Open Flow is capable to link to these Resource Descriptions and retrieving the resource's fact card from the service. The image of resource and its key details are visualized in the Open Flow interface.

The modelled resources for WG use case are:

- UR10 collaborative robot
- Roboception RC Visard 65-4-M (3D stereo camera)
- LMS gripper : Magnetic / Schunk
- LMS gripper : Vacuum
- LMS gripper : Flexible and soft / Festo
- LMS tool changer stand
- MS Kinect Azure (RGBD camera)
- Projector
- PILZ Light curtain

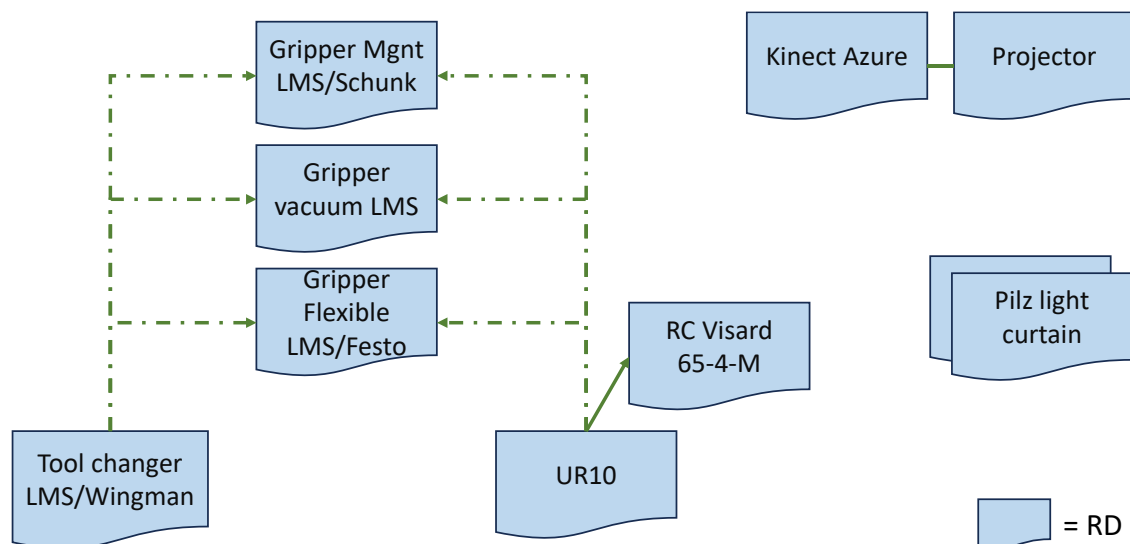


Figure 102: Liaison graph between Resources

Overall, 32 resources used in ODIN use cases are modelled with the Resource Descriptions. This set of resources are covering all three ODIN use cases including also RDs used in automotive and aeronautics cases.

5.2.2.2. Digital Simulation

During the final period of the project, the latest version of the White Goods simulation has been prepared by BEKO. This simulation is centralized on the execution of the assembly operation utilizing the required robotic and human resources. The White Goods pilot layout has been designed for the installation of the pilot at BEKO premises based on corresponding robots' reachability and components dimensions as well as their installation location. The final version of the White Goods pilot simulation is presented in the following figure.

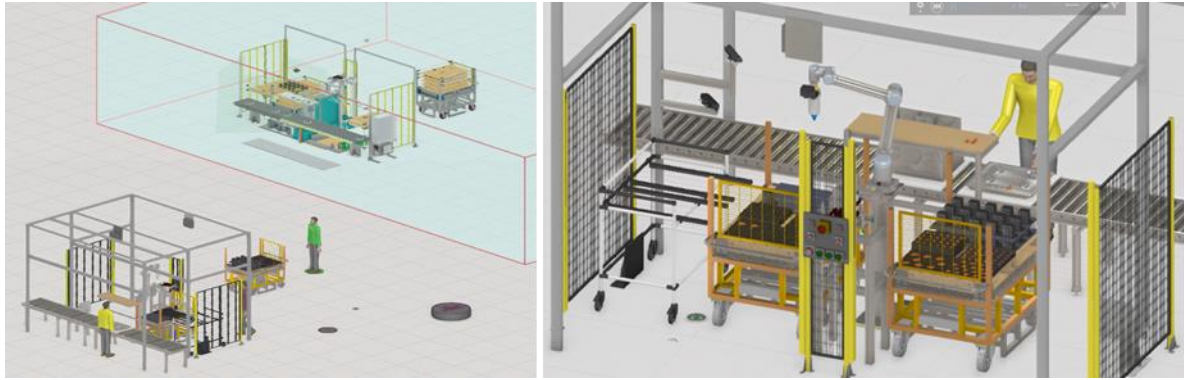


Figure 103: White Goods demonstrator simulation layout

The final version of the White Goods pilot simulation layout has been modelled and added in the ad-hoc library of Visual Component in order to be easily accessible by the ODIN partners.

5.2.2.3. Digital Twin

As already documented in section 3.2.2.2, the Digital Twin of ODIN provides visualization and connectivity features through the Visual Components software. The Digital Twin of the White Goods pilot integrated at BEKO premises includes the following information:

- UR10 robot

As presented also in deliverable D5.4, the actions of the UR10 robot can be visualized inside the Digital Twin of the White Goods pilot thanks to this module's connection with OpenFlow.

- Conveyor

The automotive pilot's conveyor has been modelled inside the Visual Component by LMS. In the final version of the White Goods pilot, this VC model is connected with OpenFlow in order to visualize dynamically the start-stop actions and speed adjustments of the real conveyor.

- Human state

Thanks to the human motion detection and intention estimation module, the skeleton data of the human operator can be transferred to the Visual Component software in order to visualize the motions of the human operator inside the Digital Twin of the White Goods pilot.

- Object detection module's results

The results of the object detection module are visualized inside the Visual Component software.

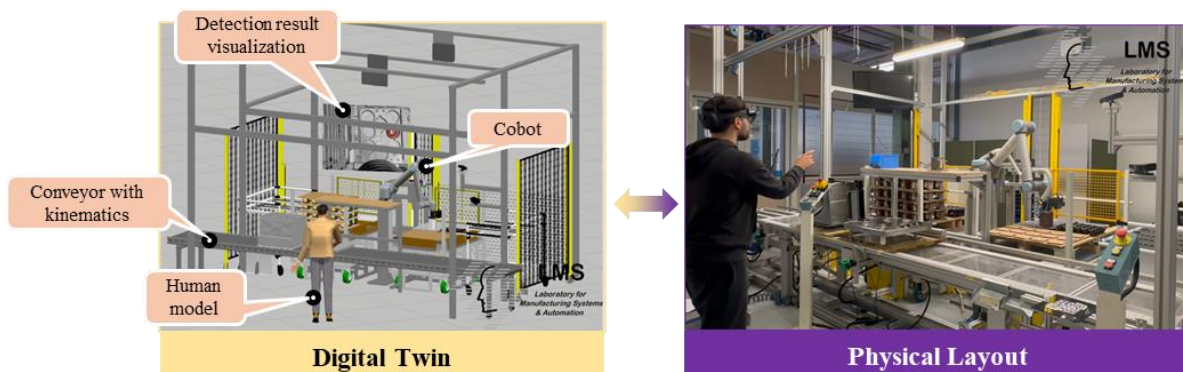


Figure 104: Integration of Digital Twin module at BEKO industrial demonstrator

5.2.2.4. AI Task Planner

The AI Task Planner of ODIN was the key component for the validation of ODIN solution at BEKO premises. In its final version, the database of the AI Task Planner has been updated in order to include all the required resources for assembly tasks' allocation and execution (conveyor, cobot, human operator and projector interface). The final version of this module's User Interface is visualized in the following figure.



Figure 105: Integration of ODIN AI Task Planner with the White Goods demonstrator at BEKO

The final version of the task planning procedure for the White Goods pilot consists of 33 assembly tasks able to be assigned no the available resources depending on the type of each task and available resources' capabilities. In its final form, an indicative assembly tasks' schedule can be visualized is a big-sized tree of tasks as presented in the following figure. This figure is an example of a small part of a generated assembly tasks tree.

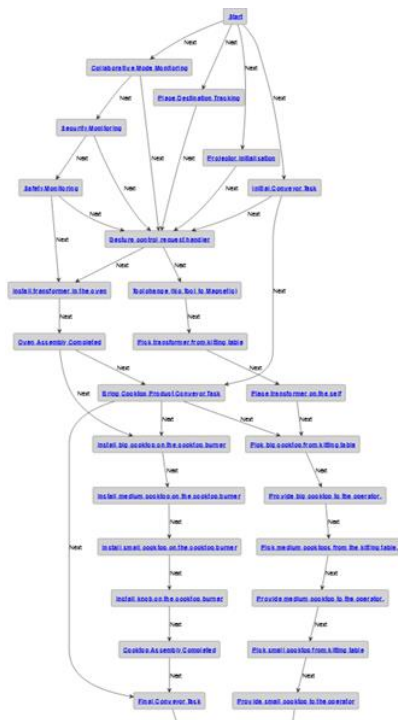


Figure 106: White Goods pilot assembly schedule

5.2.2.5. Virtual Commissioning

As already mentioned in section 3.2.2.4, the virtual commissioning module is based on the usage of Visual Component software and its functionality to generate executable programs for COMAU and Universal Robot controllers. The final version of the Virtual Commissioning module has been validated in the White Goods pilot demonstrator at BEKO premises.

The validation of the Virtual Commissioning module in the White Goods pilot is based on the same concept as described in previously submitted deliverable D5.4. The updates during the last period of the project are centralized on the calibration of Virtual Commissioning module simulated layout with the physical working cell in order to achieve the required accuracy of the executed robot trajectories as well as the removal of post processor technique from the Virtual Commissioning process. In the latest version of the Virtual Commissioning, the designers are able to design the new robot trajectories in the simulated environment and directly send the motion commands remotely to the robot controller through the User Interface of Visual Component software.

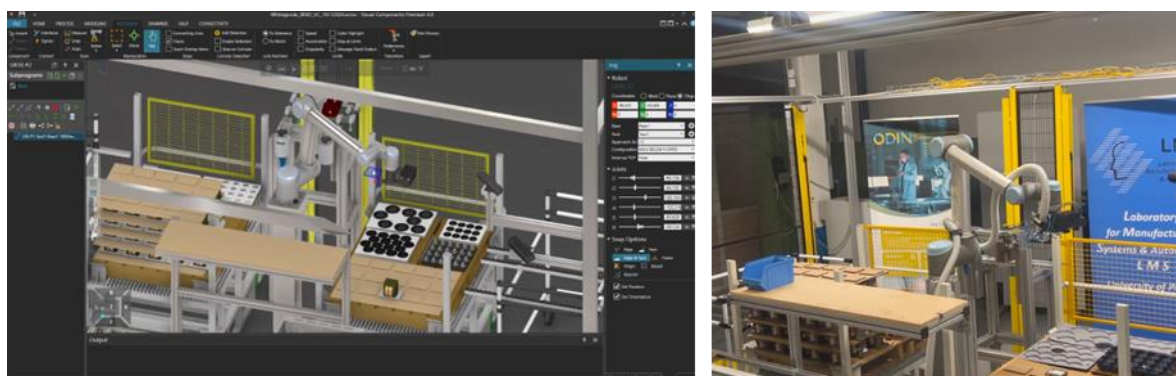


Figure 107: Virtual commissioning validation in the White Goods industrial demonstrator

5.2.3. Integration of Networked Component with White Goods initial industrial pilot

All the Networked Component modules have been integrated and validated in the industrial demonstrator of the White Goods pilot at BEKO premises.

5.2.3.1. OpenFlow

The industrial pilot case, located at BEKO's premises, has already deployed the final version of OpenFlow. It coordinates the execution of tasks at the workstation, managing the interactions between human operators and robotic resources. Due to its integration with the latest version of ODIN's key modules, OpenFlow monitors the progress of each task while keeping an overview of the status of all resources for uninterrupted production. If necessary, it can also trigger the AI Task Planner module to replan tasks in such a way that continuity in workflow and avoidance of delay can be ensured.

Similarly with the other two pilots of ODIN, OpenFlow module's integration in the White Goods demonstrator is based on a docker image of the module installed and running in the central PC of the workstation.

As presented in deliverable D5.4, several ROS action servers are utilized to achieve seamless control over the execution of White Goods assembly process. The expanded list of the required servers is presented in Table 14.

Table 14: ROS action servers for White Goods pilot case execution

ROS Action Servers	Description
Move Cartesian Action Server	Action server for the planning and execution of robot motions using Cartesian space goals.
Move Joint Action Server	Action server for the planning and execution of robot motions using Joint space goals.
Configure Payload Execution Action Server	Action server for updating the payload of UR10 robot through ROS when robot carries high payload parts (transformer).

ROS Action Servers	Description
Configure TCP Action Server	Action server for updating the robot end effector through ROS when robot carries parts (move the end effector at the end of the carried part).
Detection Action Server	Action server for the pose estimation of parts need to be manipulated by the robot.
Gesture Control Server	Action server for enabling the gesture control functionality allowing the operator to move the robot using gestures.
Projector Interface Server	Action server that manipulates the zones presented in the shelf and the projection button for execution control by the operator.
Safety Action Server	Action server to communicate the Safety status of the cell to the Openflow module.
Execute Human Task Action Server	Action server for the connection of AR operator support application with the OpenFlow.
Control Gripper Action Server	Action server for enabling / disabling robot grippers.
Control Conveyor Action Server	Action server for enabling / disabling conveyor.

The connection between the described ROS action servers and the OpenFlow module is detailly presented in the following figure.

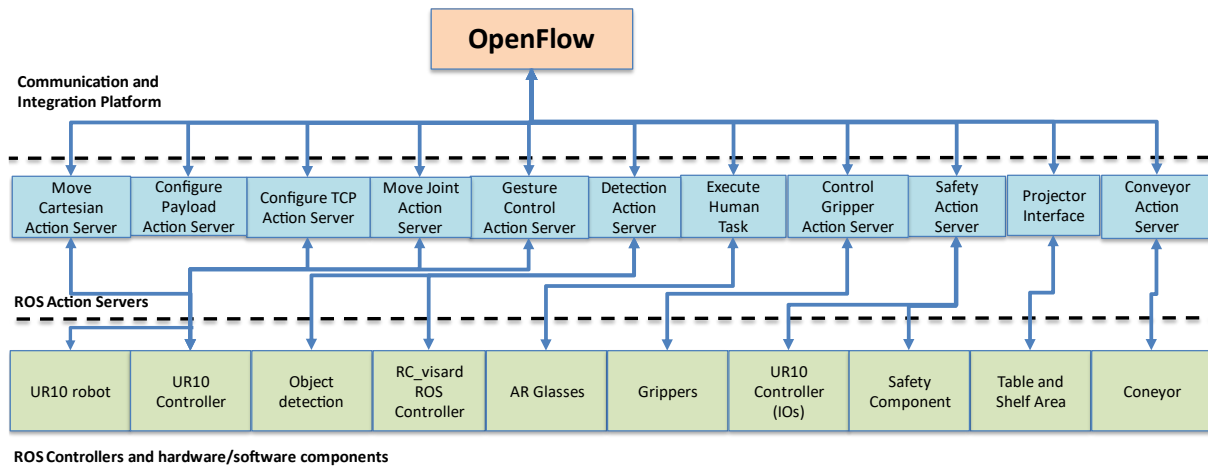


Figure 108: OpenFlow connection with ROS action servers for White Goods pre-industrial demonstrator

5.2.3.2. Cyber security

The final version of the cyber security module has been integrated inside the White Goods case pilot demonstrator at BEKO for the detection of cyber security threats in the local network of the cell. As presented in D4.3, this module is based on the connection of three different computers.

The module's functionality is centered on detecting incoming cyberattacks from outside the network. The integration of the module was successfully completed at BEKO premises, where testing involved using a third-party PC to simulate an out-of-network attack through Zenmap-Nmap software. The system successfully detected the Nmap scan, and the identified attack was relayed to the SOAR component via a direct connection to TheHive.

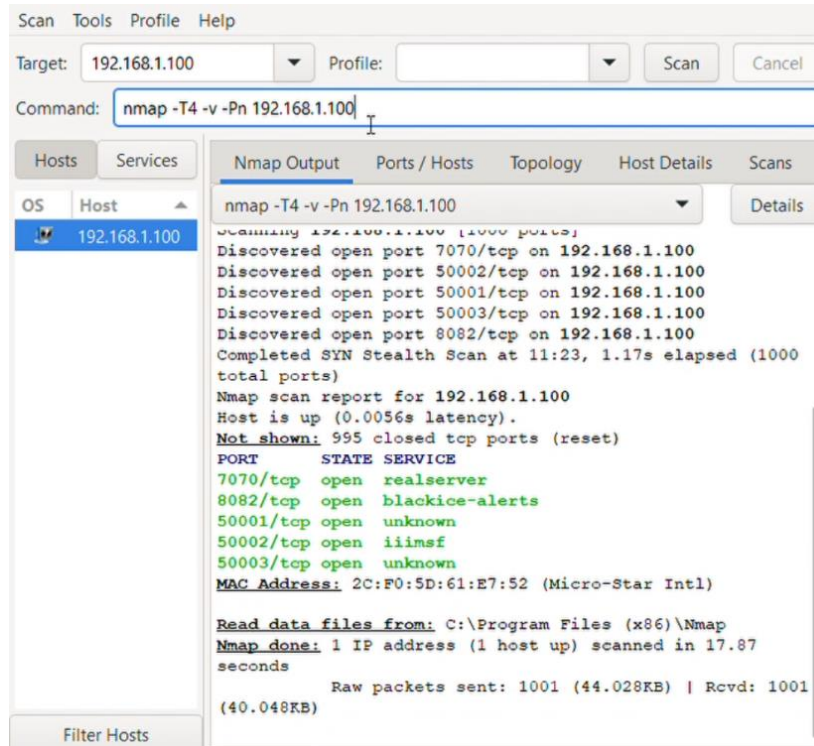


Figure 109: Zenmap software nmap attack

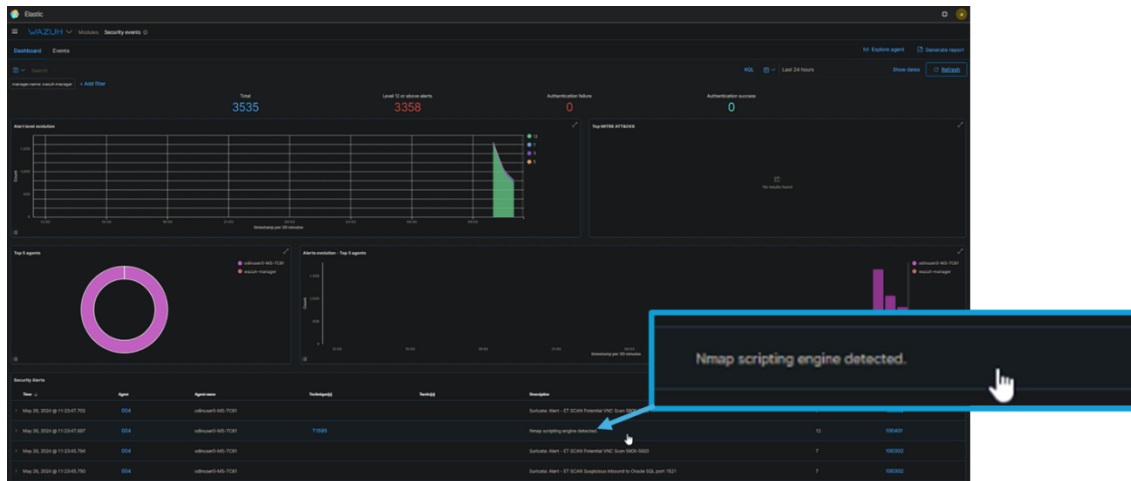


Figure 110: SIEM detection of nmap attack

Following this detection, the SOAR component communicated with the OpenFlow PC, publishing an alert to a monitored ROS topic. The OpenFlow module responded by executing a STOP command to the execution schedule and sending a notification to the AR operator support application in order for the operator to be aware about the state of the production.

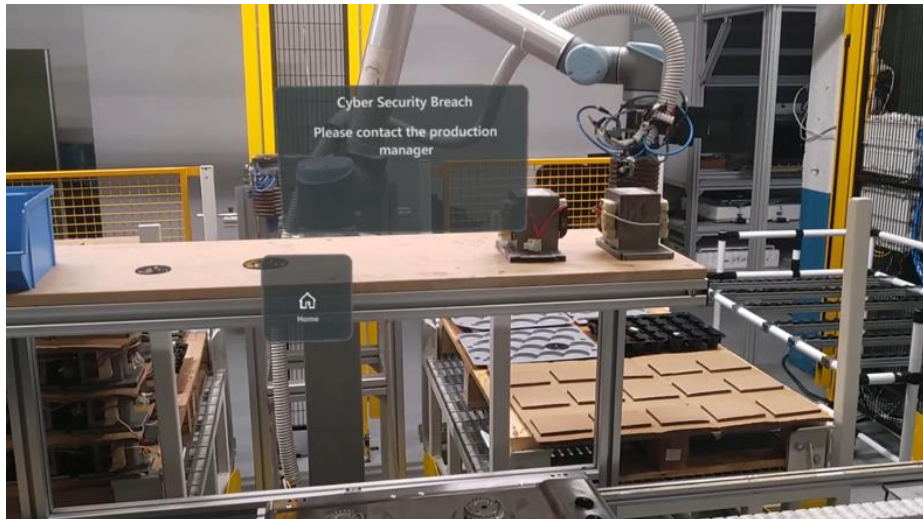


Figure 111: Notification about cyber attack in the AR operator support application

5.2.4. White Goods pilot safety concept integration with White Goods industrial pilot

This section outlines the integration of the safety concept and presents the results of the Risk assessments conducted for the White Goods pilot at BEKO premises.

5.2.4.1. White Goods pilot safety concept integration

The safety concept validation procedure carried out at BEKO premises was based on a series of requirements detailed in the document included in **Annex 9.1.3**.

The integration of safety devices will be detailed in separate subsections for each individual safety device in the following sections.

- Safety light barriers

Two pairs of safety light barriers have been installed in the rear area of the White Goods pilot. These safety light barriers are designed to detect the presence of human operators and/or trolleys within the designated area. In the event that an operator infringes the safety beams, the system responds by either stopping or adjusting the speed to collaborative (Figure 112) of the UR10 robotic arm, depending on the situation.



Figure 112: Safety verifications the robot must change to collaborative speed when light barriers are triggered

If the pneumatic gripper is attached to the robot at the time, the system takes appropriate actions to ensure safety stopping the robot's motion as shown in the Figure 113. This safety configuration is essential for maintaining a safe and collaborative working environment, ensuring that the robot's operation adapts to the presence of personnel as described in D5.4.



Figure 113: Safety verifications where the robot must immediately stop if attached to the robot is the pneumatic gripper and the light barriers are triggered

- Emergency and reset buttons

Four emergency stop buttons and two reset buttons have been strategically installed within the White Goods pilot to enable operators to immediately stop the assembly process if necessary. The reset buttons, allow operators to safely resume the assembly process.



Figure 114: Emergency stop and reset buttons integration

- Safety PLC

The safety PLC of the White Goods pilot is fully integrated with all the safety hardware devices within the robotic cell, ensuring centralized control and monitoring of safety functions. The safety logic implemented in the PLC has been thoroughly verified and updated to incorporate the new safety concepts explained hereafter in the next sections, building upon the previous safety concept outlined in deliverable D5.3.



Figure 115: Safety PLC integration

- Safety laser scanners

A safety laser scanner has been installed at the top of the cell, as depicted in Figure 116. The purpose of this new implementation is to increase the speed of the robotic arm throughout the entire process, thereby optimizing the takt time (KPI) for the overall process of the pilot. Following thorough verification, it was necessary to adjust the installation distance between scanner and the robot to ensure compliance with safety standards.

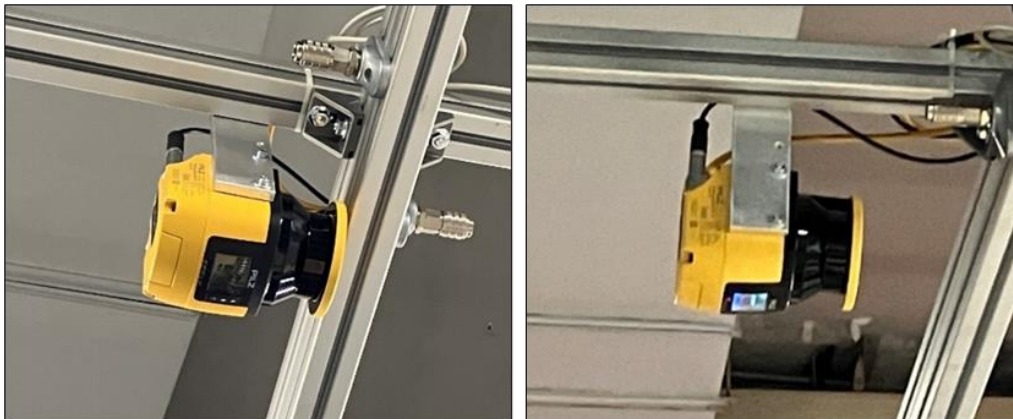


Figure 116: Safety scanner integration

The purpose of the laser scanner is to safely adjust the speed of the robot to a collaborative mode when the scanner's safety zone is triggered by the presence of a human operator. This is particularly important when the robot's position is in close proximity to the operator, reducing the risk of a potential collision. The scanner detects the operator presence and ensures the robot operates at a slower speed to minimize any safety hazards. Figure 117 illustrates the verifications we conducted at BEKO premises to confirm the effective implementation of this safety feature, ensuring that the system operates within the defined safety parameters.



Figure 117: Safety verifications to reduce the speed of the robot when human operator triggers the safety zone of the scanner

- Additional guards to prevent front area access

To prevent the access to the front area of the cell, we had to increase the height of the conveyor adding extra panels (Figure 118) to ensure that the height is minimum one meter. According to the safety standards, a height of one meter is considered sufficient to prevent operators access to the hazard zone.



Figure 118: Additional panels integration

5.2.4.2. White Goods pilot risk assessment results

The following section presents a summary of the initial and final risk assessment conducted for the White Goods pilot. This analysis aims to identify, evaluate, and mitigate potential risks that could impact safety outcomes. Table 15 outlines the key risks identified.

Table 15: White Goods pilot risks identified

Priority	Hazard No	Hazard Name	PHR	Risk Level	Post PHR	Post Risk Level
1	1.2	Impact with the Robot in back area	625	Very High Risk	62	Significant Risk
2	1.14	Lack of marking of collaborative workplace	N/A	Not Acceptable	N/A	Not Acceptable
3	2.2	Inability to perform a simultaneously emergency stop between the conveyor and the robot	937	Very High Risk	N/A	Not Acceptable
4	1.8	Crushing with the pneumatic gripper actuators	120	Significant Risk	37	Low Risk
5	2.1	Inability to perform an emergency stop	937	Very High Risk	18	Very Low Risk
6	1.3	Impact with the process part during placement	781	Very High Risk	14	Very Low Risk
7	2.7	Unexpected movements due to new start-up	234	High Risk	9	Negligible Risk
8	2.8	Unexpected movements due to mode selection	312	High Risk	9	Negligible Risk
9	1.5	Falling or ejection of the process part	390	High Risk	3	Negligible Risk
10	1.4	Impact during the pallet change operation	625	Very High Risk	2	Negligible Risk
11	1.10	Impact of robot moving parts against a fixed part	343	High Risk	2	Negligible Risk
12	1.12	Hazards due the stability of the robot	390	High Risk	2	Negligible Risk
13	1.1	Impact with the Robot in operator area	781	Very High Risk	1	Negligible Risk
14	1.6	Drawing in or trapping with the linear conveyor	150	Significant Risk	1	Negligible Risk
15	1.7	Falling of the process part in the conveyor	93	Significant Risk	1	Negligible Risk
16	1.9	Impact with the robot during teaching operation	78	Significant Risk	1	Negligible Risk
17	1.11	Robot movements beyond the expected boundaries	78	Significant Risk	1	Negligible Risk
18	1.13	Hazards generated by the loss of end effector	78	Significant Risk	1	Negligible Risk
19	2.3	Failure of the safety related part of control system - Robot	N/A	Further Review	N/A	Acceptable

Priority	Hazard No	Hazard Name	PHR	Risk Level	Post PHR	Post Risk Level
20	2.4	Failure of the safety related part of control system - End Effector	N/A	Further Review	N/A	Acceptable
21	2.5	Failure of the safety related part of control system - Conveyor	N/A	Further Review	N/A	Acceptable
22	2.6	Failure of the safety related part of control system - Pneumatic System	N/A	Further Review	N/A	Acceptable
23	2.9	Inability to warn about status of Robot	N/A	Not Acceptable	N/A	Acceptable

5.2.4.3. White Goods pilot risk assessment conclusions

Annex 9.2.3 contains the body of the design and on-site risk assessments, where the correct application of the safety concepts applied during the development of the White Goods pilot is shown. However, relevant non-conformities are identified, which should be corrected or taken into account in subsequent stages.

Furthermore, the pilot risk assessment mentions outstanding, documentary or technical aspects, which may change depending on the final or actual service conditions.

Following the results obtained in the on-site evaluation of the implementation of the applied safety concepts for the WG pilot, and taking into account an upcoming objective to industrialise the application by putting it into service, the following aspects should be considered:

- The risk assessment should be complemented and adapted to the final operating conditions, considering the spatial limits of the target installation. For example, the back area may be different. Thus, variations on the safety concepts foreseen in this pilot may be necessary.
- Transient or quasi-static contact impact measurements should be performed again, when changing the conditions of the collaborative space and/or the robot paths, with respect to the pilot.
- As the final conditions change with respect to the pilot, it will be necessary to reconfigure and document the configurations and validations of safety equipment such as the scanner or light curtains.
- The final assembly shall comply with good engineering practice and state of the art. For example, respecting electrical wiring or pneumatic installation techniques, even if these were not shown to be the main objective in the development of this pilot.
- Complementary local regulations should be considered. For example, lighting conditions, electrical supply system conditions (indirect contacts, etc.).
- At the documentary level, the technical file must be compiled, with the contents indicated in Annex VII of 2006/42/EC, including the documents derived from this project or mentioned in it and adapted to the final application. It is essential to have the declarations of conformity and/or incorporation of the equipment constituting the application, as well as the rest of the compulsory documentation for this equipment, instruction and/or assembly manuals. The integrator must take them into consideration when preparing the technical dossier for the application.
- An important part of the technical dossier is the instruction manual. The contents of the manuals shall comply with Part 1.7.3 and 3.6 of Annex I of 2006/42/EC and the information for use found in the applicable type C standards (EN ISO 10218-2, EN 619, ISO TS 15066) and other relevant standards.

- It is noted that the conditions of the applicable standards, both legal and technical, may change over time, as a consequence of the evolution of technology and state of the art. The machinery regulation 2023/1230 will be applicable in January 2027.
- Operators will have to be trained and informed on the basis of the instruction manuals of the application and the machines that make it up.

In summary, the final application will need to be technically and documentarily validated, considering hazards beyond those specific to collaborative robotics, before it is put into service. After validation, the declaration of conformity will be issued by the integrator and the CE marking will be affixed to the assembly. Commissioning will then be carried out with guarantees of compliance with the regulations in force.

5.2.5. Identified limitations

During the validation of ODIN solution at the industrial pilot of BEKO, the partners identified a set of specific improvements which are required before this solution deployment in the real production line. The main limitation that needs to be overcome is the speed of the assembly operation for products which needs to be increased in order to meet the requirements from BEKO side regarding the existing takt time of the production system. Possible solutions that could help to overcome the identified constraints are listed below:

- Next generation of safety regulations – one of main factors constraining robot's speed are the speed limits indicated by the safety related regulation (ISO/TS 15066 and ISO 12018). This raises the need for the R&D partners synergy with the safety related aspects technology providers towards producing new sensing devices as well as control software components that can contribute to the generation of enhanced safety regulations.
- 5G based networking capabilities. The ODIN partners have identified big delays in the assembly execution time due to the large amount of data needs to be captured, consumed and communicated across the involved modules. This leads to bandwidth saturation delaying the transfer of information between the OpenFlow and the robot, the AR application, the projector-based interface, the gripping tools etc.
- Detection module can be further optimized to perform the detection of blister which can be manipulated by the collaborative robot.
- Cooktops are currently being manipulated one by one. This could be further investigated in order for the collaborative robot to be able and pick multiple cooktops at once which will further reduce the takt time of the line.

5.2.6. Performance assessment of the White Goods industrial pilot

5.2.6.1. Evaluation metrics and KPIs

During the first period of the project, LMS and BEKO identified a set of KPIs as documented in D1.1 for the White Goods pilot's evaluation. A detailed list of the KPIs including the baseline and the target value as defined by BEKO but also the ODIN solution achieved value for each KPI are presented in the following table.

Table 16: White Goods pilot KPIs values

KPI	Baseline	ODIN solution	Target
Time to develop	26 weeks	6 weeks	6 weeks
Development cost	100%	~80.92%	≤85%
Takt time	45.5 sec	41 sec ^{*2}	45.5 sec
End Effectors managed	2	3	3

² Detailed explanation provided in subsection 5.2.6.2.3.

KPI	Baseline	ODIN solution	Target
Different products managed by the same workstation	1	2	2
Different components manipulated by the same workstations	1	5	5
Line in continuous flow	Present	Present	Present
End-Effector optimization	No optimization	Optimization of end-effector	Optimization of end-effector
Reconfigured workstation through digital simulation	0	1	1
Components handling failure	5%	1%	1%

5.2.6.2. Validation process and results

The validation process for the industrial pilot and detailed presentation of the results per each KPI is presented in the following subsections.

5.2.6.2.1. Time to develop

This KPI refers to the time (weeks) required in order to develop a new cell or upgrade it through the digital commissioning process. In the current BEKO state, 26 weeks are needed in order to perform these activities. In more details, 6 weeks are needed to design and validate the workstation and extra 20 weeks are required for its programming (in case of new work cell) or reconfiguration (in case of existing work cell). However, the ODIN solution is expected to reduce this time duration from 26 weeks to 6 weeks. Thanks to ODIN solution, it is foreseen that 1.5 weeks will be needed to design and validate the workstation and extra 4.5 weeks for its programming or reconfiguration.

5.2.6.2.2. Development cost

Based on cost benefit analysis of ODIN White Goods pilot, the equipment cost is estimated to 60.000 Euros. Having in mind that the personnel cost for 26weeks for 3 operators is 33.800, then the development cost for the pre-ODIN solution is estimated as follows:

- **Current solution cost** → Personnel cost (26 weeks for 3 operators) + Equipment cost = 33.800 + 60.000 = **93.800 Euros**

As presented in subsection 5.2.6.2.1, due to the integration of ODIN solution, the time to develop for the White Goods pilot is reduced from 26 weeks to 6 weeks. This reduction results to 26.000 Euros reduction required for personnel cost. Additionally, BEKO estimates a saving of costs about 5.000/10.000 Euros since the simulation will allow to see and identify problems and issues in advance and solve them promptly during the development phase. In this case, the development cost for the ODIN solution is estimated as follows:

ODIN solution cost → Personnel cost (6 weeks for 3 operators) + ODIN Equipment cost – Savings due to ODIN simulation = (33.800 – 26.000) + 78.100 – 10.000 = **75.900 Euros**

The above numbers result in a reduction of the development cost by approximately 19.08%.

5.2.6.2.3. Takt time

According to submitted deliverable D1.1, two different business KPIs have been defined to evaluate the ODIN solution integration at the White Goods pilot use case. During the progression of the project and to further pushing the limits of ODIN solution impact in the White Goods pilot, the partners have defined a series of more technical KPIs to check how far can the impact of the ODIN solution go. In

this case, the partners together with BEKO have defined a KPI related to the takt time of the assembly line at Cassinetta factory currently used for the assembly of ovens.

The ODIN solution was able to bring innovative modules to the industrial environment like the dynamic detection of the parts' to be manipulated and the safety concept to ensure operators' safety when collaborating with the industrial robot but in parallel reduce the takt time of the oven product assembly from 45.5 seconds to 41 seconds. Through the implementation of ODIN solution, the number for the execution of the robotic tasks can be reduced to 28 seconds as the tool change robotic task needs to be executed only in the first iteration. The second time that an oven needs to be assembled, the magnetic gripper is already attached to the robot. The idle time of the robot can be used by the robot in order to execute the tasks for the next products' assembly.

In the scope of reconfigurability increasement, a gas cooktop burner has been selected as a second product to-be assembled from another factory of BEKO. This product consists of a high variety of parts with different geometrical and material characteristics to validate the concept of reconfigurability. During the final stage of the project, the partners were able to validate ODIN solution and the reconfigurable robotic tools module during the assembly of the second product calculating the time needed to perform each step:

- Big cooktop manipulation → 30 seconds
- Medium cooktop manipulation → 30 seconds
- Small cooktop manipulation → 30 seconds
- Knob manipulation → 40 seconds

As a future step, the partners will investigate the further reduction of the time needed for the manipulation of the second product's parts towards the optimization of detection module (e.g. single detection action with multiple parts localization), safety concept, robotic cell layout to increase robot's speed as well as picking of multiple parts in parallel.

5.2.6.2.4. End Effectors managed

As already mentioned in section 5.2.1.1, the manipulation of the required parts in the White Goods pilot is based on a Universal Robot UR10 and a modular framework. This framework consists of three different types of grippers: a) Magnetic, b) Flexible and c) Vacuum grippers.

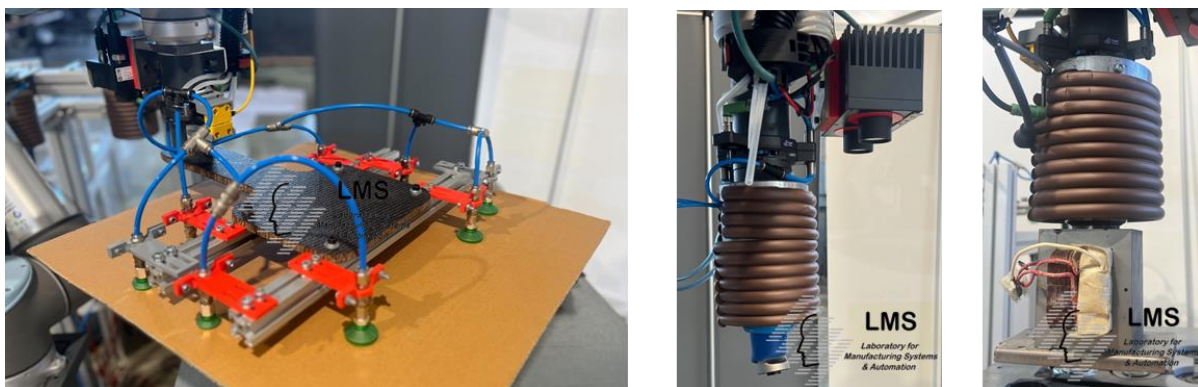


Figure 119: Robotic end-effectors of White Goods pilot

5.2.6.2.5. Different products managed by the same workstation

This KPI refers to the total number of products able to be assembled under the workstation of ODIN White Goods pilot. In the final version of the demonstrator, two different products are able to be assembled by the robot and the human operator, namely Ovens and Gas cooktop.

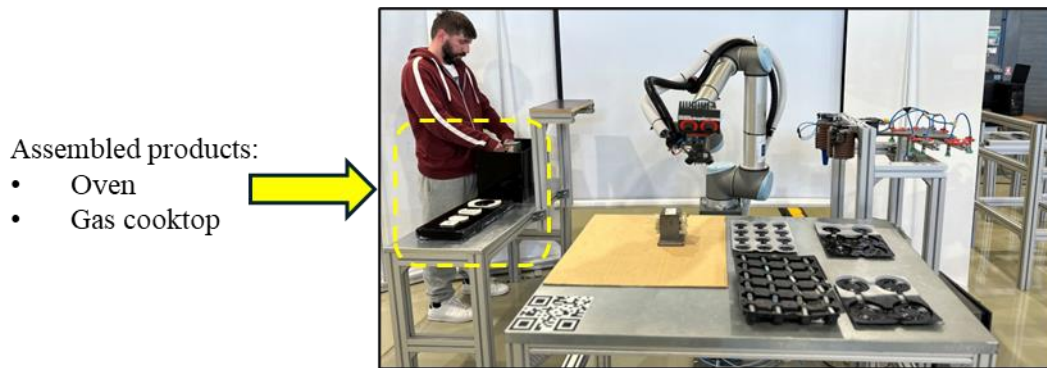


Figure 120: Products being assembled under the White Goods pilot demonstrator

5.2.6.2.6. Different components manipulated by the same workstations

This KPI refers to the total number of parts able to be manipulated by the collaborative robot under the workstation of ODIN White Goods pilot. More detailly, the collaborative robot is able to manipulate 5 different parts thanks to the reconfigurable robot tool of ODIN as presented in the following figure.

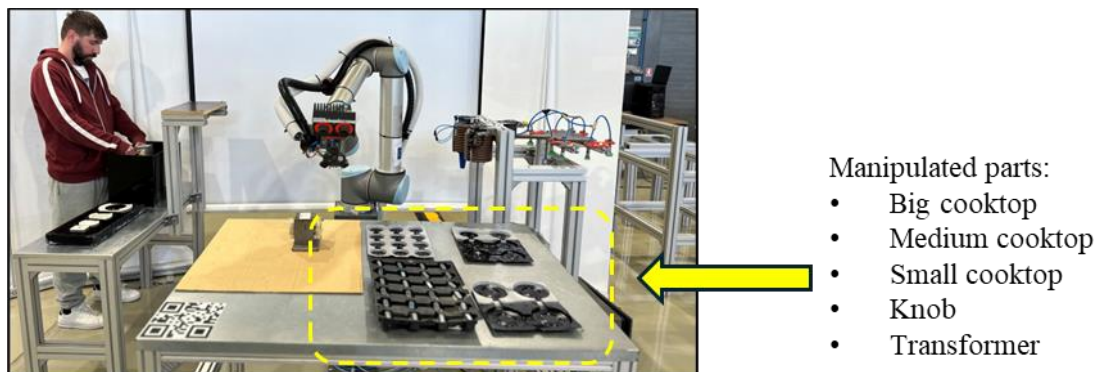


Figure 121: Parts being manipulated under the White Goods pilot demonstrator

5.2.6.2.7. Line in continuous flow

This KPI refers on the ability of ODIN solution to be implemented at BEKO premises utilizing the movable conveyor for assembled parts transportation. Thanks to ODIN solution, both Oven and Gas cooktop products were able to be assembled at BEKO premises maintaining the same conveyor speed throughout the execution of the required assembly tasks.

5.2.6.2.8. End-Effector optimization

As documented in deliverable D1.1, this KPI refers to the ability of ODIN end-effectors to change strategy dynamically defined based on the products pipeline mix on the assembly line. This KPI is achieved thanks to the connection of factory's ERP system (including information about the sequence of products to be assembled) with the OpenFlow and AI-based decision making modules. Additionally, in ODIN solution there is no idle configuration for the robot in terms of attached robotic gripper on the robot. Depending on the next product to-be assembled, the OpenFlow sends the corresponding actions on the robot for automated tool exchange.

5.2.6.2.9. Reconfigured workstation through digital simulation

This KPI is centralized on the leverage on digital simulation tool enabling the reconfiguration in the White Goods demonstrator. In order to achieve this KPI, the Digital Simulation module of ODIN includes the following features:

- Collision detection between human operators, robots and obstacles.
- Generation of evaluation data to be used by the AI Task Planner regarding robot's motions.
- Modelling of safety components (safety scanners and light barriers) in Visual Component software:
 - Safety functions on both models are included informing the user of the Visual Component software if the sensors are placed on the correct distance relatively to the robotic resources or not.
 - Easy reconfiguration of light barriers length.
 - Easy reconfiguration of safety zones through the User Interface of Visual Component software.
 - Dynamic re-configuration of safety zones for laser scanners is supported based on work cell's robots' configuration.

5.2.6.2.10. Components handling failure

This KPI refers to the reduction of components' loses events using the reconfigurable grippers of ODIN solution. During the final integration meeting at BEKO premises, the assembly process executes 12 times and the partners collected valuable information regarding the successful picking of cooktops, knobs, blisters and cardboards. This data analysis resulted in the following statistics per each gripper of the White Goods pilot:

- Magnetic gripper was able to grasp cooktops and transformers with success rate of 100% as all the parts were able to be successfully manipulated by the collaborative robot during the 12 runs of the assembly process.
- Flexible gripper was able to grasp knobs with success rate of 100% as the knobs were able to be successfully manipulated by the collaborative robot during the 12 runs of the assembly process.
- Vacuum gripper was able to grasp cardboards and blisters with success rate of 96% as the collaborative robot was able to successfully grasp 23 times out of 24 each part using this gripper.

In total, the average value for the investigated KPI regarding all gripping tools is calculated at 1%.

5.2.6.3. Cost benefit analysis of the White Goods pilot

ODIN partners have performed a cost benefit analysis towards the calculation of the return of investment for the current set up at BEKO as well as the ODIN solution implementation case.

Two different cases in terms of cost have been calculated, the optimistic and the pessimistic. Following the same methodology presented in section 3.2.6.3 for the Automotive pilot, two group of costs have been considered for each of the cases: a) the investment cost which involves the costs for equipment acquisition and commissioning of the workstations – before starting the operation of the process and b) the operating cost which involve the annual required costs for the operation of the workstation. The investment cost that was required for the current set up at BEKO as well as the for the two cases of ODIN solution implementation are presented in the following table.

Table 17: Investment cost of Current BEKO state vs ODIN solution (2 cases)

Cost category	Current BEKO state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Equipment Cost	60.000 €	78.100 (37.000 € UR10 robot, 10.000 conveyor, 3.000 robot base, 4.000 alluminum profiles, 6.000 for PLC, 5.000 for safety barriers, 100 for emergency and reset buttons, 5.000 for	105.200 (40.000 € UR10 robot, 12.000 conveyor, 5.000 robot base, 8.000 alluminum profiles, 8.000 for PLC, 6.000 for safety barriers, 200 for emergency and reset buttons, 6.000 for

Cost category	Current BEKO state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
		laser scanner, 3.000 for cameras, 3.000 PCs, 2.000 consumables)	laser scanner, 5.000 for cameras, 7.000 PCs, 9.000 consumables)
Engineering cost	5.000 €	2.000 €	2.000 €
Commissioning labour cost	30.000 €	20.000 €	25.000 €
Energy lines (Electric, Pressurised air etc.)	10.000 €	12.000 €	15.000 €
Total investment Cost (€)	105.000 €	112.100 €	147.200 €

In the following table, the operating costs of the above cases has been estimated by the consortium based on current values from the end user and experience of the technology providers and the system integrators.

Table 18: Operating cost of Current BEKO state vs ODIN solution (2 cases)

	Current BEKO state	ODIN solution - Optimistic Case	ODIN solution - Pessimistic Case
Maintenance cost	10.000 €	5.000 €	5.000 €
Operation cost – Electricity, Air	1.000 €	1.000 €	1.000 €
Labour cost	15.000 €	7.500 €	9.000 €
Total running Cost (€)	26.000 €	13.500 €	15.000 €

Based on the above analysis, the payback Head To Head Point (HTHP) has been calculated for both the optimistic and pessimistic case of cell deployment. As illustrated in the following figure, in the optimistic case the HTHP is in 8 months, while for the pessimistic case is in 46 months.

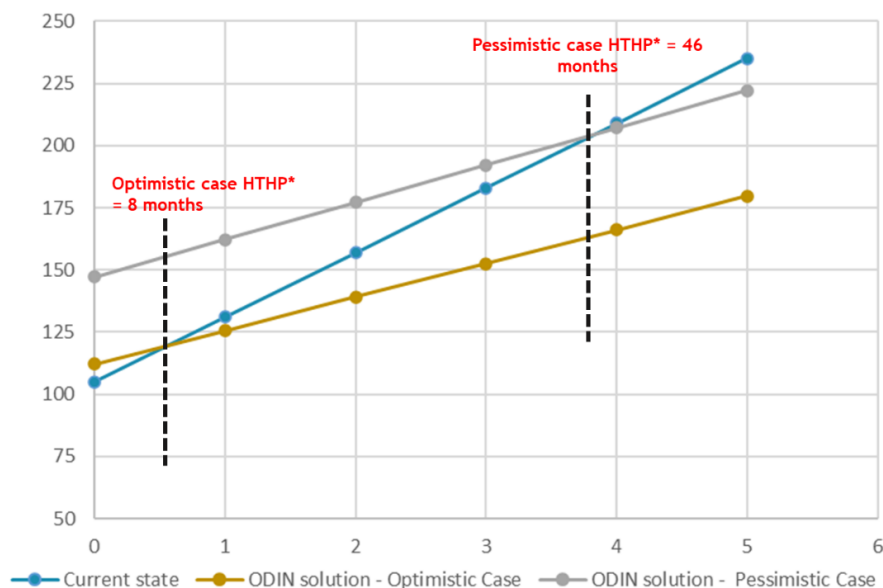


Figure 122: HTHP³ after ODIN solution deployment

³ Payback Head To Head Point (HTHP)

The ODIN partners estimate that the realistic case for ODIN solution is the Optimistic one with the HTHP calculated at 8 months.

5.2.7. Feedback received for ODIN solution

After the integration of ODIN solution at BEKO premises, ODIN partners had the chance to organize a series of workshops with operators and managers from the BEKO group in order to showcase the results of ODIN White Goods demonstrator.



Figure 123: Workshop organized at STELLANTIS factory showcasing a) Assembly process of industrial demonstrator, b) VR safety training module

LMS in collaboration with BEKO drafted a questionnaire with key questions in order to collect valuable information during these workshops at BEKO premises. These questionnaires included general questions regarding the flexibility and the functionality of overall ODIN solution but also technical questions more focused on the ODIN modules. This questionnaire is presented in the following figure.

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Gender:
 Age: (20-30) (30-40) (40-50) (50-60)
 Educational level:
 Role in the company:

1. Indicate the areas where you think robots may be useful:

a. Final Assembly	c. Inspection & Maintenance activities.
b. Sanding, deburring and other machining operations.	d. Logistics.
e. Other (.....)	

2. Which you consider the most promising technology for improving production performance?

a. Human safety	d. Process optimization and execution coordination
b. Robot perception	e. Human operator support interfaces
c. Reconfigurable robot grippers	

3. Which you consider the most challenging to deploy technology?

a. Human safety	d. Process optimization and execution coordination
b. Robot perception	e. Human operator support interfaces
c. Reconfigurable robot grippers	

4. Are you familiar with Augmented Reality (AR) technology?

a. I am a first-time user.	c. I am an intermediate user.
b. I have used AR technology less than 10 times.	d. I am a AR application developer.
	e. I am an expert in AR technology.

5. Do you think this AR application will be useful for the operators?

a. I strongly agree.	d. I disagree.
b. I agree.	e. I strongly disagree.
c. I am not sure.	

6. Do you think it would be easy for other people to get familiarized with the AR application?

a. I strongly agree.	d. I disagree.
b. I agree.	e. I strongly disagree.
c. I am not sure.	

7. How would you rate the functionality of the system?

a. Very poor.	d. Good.
b. Poor.	e. Excellent.
c. Average.	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no° 101017141.

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8. Would you feel comfortable co-existing/working with collaborative robots?

a. I strongly agree.	d. I disagree.
b. I agree.	e. I strongly disagree.
c. I am not sure.	

9. Do you believe that the ODIN solution for products' assembly increase human ergonomics?

a. I strongly agree.	d. I disagree.
b. I agree.	e. I strongly disagree.
c. I am not sure.	

10. Do you believe that the ODIN solution promotes gender balance in industrial shop/floors?

a. I strongly agree.	d. I disagree.
b. I agree.	e. I strongly disagree.
c. I am not sure.	

11. Do you believe that the ODIN solution promotes reconfigurability in current workstations for multiple products assembly?

a. I strongly agree.	d. I disagree.
b. I agree.	e. I strongly disagree.
c. I am not sure.	

12. Kindly recommend any improvement(s) for the system (if applicable).

13. In which part of the production you think this system would be useful? (e.g., Assembly, Logistics etc.)

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Figure 124: White Goods pilot questionnaire

Using the feedback from the collected questionnaires, ODIN partners were able create statistics regarding the functionality of the overall ODIN solution as well as their modules.

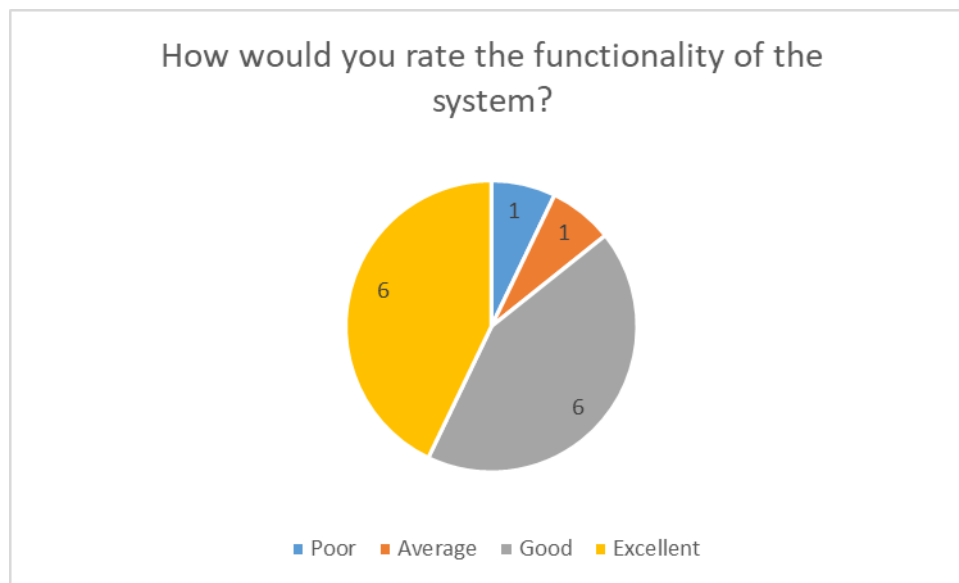


Figure 125: Evaluation of ODIN solution functionality in BEKO demonstrator

ODIN partners were able to evaluate how comfortable do the operators feel when coexisting/working with the collaborative robot of ODIN.

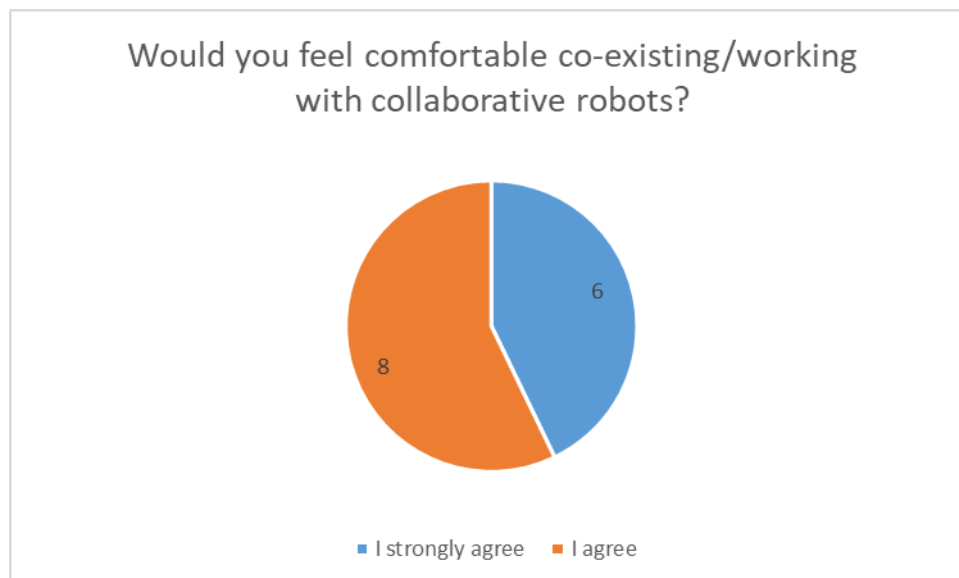


Figure 126: Evaluation of how comfortable do the operators feel while coexisting/working with collaborative robots

Additionally, ODIN partners were able to measure the impact of ODIN solution to human ergonomics during assembly process execution.

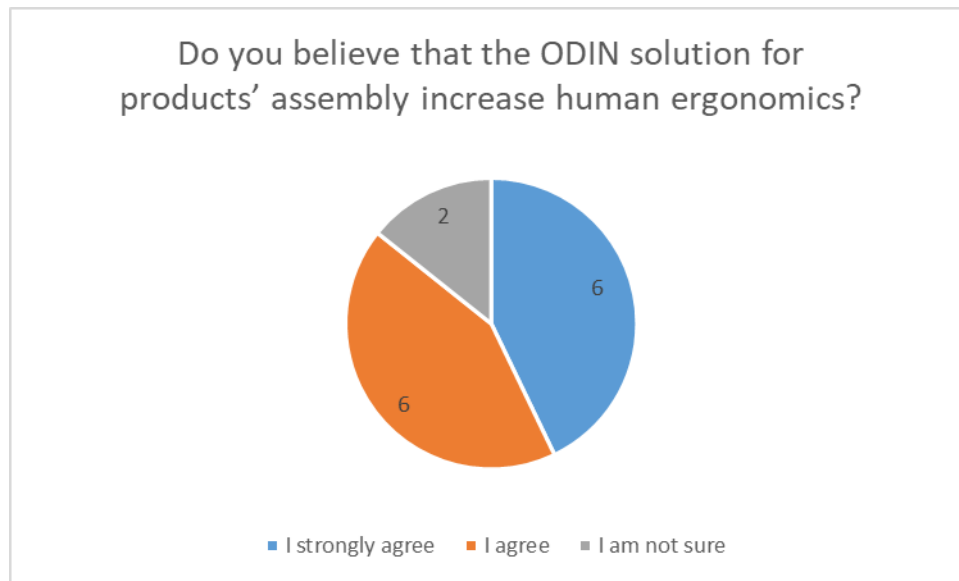


Figure 127: Evaluation of ODIN solution impact to human ergonomics during assembly process
ODIN partners were able to validate reconfigurability increase due to ODIN solution implementation.

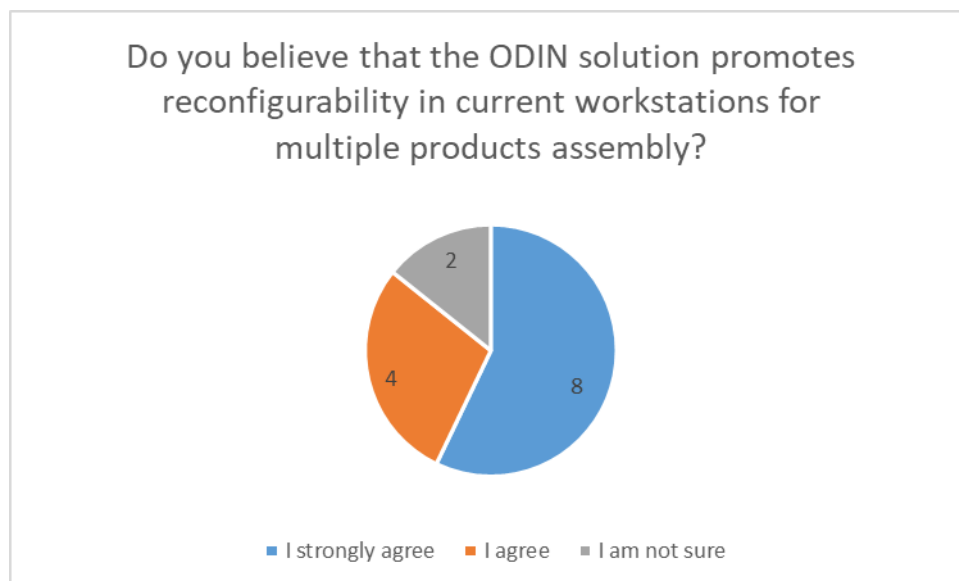


Figure 128: Evaluation of production system reconfigurability increase due to ODIN solution implementation

6. CONCLUSIONS

The final version of ODIN Industrial Component is presented in this deliverable. The focus is given on the large-scale pilot lines developed in ODIN. The integration of ODIN Full scale pilots' demonstrators are presented in detail.

The main conclusion from Open, Digital and Networked Components integration inside ODIN large-scale pilots is that the final demonstrators have been validated as expected without any major delays. The following information per each demonstrator is presented in this deliverable:

- Large-scale pilot demonstrators in their final and existing form executed and validated.
- Successful integration of the ODIN Components and individual modules on each large-scale demonstrator.
- First integration and running of pilots' execution flow utilizing the aforementioned modules in their final setups.
- Final Safety risk assessments and safety concept validation in the large-scale pilots.

The integration of Open, Digital and Networked Components in the three large-scale pilots of ODIN has been finished successfully, and their descriptions are presented in this deliverable.

7. GLOSSARY

AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AR	Augmented Reality
CAD	Computer Aided Design
CNN	Convolutional Neural Network
DC	Digital Component
FC	Fan Cowl
FOV	Field Of View
GUI	Graphical User Interface
HW	Hardware
OEM	Original Equipment Manufacturer
OISP	On-site Interactive Skill Programming
PLC	Programmable Logic Controller
QI	Quality Inspection
ROI	Regions of Interest
ROS	Robot Operating System
SOP	Start of production
SRP/CS	Safety-related parts of controls systems
SW	Software
TIER	Provider level
UDP	User Datagram Protocol
VC	Visual Components
XML	eXtensible markup language

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9. ANNEX

9.1. Safety concept verifications

9.1.1. Automotive pilot safety verifications

No.	Description	OK	NOK	N/A
AUTO-BUC-01				
AURA Robot Autonomous Operation				
1.1	The two safety scanners have been installed properly	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2	Distance to hazard points is in accordance to ISO 13855 (Robot in area 1: 1.98m, Robot in area 2: 1.7m)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.3	Different zones have been programmed for the scanners	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.4	Movement of the robot is stopped if danger zone is triggered	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.5	Auxiliary elements are stopped if scanners are interrupted	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.6	The robot speed it's reduced if warning zone is triggered (250 mm/s)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.7	Verify if the high speed (500 mm/s) of AURA robot it's safety monitored	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.8	A manual reset is needed after the interruption of movement	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Access From Infeed Area				
2.1	The pair of light curtains and mirrors was installed properly	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.2	Distance to hazard points is in accordance to ISO 13855 (1.46m)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2.3	Movement of the robot is stopped if light curtains are interrupted	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.4	A manual reset is needed after the interruption of movement	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.5	Auxiliary elements are stopped if light curtains are interrupted	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Safe monitoring of the parts grasping				
3.1	The interlocking system of the gripper is intrinsically safe	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.2	A redundant solenoid valve has been installed in the gripper	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.3	Pressure switch have been installed to monitor the status	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.4	Under pressure switch has been installed to prevent start-up	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.5	Position monitoring sensor have been installed in the cylinders	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.6	The circuits are designed considering the exclusion of failure	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hand-guiding operation				

4.1	The enable switch devices have been installed properly	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.2	Ergonomic hazards were avoided in the gripper design	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.3	The robot movement is only enabled when switch is active	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.4	The hand guidance can only be used with mode selector	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.5	The gripper push-buttons are installed outside hazard area	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.6	Release of process part is only allowed in restricted volume	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4.7	Verify if two-hand control device is in accordance with ISO 13851:2019	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Emergency stop and interconnection of mobile platforms				
5.1	The ESTOP Push-Buttons has been installed properly	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.2	The ESTOP Push-Buttons are in accordance with ISO 13850	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.3	If any ESTOP Push-Buttons are pressed all actuators must stop	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.4	A manual reset is needed after an actuation of ESTOP buttons	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.5	The R3 Echo Ring devices have been properly installed	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.6	Interconnection between devices is working in accordance with section 5.2 (Safety Concepts) D5.3	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.7	In case of connection failure, there is an immediate stop	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.8	A manual reset is needed in case of connection failure	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Operating mode selection				
6.1	Mode selector has been installed properly	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.2	The mode selector has been outside the hazard area	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.3	After a mode change, the system needs a manual reset	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.4	Automatic mode only works with all safety devices enabled	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.5	Hand-guidance mode only works with both enable switches	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6.6	Only one operation mode can be selected at the same time	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AUTO-BUC-02				
Mobile Platform Operation				
7.1	The laser scanners of the mobile platform have been installed properly	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.2	Fields of the mobile platform have been adapted while moving in accordance to ISO 3691-4	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.3	Fields of the mobile platform have been adapted while coupled	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.4	Protective stop is triggered after the detection of an person while moving	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

7.5	Movement of the robot is disabled when platform is moving	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.6	All parts of the robot are inside the platform when moving whit the exception when the mobile platform is coupled with the conveyor	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7.7	Light indicator has been programmed to different operations	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mobile platform operations linked to conveyor				
8.1	Safety function of the scanner (contour detection) has been implemented to send a signal that the mobile platform is coupled to the conveyor	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8.2	Coupling between the mobile platform and the conveyor is a safe signal	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AUTO-BUC-03				
Mobile Platform Operation				
9.1	The laser scanners have been installed properly	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.2	Fields of the mobile platform have been adapted while moving in accordance to ISO 3691-4	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.3	Fields of the mobile platform have been adapted while coupled	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.4	Protective stop is triggered after the detection of an person while moving	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.5	Movement of the robot is disabled when platform is moving	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.6	All parts of the robot are inside the platform when moving	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9.7	Light indicator has been programmed to different operations	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mobile platform operations linked to conveyor				
10.1	Optoelectronic sensors have been installed properly	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10.2	Coupling between the mobile platform and the conveyor is a safe signal	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

9.1.2. Aeronautics pilot safety verifications

No.	Description	OK	NOK	N/A
AUTO-BUC-01				
1.1	Different zones have been programmed for the mobile platform scanners	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.2	Fields of the mobile platform have been adapted while moving in accordance to ISO 3691-4	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.3	Movement of the mobile platform is stopped if danger zone is triggered	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

1.4	Different zones have been programmed for the scanners in accordance to ISO 13855 when the mobile platform is not moving	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.5	Movement of both arm robots is disabled when mobile platform is moving	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.6	Movements of both robotic arms of the mobile platform and the screwing tool gripper stop if danger zone of the scanner is triggered	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1.7	All parts of the mobile platform are inside the platform when moving	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
1.8	Safety contour detection of the scanners it's used to know if the mobile platform is in position	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AUTO-BUC-02				
2.1	Different zones have been programmed for the mobile platform scanners	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.2	Fields of the mobile platform have been adapted while moving in accordance to ISO 3691-4	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.3	Fields of the mobile platform have been adapted while coupled with the fan cowl	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.4	Movement of the mobile platform is stopped if danger zone is triggered	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.5	Movement of the mobile platform is stopped if the fan cowl uncoupled mobile platform	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.6	Movement of both arm robots is disabled when mobile platform is moving	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2.7	All parts of the mobile platform are inside the platform when moving	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
2.8	Safety contour detection of the scanners it's used to know if the mobile platform is in position	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
AUTO-BUC-03				
3.1	Different zones have been programmed for the mobile platform scanners	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.2	Fields of the mobile platform have been adapted while moving in accordance to ISO 3691-4	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.3	Movement of the mobile platform is stopped if danger zone is triggered	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.4	Different zones have been programmed for the scanners in accordance to ISO 13855 when the mobile platform is not moving	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.5	Movement of both arm robots is disabled when mobile platform is moving	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.6	Movements of both robotic arms of the mobile platform and the screwing tool gripper stop if danger zone of the scanner is triggered	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

3.7	All parts of the mobile platform are inside the platform when moving	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
3.8	Safety contour detection of the scanners it's used to know if the mobile platform is in position	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

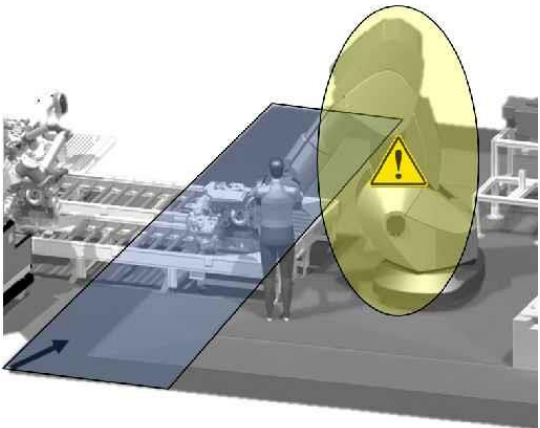
9.1.3. White goods pilot safety verifications

No.	Description	OK	NOK	N/A
1	The installation distance of the safety scanner is in accordance to ISO 13855 (452mm)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	Speed of the robot is set to collaborative speed if the robot position it's close to the working area of the operator and danger zone of the scanner is triggered	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	Both light curtains has been installed properly in accordance to ISO 13855	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
4	Speed of the robot change to collaborative speed if light curtains are interrupted	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	Movement of the robot stop if light curtains are interrupted where the pneumatic gripper is attached to the robot	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	Both ESTOP Push-Buttons has been installed properly	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	The ESTOP Push-Buttons are in accordance with ISO 13850	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8	If any ESTOP Push-Buttons are pressed all actuators must stop	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9	A manual reset is needed after an actuation of ESTOP buttons	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10	The height of the conveyor is in accordance with EN619 to prevent the access of the operator to the hazard zone	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11	Light indicator has been programmed to show the status of the cell	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12	Verification of the safety logic program	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>


9.2. Risk assessment tables

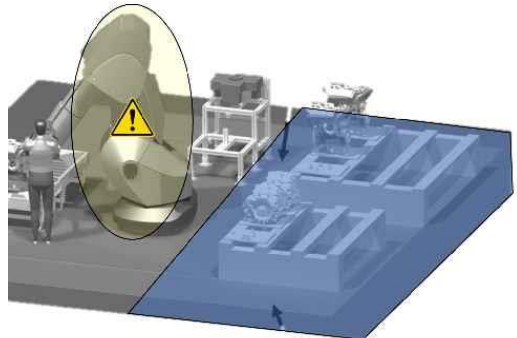
9.2.1. Automotive pilot Risk assessment conducted


9.2.1.1. Mechanical Hazards: AUTO-BUC-01

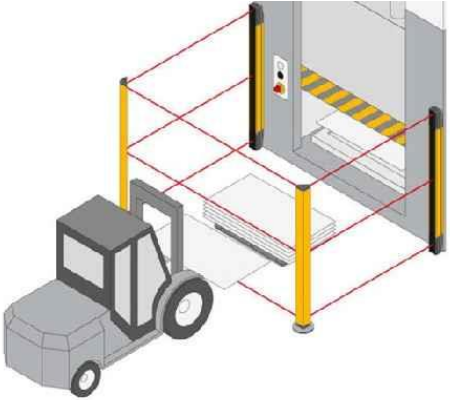
Hazard Identification		Hazard No:	1.1
Title	Impact with the AURA Robot in conveyor area		
Location	Operator Area		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Pick and Place		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Mechanical hazards due to the exposed risk of impact with the robot structure while the robot is moving in the conveyor area to release the process parts on the conveyor. The robot will be running in a fenceless environment and there are no sensors installed in the area.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	781	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Install light sensing devices (scanner) to detect the presence of the operator. • Use of safety zones to detect the presence of the operator (green, yellow and red). • Slow speed robot movements near foreseeable access points. • Perimeter guarding where access is not required. • Robot path programmed to avoid crossing torso and head areas. • Training and information for use about residual risk. 		EN ISO 13855 EN ISO 13849-1 EN ISO 10218-2	
Possible Residual Risk			


Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk

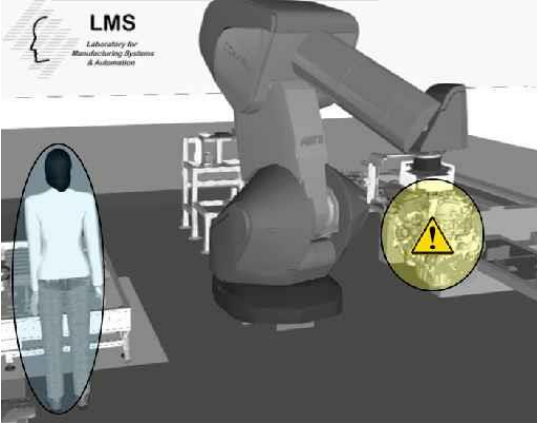
Post Measures Risk Assessment	
Assessment Date	12-sep-2024
Degree of Possible Harm	25
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	0.75
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	4
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>A combination of fixed perimeter protection and optoelectronic protection devices is established as a means of controlling access to the hazardous area of the AURA robot, in AUTO - BUC 01 operation, causing the robot to stop, when it is in operation zone 1, and de-energising actuators, without dropping the workpiece.</p> <ul style="list-style-type: none"> - Body access control barrier, arranged on the non-physical perimeter of the operating area, except in monitored areas by scanners. - Scanner of operation zone 2, which supervises approach or access from operation zone AUTO BUC 02. - Scanner of airside 3, monitoring approach or access from airside AUTO-BUC 03. <p>If the operator accesses the conveyor zone according to the established procedure, acting on the PIT Reader mode selector when the robot is already on the conveyor, the detection of the scanner of operation zone 2 is inhibited and the robot automatically becomes controllable under HGC task, without significant risk of impact. In the event of unauthorised access, the scanner commands a safety stop.</p> <p>Restarting after a safety stop requires manual reset from outside the protected area. From the reset position, there is visual monitoring of the danger zone.</p> <p>Remark: The restart is preceded by an acoustic warning.</p>	<p>EN ISO 13855 EN ISO 13849-1 EN ISO 10218-2</p>
Residual Risk	
<p>The training, general and specific knowledge, experience and information that operators must have shall be reflected in the instruction manual. This statement applies to the control of all identified risks.</p>	


Hazard Identification		Hazard No:	1.2
Title	Impact with the AURA Robot in warehouse area		
Location	Warehouse Area		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Pick and Place		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Mechanical hazards due to the exposed risk of impact with the robot structure while the robot is moving in the warehouse area in order to grab the process parts. The robot will be running in a fenceless environment and there are no sensors installed in the area.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	781	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Install fixed guards in accordance to the EN ISO 13857 to protect the access to the back area. • Install light sensing devices (light barriers) if there is the need to use a forklift to change the pallets. • Training and information for use about residual risk. 		EN ISO 13855 EN ISO 13849-1 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk

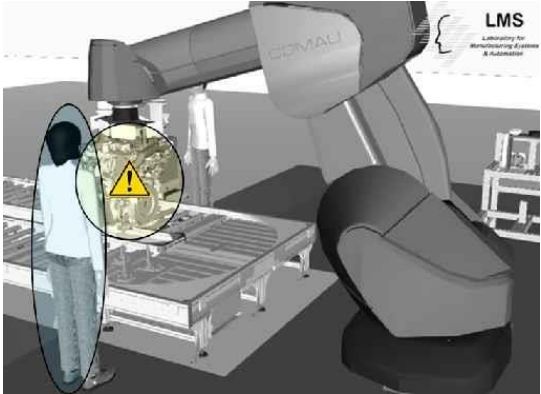
Post Measures Risk Assessment	
Assessment Date	12-sep-2024
Degree of Possible Harm	25
Probability of Occurrence of a Hazardous Event	1.25
Possibility of Avoidance	2.5
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	390
Summary Level	
High Risk	
	
Risk Reduction Measures Description	Reference
<p>A combination of fixed perimeter protection and optoelectronic protection devices is established as a means of controlling access to the hazardous area of the AURA robot, in AUTO - BUC 01 operation, causing the robot to stop, when it is in operation zone 1, and de-energising actuators, without dropping the workpiece.</p> <ul style="list-style-type: none"> - Body access control barrier, arranged on the non-physical perimeter of the operating area, except in monitored areas by scanners. - Scanner of operation zone 2, which supervises approach or access from operation zone AUTO BUC 02. - Scanner of airside 3, monitoring approach or access from airside AUTO-BUC 03. <p>The operator can access the storage or pick-up area or the tool change area of the robot, however any of the above devices will cause a safety stop.</p> <p>Restarting after a safety stop requires manual reset from outside the protected area. From the reset position, there is visual monitoring of the danger zone.</p> <p>However,</p> <ul style="list-style-type: none"> - Space limitations in the pilot do not allow the distance from the barriers to the nearest hazardous point to comply with the distances of EN ISO 13855. The minimum distances of EN ISO 13855 must be respected. - It is possible to access the AURA robot area by walking over the conveyor. Risk of malpractice or insufficient training. To be completed with additional fixed guard. <p>Remark: The restart is preceded by an acoustic warning. For automatic reset, it would be necessary to monitor the absence of people in the entire danger zone by means of an additional scanner or safety radar.</p>	<p>EN ISO 13855 EN ISO 13849-1 EN ISO 10218-2</p>
Residual Risk	


Hazard Identification		Hazard No:	1.3
Title	Impact during placement of the process parts in warehouse		
Location	Warehouse Area		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Feeding, filling, loading of raw material		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Mechanical hazards due to the exposed risk of impact during the manual process of placing the process parts in the warehouse area. It is expected that the process part placement will be done by using forklifts.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	625	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Create a procedure to load the process parts in the warehouse area. • Disable the robot movement while the operation is being performed in the back area. • Training and information for use about residual risk. 		EN ISO 13855 EN ISO 13849-1 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	12	Summary Possible Level:	Very Low Risk

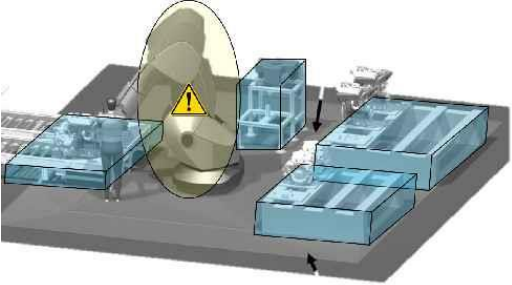
Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	4	
Pilz Hazard Rating (PHR)	3	
Summary Level		
Negligible Risk		
Risk Reduction Measures Description		Reference
<p>Any access to the AURA robot's hazardous area shall be detected by the combination of protection means indicated above for AUTO BUC 01. leading to a protective stop of the robot.</p> <p>Remark: The procedure to load the process part in the warehouse area will depend on the final operating conditions, in case of industrialisation of the pilot.</p>		<p>EN ISO 13855 EN ISO 13849-1 EN ISO 10218-2</p>
Residual Risk		
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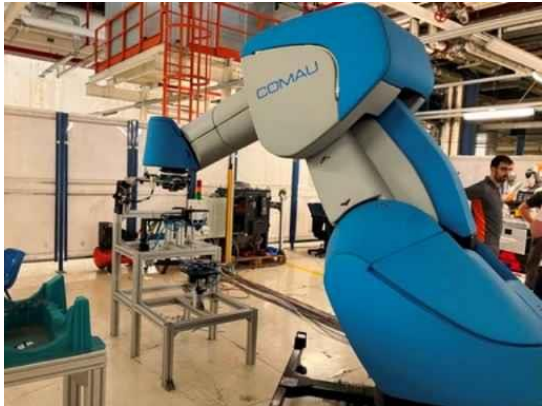
Hazard Identification		Hazard No:	1.4
Title	Falling or ejection of the process part		
Location	Robot Perimeter		
Target	People / Machine		
Activity	Normal Operation		
Task	Operation		
Sub Task	Clamping/fastening the workpiece		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Falling or ejected objects		
Description	Mechanical hazards due to the exposed risk of impact with the process part while the robot is performing the pick and place operation of the process part. The part can be dropped by gravity, loss of power excessive speed of manipulation or wrong intrinsically design of the fixation mechanism.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	390	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Use a intrinsically safe mechanical locking system in the gripper to hold the part in place. • Robots shall be designed and constructed so that loss or change of electrical, pneumatic or vacuum energy does not result in a hazardous situation. • Proper positioning and closing of the gripper should be monitored before allowing robot movements. • Speed reduction when reaching outer areas will help to reduce kinetic energies in case the product gets detached. • Warning pictograms, training and information for use about residual risk. 		EN ISO 12100 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk

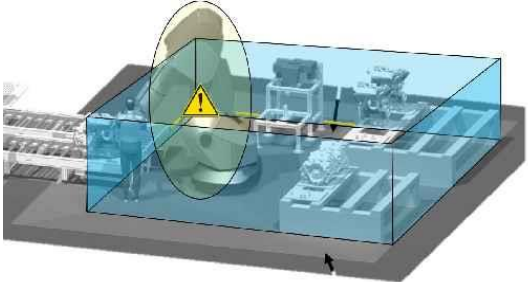
Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	4	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The mechanical connection between the gripper and the workpiece is designed and constructed specifically for the given application. The correct grip of the workpiece is monitored prior to the movement of the motor.</p> <p>In case of loss of electrical or pneumatic power supply, the gripper does not release the workpiece. When the robot enters the conveyor zone, if the scanner detects presence, the robot slows down and enters collaborative mode.</p> <p>When the operator approaches the workpiece to proceed under HGC technology, the workpiece will already be on the conveyor, the risk of the workpiece (motor or gearbox) falling on the operator's feet is negligible.</p> <p>The gripper should be certified by its manufacturer as part of the robotic system integration.</p>		<p>EN ISO 12100 EN ISO 10218-2</p>
Residual Risk		
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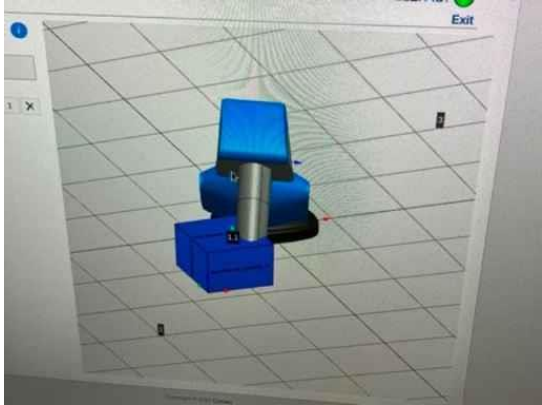
Hazard Identification		Hazard No:	1.5
Title	Crushing during the hand guidance operation		
Location	Conveyor Area		
Target	People / Machine		
Activity	Normal Operation		
Task	Operation		
Sub Task	Clamping/fastening the workpiece		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Crushing		
Description	Mechanical hazards due to the exposed risk of impact with the process part while the operator is performing the hand-guidance operation of the process part (motor or gearbox). During the hand-guidance operation there is the possibility of a crushing hazard between the process part and the conveyor.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	275	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Use a mode selector with dual channel architecture to change the operation mode of the robot • Use two enable switch devices for the gripper hand-guidance operation • The person who guides the gripper needs to press the both enable devices on the hand guiding wheel • Install the buttons to release the part outside the hazard area 		EN ISO 12100 ISO/TS 15066 EN ISO 10218-2 ISO TR 20218-1	
Possible Residual Risk			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	5	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	11	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	4	
Pilz Hazard Rating (PHR)	5	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The AURA robot operates under task or HGC method after activation of the PITReader and subsequent pressing of the manual reset, when the robot is positioned on the conveyor.</p> <p>The HGC method is designed and implemented considering the requirements of 5.5.3 of ISO TS 15066, 5.10.3 of EN ISO 10218-1 and 5.11.5.3 EN ISO 10218-2.</p> <p>The robotic application allows direct control of the movement by the operator. While using HGC, the operator has a clear visibility of the danger zone while manually guiding the robot system to the intended position.</p> <p>The robot has a 'Hold to Run' safety function in which activation of the hold-to-run control device enables motion and deactivation of the stop control device initiates a protective stop and, after the stop, a guarded stop is activated. The Hold to Run controls comply with EN IEC 60204-1.</p> <p>The robot has a monitored speed safety function;</p> <p>The robot has software-based limiting safety function(s).</p> <p>Remark: For industrialisation, the conditions of section 5.14 of ISO FDIS 10218-2 should be considered in addition.</p>		<p>EN ISO 12100 ISO/TS 15066 EN ISO 10218-2 ISO TR 20218-1</p>
Residual Risk		


Hazard Identification		Hazard No:	1.6
Title	Movement of robot moving parts against a fixed part		
Location	Robot Perimeter		
Target	Entire Body		
Activity	Normal Operation		
Task	Setting Teaching/programming and/or process changeover		
Sub Task	Adjustment and setting or verification of functional parameters of the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Approach of a moving element to a fixed part		
Description	There are some other elements present in the working radius of the robot such as the conveyor and the pallet supports for the motors and gearboxes. This and other fixed machine elements within the working space of the robot may present a crushing hazards between fixed and moving parts for personnel. This is especially true in the event of a machine unexpected start-up when personnel are conducting operations within the robotic work space envelope, for example teaching.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	11	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	687	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Perimeter guard installation to take safety distances specified in EN 349 into account. • Definition of a restricted space within a limit robot envelope area • Mechanical hard stop and/or safety-rated soft limits to reduce and monitor operating space • Provide information and warning in relation to maximum space which can be swept by moving parts of the robot including the robot's end-effector and work-piece. 		EN ISO 14120 EN ISO 13857 EN 842 EN 349 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	6	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment	
Assessment Date	12-sep-2024
Degree of Possible Harm	11
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	2.5
Frequency And / Or Duration of Exposure	4
Pilz Hazard Rating (PHR)	5
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>The installation with the observed paths offers no crush points against fixed parts, except in the conveyor area, where it is always operated under HGC method. The trajectories are programmed taking into account the axis constraints to avoid crush points between moving robot parts, including its back, the end effector and the workpiece. Teaching is performed in manual reduced speed mode, in accordance with part 5.6.4.2 of EN ISO 10218-2. The Teach Pendant console complies with parts 5.8 of EN ISO 10218-1 and 5.7 of EN ISO 10218-2.</p> <p>Information regarding maximum, operational, restricted and collaborative spaces shall be part of the instructions.</p> <p>Remark: The possible presence of shelving or other fixed storage structures or the target building itself could condition the need for new robot paths that comply with the distances of EN ISO 13854.</p>	<p>EN ISO 14120 EN ISO 13857 EN 13854 EN ISO 10218-2</p>
Residual Risk	


Hazard Identification		Hazard No:	1.7
Title	Robot movements beyond the expected boundaries		
Location	Robot Perimeter		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Moving elements		
Description	During normal operation the robot and other associated machine elements and products stay inside a limited (and typically safeguarded) area. If due to an operational or control fault the robot or work-piece extends beyond the distance guard there is a potential impact risk for personnel in the vicinity.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	781	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Definition of a restricted space within a limit robot envelope area • Mechanical hard stop and/or safety-rated soft limits to reduce and monitor operating space • Perimeter guards installed are able to contain and withstand robot impact forces • Provide information about established limits in "Information for Use" 		EN ISO 14120 EN ISO 10218-1	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	11	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	4	
Pilz Hazard Rating (PHR)	5	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The AURA robot operates in the so-called Safe Box, restricting movements by means of software-controlled axis limiters. This is a function integrated in the robot and certified by the robot manufacturer in the declaration of incorporation. The observed paths do not pass close to the perimeter protection. This prevents the robot, the end effector or the workpiece from leaving the operating space or beyond the safety space. It is therefore not necessary for the physical enclosure to be strong enough to withstand impacts.</p> <p>Information regarding maximum, operational, restricted and collaborative spaces shall be part of the instructions.</p>		<p>EN ISO 14120 EN ISO 10218-1</p>
Residual Risk		
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Hazard Identification		Hazard No:	1.8
Title	Hazards generated by the loss of end effector		
Location	Robot Perimeter		
Target	Entire Body		
Activity	Normal Operation - Maintenance		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Kinetic energy		
Description	The movement of the robot presents the risk that the tool may detach and fall or as a result of the dynamic forces involved be ejected at speed. This can put personnel within range of the robot in danger.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	781	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Ensure that the fixing systems of the end effector is secured mechanically • Position of end effector shall be monitored • Information for use shall contain details of end effector and inspection intervals for connection details 		EN ISO 12100 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk

Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	15	
Summary Level	Very Low Risk	
Risk Reduction Measures Description		Reference
<p>The mechanical joint between the gripper and the robot wrist is designed and built specifically for the intended application, including the static and dynamic limits set by the robot manufacturer. The joint is shown to be visually and/or apparently adequate.</p> <p>The gripper should be certified by its manufacturer as part of the robotic system integration. Information for the use of the gripper, including inspection, maintenance and repair of the mechanical joints, shall be part of the instructions.</p> <p>Remark: Industrialisation shall require static (1.25) and dynamic (1.1) load testing of all parts of the robotic application involved in lifting loads (such as the Automotive pilot), in accordance with 5.2. of ISO FDIS 10218-2.</p>		<p>EN ISO 12100 EN ISO 10218-2</p>
Residual Risk		

Hazard Identification		Hazard No:	1.9
Title	Hazards due the stability of the robot		
Location	Robot Perimeter		
Target	People / Machine		
Activity	Assembly and Installation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Instability		
Description	Mechanical hazards or other hazards due to lack of stability of the robot during operation.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	781	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Mass and/or weight of robot to be marked on machine • Information for use to contain adequate mounting, anchorage / foundations details of the robot • Consideration to be given to tools, work-pieces • Frequency of inspections of robot fixings / anchorage to be specified as part of maintenance schedule 		EN ISO 12100	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk

Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	15	
Summary Level	Very Low Risk	
Risk Reduction Measures Description		Reference
<p>The assembly, fastenings and installation of the robot show no apparent signs of instability. The assembly is carried out according to the manufacturer's instructions and taking into account the established limits.</p> <p>The mass of the robot is 1615 kg, according to its nameplate.</p> <p>Remark: The industrialisation of the application will require a specific mechanical validation in accordance with the manufacturer's recommendations (after the load tests mentioned above).</p>		EN ISO 12100
Residual Risk		
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Hazard Identification		Hazard No:	1.10
Title	Lack of marking of collaborative workplace		
Location	Robot Perimeter - Collaborative Area		
Target	Upper Limbs		
Activity	Normal Operation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Mechanical hazards		
Sub Type	Inadequate identification		
Description	The collaborative space of the robot cell is not identified with a label, as required by EN ISO 10218-2. On the other hand, the collaborative workplace where the operator can interact directly with the robot, is not clearly defined or warned.		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Not Acceptable
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Robot shall be labelled with the signal above attached. • Additionally, a mark or sign must be fitted on the workbench, to warn about the possibility to interact directly with robot. 		ISO/TS 15066 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable

Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level		
Not Acceptable		
Risk Reduction Measures Description		Reference
<p>Cell and robot labelling, conforming to 5.11 of EN ISO 10218-2 is pending. The final signage, positioning and appropriate size will depend on the characteristics of the target location.</p>		<p>ISO/TS 15066 EN ISO 10218-2</p>
Residual Risk		
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9.2.1.2 Mechanical Hazards: AUTO-BUC-02 & 03


Hazard Identification		Hazard No:	2.1
Title	Impact with the mobile platform during mobility		
Location	Mobile Platform Perimeter		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Machine mobility		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Hazard of impact with the mobile platform during mobility. With the use of the mobile platform, there is an increased risk of impact and/or crushing due to its mobility. This is a direct consequence of the machine operating within an area where pedestrian traffic cannot be fully excluded.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	343	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Install a combination of protective devices (safety scanners) according to EN ISO 14120, EN ISO 13857 and EN ISO 13855 to prevent access to hazard zone. • Operating zones need to be defined and provided which ensure a minimum safe clearance distance of 0.5 metres wide for a height of 2.1 meters on both sides. This is measured between truck and/or load and adjacent fixtures along the path. Where this clearance is not achievable further measures are necessary as outlined in other hazards. • Wherever possible segregation of AGV operating zone and pedestrian traffic areas should be implemented, ideally with the introduction of physical barriers or markings on the floor. • Personnel need to be informed about residual risk through adequate warning signage and receive adequate training with respect to the hazards posed by an AGV. 		EN ISO 12100 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5

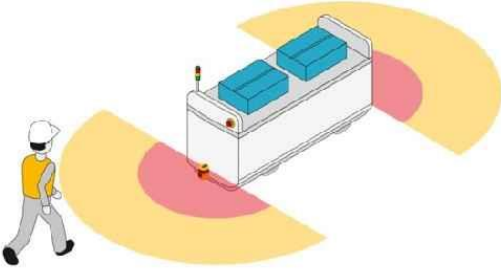
Pilz Hazard Rating (PHR):


6

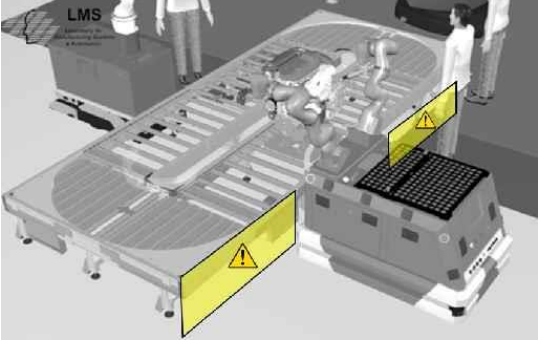
Summary Possible Level:


Negligible Risk


Post Measures Risk Assessment	
Assessment Date	12-sep-2024
Degree of Possible Harm	11
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	0.75
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	2
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>Both AMR (Autonomous Mobile Robot), Tecnalía and Agile, with their corresponding HRC robots on board, constitute certified units in accordance with current regulations:</p> <ul style="list-style-type: none"> - They have a system for detecting people in their field of action, by means of laser scanners that detect the entire perimeter of the AMR, even if their operating speed is less than 300 mm/s. - The areas where there is a risk of entrapment or crushing between the AMR and fixed parts are those adjacent to the conveyor and the loading area of the Agile robot in AUTO BUC-03. - The scanner is muted when, in the docking phase, the distance is sufficiently small that a person cannot remain in the area. - HRC robots on board both AMRs do not move without docking of the AMR to the conveyor, at which point the risk of entrapment or crushing no longer exists. - The docking of the Agile robot to its battery charging area conforms to EN ISO 3691-4, approaching with detection up to 180mm. - The pedestrian area where the operator is expected to walk is visibly marked on the ground. <p>In this way the risk of impact with the Tecnalía and Agile AMRs during their movement is satisfactorily controlled.</p> <p>The certification of the AMRs, the on-board robots and their integration as a whole shall be part of the technical documentation of the overall implementation of the Automotive pilot.</p> <p>The classification of the zones according to EN ISO 3691-4 for the AMR system shall also be part of the technical documentation of the overall implementation of the Automotive pilot.</p>	<p>EN ISO 12100 ISO/TS 15066</p>
Residual Risk	
<p>The training, general and specific knowledge, experience and information that operators must have shall be reflected in the instruction manual. This statement applies to the control of all identified risks.</p>	

Hazard Identification		Hazard No:	2.2
Title	Impact hazards due to configuration of safety scanners		
Location	Mobile Platform Perimeter		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Machine mobility		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Mechanical hazards due the installation and the configuration of the safety scanner. There are two safety scanners at the perimeter of the machine to prevent mechanical hazards due to the machine in motion.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	343	Summary Level:	High Risk
Risk Reduction		Reference	
The safety scanners shall be: <ul style="list-style-type: none"> • operate at least over the maximum width of the truck and its load in the direction(s) of travel: • designed that trucks shall stop before contact between the rigid parts of the truck or load and a stationary person (not a person stepping into the truck path or moving toward it). • It shall be positioned at a minimum distance (s) according to EN ISO 13855 and IEC 62046. • In addition, according to IEC 62046 the height of the detection plane of the scan should be as near as possible to the floor and not higher than 200 mm. 		EN ISO 13855 EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	6	Summary Possible Level:	Negligible Risk

Post Measures Risk Assessment	
Assessment Date	12-sep-2024
Degree of Possible Harm	11
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	0.75
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	2
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<ul style="list-style-type: none"> - Safety scanners operate at least over the maximum width of the AMR in the direction(s) of travel. - The detection of the scanners leads to stopping of the AMR and stopping before contact with a stationary person. - The detection fields and the installation of the scanners take into account EN ISO 13855 and EN IEC 62046. The height of the detection plane of the scanner does not exceed 200 mm. - The robots on board both AMRs are located in their initial position and do not move without being coupled to the conveyor. <p>The final configuration of the detection fields of the scanners shall be recorded and shall be part of the technical documentation of the overall application, in case of final industrialisation.</p>	
Residual Risk	


Hazard Identification		Hazard No:	2.3
Title	Crushing between the mobile platform and the conveyor during approach		
Location	Mobile Platform Perimeter		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Machine mobility		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Hazard of impact with the mobile platform while it is approaching the conveyor for the kitting or inspection operations. During the approach to the conveyor, the mobile platforms need to monitor if there is a person in between.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	275	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Use the existing I light sensing devices (scanner) to detect the presence of the operator. • Assure that the safety scanners cover the area until the AGV is safely positioned to start the operation. • Slow the speed of the mobile platform movements when is approaching the conveyor. 		EN ISO 12100 ISO/TS 15066 EN ISO 13855	
Possible Residual Risk			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	5	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment	
Assessment Date	12-sep-2024
Degree of Possible Harm	11
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	0.75
Frequency And / Or Duration of Exposure	4
Pilz Hazard Rating (PHR)	1
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<ul style="list-style-type: none"> - The scanners fitted to the AMRs detect the presence of the operator in the considered area. The scanner is not overridden until the distance to the conveyor is sufficiently small to prevent an undetected person from remaining in the hazardous area. - The approach speed is less than or equal to 300mm/s, considered safe by EN ISO 3691-4. - Robots on board AMRs are positioned in initial position (within the footprint of the platform) and do not move until docking to the conveyor is confirmed. <p>The risk due to possible contacts on the approach to the conveyor is adequately reduced.</p>	<p>EN ISO 12100 ISO/TS 15066 EN ISO 13855</p>
Residual Risk	


Hazard Identification		Hazard No:	2.4
Title	Impact hazards due to riding on the mobile platform		
Location	Mobile Platform		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Machine mobility		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Mechanical hazards due to the machine in motion if someone run on the truck. The truck is not designed for an operator or operators to ride on the truck.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	343	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • A combination of fixed guards needs to be installed in the structure in accordance with EN ISO 14120 to avoid that an operator climbs the truck. • Warning signs have also been installed to inform about the prohibition of run on the truck. • The residual risk of climbing on the vehicle needs to be included in the instruction manual. 		EN ISO 14120 EN ISO 13855 EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	6	Summary Possible Level:	Negligible Risk

Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	5	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	3	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>Both Tecnia and Agile AMR (Autonomous Mobile Robot) with their corresponding HRC robots on board are certified assemblies according to their current regulations. Under no circumstances are they intended for transporting people or for people to circulate or access them.</p> <p>The limits of use and reasonably foreseeable misuse should be included in the AMR instruction manual and will be added to the limits of use and reasonably foreseeable misuse of the overall application which will be part of the instruction manual.</p>		<p>EN ISO 14120 EN ISO 13855 EN ISO 3691-4</p>
Residual Risk		
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Hazard Identification		Hazard No:	2.5
Title	Impact during movement caused by accessible parts of the machine		
Location	Mobile Platform Perimeter		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Injury caused by accessible parts of the machine. The two robotic arms placed on top of the mobile platform can be outside the hazard area of the safety scanners.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	275	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Guarantee that the mobile manipulators are not extended during the movement of the mobile platform. • Avoiding sharp edges and corners, and protruding parts, whenever possible. • Protect sharp edges with soft yellow-black protections and don't use sheet metal edges in the design. • Prescribe the use of personal protective equipment (PPE). 		EN ISO 12100 EN ISO 13855 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	5	Summary Possible Level:	Negligible Risk

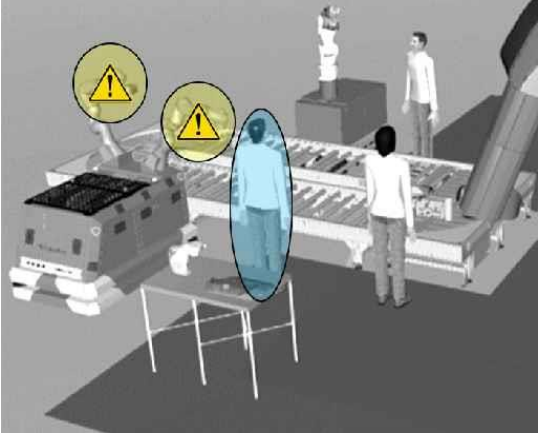
Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	0.5	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	4	
Pilz Hazard Rating (PHR)	1	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<ul style="list-style-type: none"> - Both AMR on-board robot manipulators are provided with motion only in a coupled condition to the conveyor. - The design of edges, surfaces or corners are designed to eliminate contact hazards or suitably protected to avoid cuts or lacerations. 		EN ISO 12100 EN ISO 13855 EN ISO 10218-2
Residual Risk		


Hazard Identification		Hazard No:	2.6
Title	Floor condition affecting the stopping performance		
Location	Production Floor		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Machinery mobility		
Description	The floor condition affects the ability of the AGV to operate safely. There are some floor characteristics that can lead to a hazardous situation such as extended stop time/distance, failure of the object detection system effect a stop before contact with an object, path and steering control and stability.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	5	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	312	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Instructions on floor conditions need to be specified in the instruction manual • Any deviations to the AGV manufacturers requirements with respect to the floor conditions should be rectified during the installation phase and before the AGV is put into service. • A maintenance prevention schedule should be prescribed to ensure that the floor conditions are regularly inspected to ensure they are adequate for the safe operation of an AGV. • In addition to requirements listed above the schedule should include for cleaning of the floor, removal of spillages, dust, etc. • Floor zonal marking should be regularly inspected for wear. • Confirm that the AGVs can operate safely in the defined floor specification. • Develop SOP for the cleaning of spilled fluids on the floor. 		EN ISO 12100 EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:	5	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	6	Summary Possible Level:	Negligible Risk

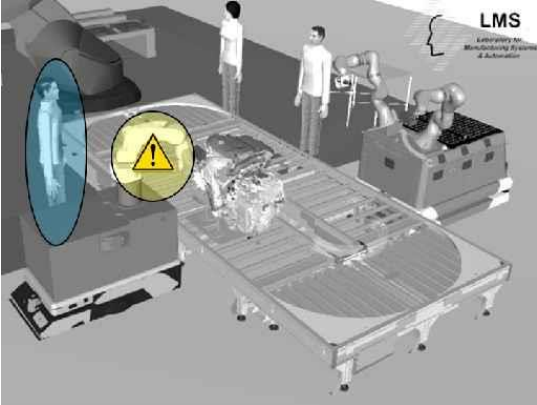
Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	5	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	3	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The floor of the pilot is suitable for the intended purpose. Floor conditions and their maintenance should be included in the instructions of the AMR with on-board robot and shall be part of the instruction manual of the overall application, in case of industrialisation.</p>		EN ISO 12100 EN ISO 3691-4
Residual Risk		
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Hazard Identification		Hazard No:	2.7
Title	Crushing caused by lack of foot protection		
Location	Mobile Platform		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Machine mobility		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Crushing		
Description	Hazard of impact or entrapped of the foot of persons standing nearby the truck during the movement of the machine.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	93	Summary Level:	Significant Risk
Risk Reduction		Reference	
Hazard of impact or entrapped of the foot of persons standing nearby the truck during the movement of the machine.		EN ISO 14120 EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	1	Summary Possible Level:	Negligible Risk

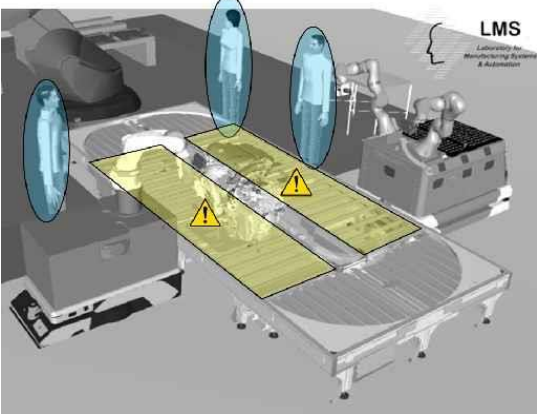
Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	3	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	1	
Summary Level		
Negligible Risk		
Risk Reduction Measures Description		Reference
<p>Both AMR (Autonomous Mobile Robot), Tecnalía and Agile, with their corresponding HRC robots on board are certified assemblies in accordance with current regulations. In both cases they have protections that prevent contact with the wheels during movement.</p>		<p>EN ISO 14120 EN ISO 3691-4</p>
Residual Risk		
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Hazard Identification		Hazard No:	2.8
Title	Impact with the dual arm manipulator or tool during kitting operation		
Location	Kitting Area		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Pick and Place		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Mechanical hazards due to the exposed risk of impact with the robot structure while the robot is performing the kitting operation. The dual arm robot is placed on top of the mobile platform and there is the risk of impact from the back area when the scanners are disabled for close contact with the conveyor.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	781	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Install a safety sensing device (scanner or radar) to detect the presence of the operator during the operation. • Use of safety zones to detect the presence of the operator (green, yellow and red). • Use light/sound indicators for when the robot is performing the operation. • Slow speed robot movements near foreseeable access points. • Training and information for use about residual risk. 		EN ISO 13855 EN ISO 13849-1 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk

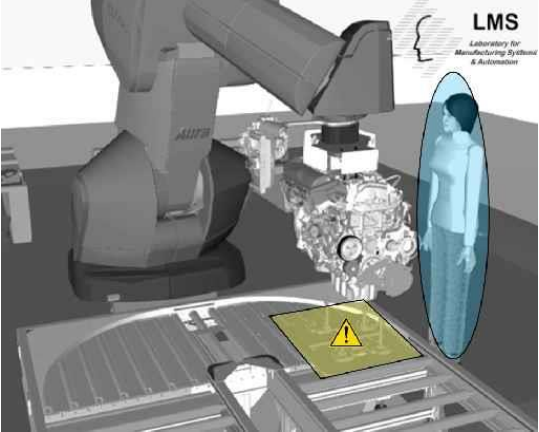
Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	0.5	
Probability of Occurrence of a Hazardous Event	1.25	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	4	
Pilz Hazard Rating (PHR)	1	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>-The approach to the AMRs during their operations on the conveyor are detected by the set of scanners carried by each platform, the platform does not move in that conditions.</p> <p>- The operations of the robots on board the AMRs are performed under collaborative technology, thus having an acceptable level of risk for possible contacts.</p> <p>The contact tests records of robots operating in PFL mode should be part of the technical documentation of the overall Automotive pilot application.</p> <p>If the application is industrialised, the tests must be adapted and documented according to the situation, final layout, robot paths, etc. of the destination installation, and thus become part of the documentation of the final application.</p>		<p>EN ISO 13855 EN ISO 13849-1 EN ISO 10218-2</p>
Residual Risk		
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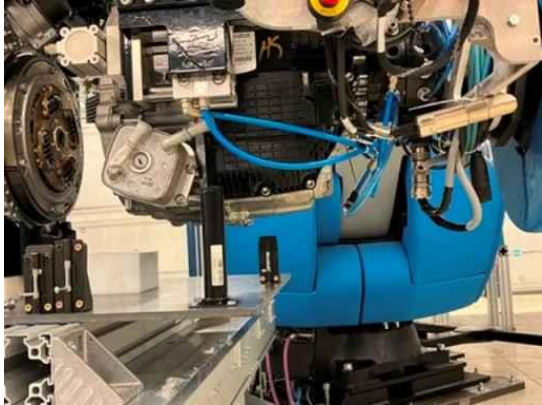
Hazard Identification		Hazard No:	2.9
Title	Impact with the single arm manipulator or tool during of inspection operation		
Location	Inspection Area		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Pick and Place		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Mechanical hazards due to the exposed risk of impact with the robot structure while the robot is performing the inspection operation. The single arm robot is placed on top of the mobile platform and there is the risk of impact from the back area when the scanners are disabled for close contact with the conveyor.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	781	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Install a safety sensing device (scanner or radar) to detect the presence of the operator during the operation. • Use of safety zones to detect the presence of the operator (green, yellow and red). • Use light/sound indicators for when the robot is performing the operation. • Slow speed robot movements near foreseeable access points. • Training and information for use about residual risk. 		EN ISO 13855 EN ISO 13849-1 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk

Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	0.5	
Probability of Occurrence of a Hazardous Event	1.25	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	4	
Pilz Hazard Rating (PHR)	1	
Summary Level		
Negligible Risk		
Risk Reduction Measures Description		Reference
<p>The approach to the AMRs during their operations on the conveyor are detected by the set of scanners carried by each platform, the platform does not move in that conditions.</p> <p>The operations of the robots on board the AMRs are performed under collaborative technology, thus having an acceptable level of risk for possible contacts.</p> <p>The contact tests records of robots operating in PFL mode should be part of the technical documentation of the overall Automotive pilot application.</p> <p>If the application is industrialised, the tests must be adapted and documented according to the situation, final layout, robot paths, etc. of the destination installation, and thus become part of the documentation of the final application.</p>		EN ISO 13855 EN ISO 13849-1 EN ISO 10218-2
Residual Risk		

Hazard Identification		Hazard No:	2.10
Title	Drawing in with the conveyor		
Location	Conveyor		
Target	Finger		
Activity	Normal Operation		
Task	Operation		
Sub Task	Minor interventions during operation		
Hazard Type	Mechanical Hazard with the consequence of		
Sub Type	Drawing-in or Trapping		
Description	Drawing-in hazard between the traction or carrying elements and supporting rollers of the conveyor. The drawing-in points need to be guarded to avoid the access with fingers. The existing gaps are more than 5 mm according to EN 619.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	4	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	150	Summary Level:	Significant Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Drawing-in points shall be guarded by the use of nip guards directly at the drawing-in point. • The maximum gap between the openings need to be 5 mm at the most. 		EN 619 EN ISO 13857	
Possible Residual Risk			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	1	Summary Possible Level:	Negligible Risk

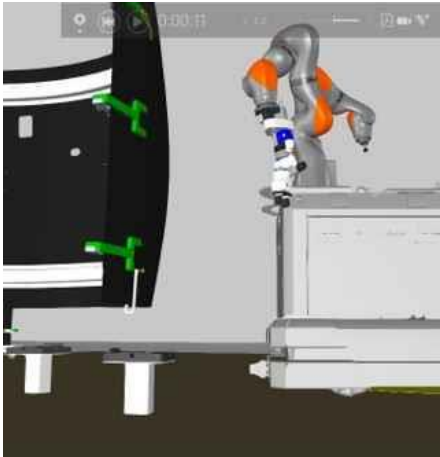
Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	3	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	1	
Summary Level		
Negligible Risk		
Risk Reduction Measures Description		Reference
<p>The conveyor is designed and built in accordance with EN 619 as certified by its manufacturer. It does not offer any hazardous points with mechanical risk.</p> <p>The conveyor manufacturer's declaration of conformity or incorporation should be part of the technical documentation of the overall application.</p> <p>Remark: Conveyor cabinet is located inside the protected area. It should be located outside the protected zone.</p>		<p>EN 619 EN ISO 13857</p>
Residual Risk		
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Hazard Identification		Hazard No:	2.11
Title	Falling of the process part in the conveyor		
Location	Conveyor		
Target	Lower Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Clamping the process part		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Falling objects		
Description	Mechanical hazards due to the exposed risk of falling of the process part while moving in the conveyor. If the part is not properly placed in the conveyor, an impact with the mobile platform can generate a falling hazard.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	93	Summary Level:	Significant Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Use a intrinsically safe mechanical locking system to hold the part in place in the conveyor. • Assure the design of the part holder is resistant to small impacts and vibrations. • Use a mechanism to lock the part in place during the movement of the conveyor 		EN 619 EN ISO 13857 EN 62061	
Possible Residual Risk			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	1	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	12-sep-2024	
Degree of Possible Harm	5	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	3	
Pilz Hazard Rating (PHR)	1	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The engine and gearbox assembly is positioned on a support plate that rests on a base that is solidly attached to the conveyor. A pre-formed cradle is positioned on the support plate to receive the assembly, providing sufficient stability for operations.</p> <p>The support plate and base assembly is secured by means of mechanical latch locks.</p> <p>The movement of the conveyor is slow, including start and stop ramps.</p> <p>Remark: Monitoring the latches is not relevant, depending on the conditions of the pilot. Parts of the conveyor are not expected to fall on people, their probability is low, as exposure is not foreseen. However, it is advisable to analyse the true presence in case of industrialisation.</p>		<p>EN 619 EN ISO 13857 EN 62061</p>
Residual Risk		
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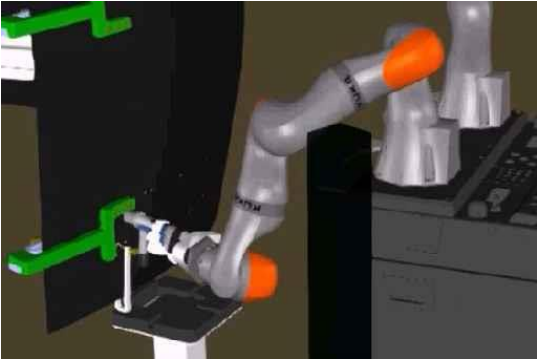
9.2.2. Aeronautic pilot Risk assessment conducted


9.2.2.1. Mechanical Hazards: AERO-BUC-01


Hazard Identification		Hazard No:	1.1
Title	Quasi-static contact between manipulator and fixed structures		
Location	Operating zone - Stakeholder		
Target	Head/Upper Limbs		
Activity	Normal Operation		
Task	Operation		
Sub Task	Control/inspection		
Hazard Type	Mechanical Hazard with the consequence of		
Sub Type	Trapping		
Description	Trapping hazards of during • Robot detection of part • Picking up the assembly part There is a risk that body parts of personnel could be clamped between the robot arms and fixed structures as the stakeholders or other fixed structures.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	1250	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Program Robot trajectory to avoid impact with personnel. • Robot's force and pressure must be set to ensure that the values do not exceed the threshold defined in the ISO/TS 15066 in case of transient contact. If is not viable to set safe dynamics, safe guarding system must be fitted to avoid contact. • Personnel must be trained and aware about the residual risks of collaborative workplace. 		EN ISO 10218-2 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5


Pilz Hazard Rating (PHR):	7	Summary Possible Level:	Negligible Risk
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Post Measures Risk Assessment	
Assessment Date	23-oct-2024
Degree of Possible Harm	5
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	2.5
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	3
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>As far as possible the trajectories are programmed to avoid impact with personnel under the expected conditions. The dual robot on board the AMR operates under PFL mode, so that transient or quasi-static contact conditions do not exceed the threshold values of ISO/TS 15066, according to model measurements performed.</p> <p>Teaching is performed under manual reduced speed mode, according to part 5.6.4.2 of EN ISO 10218-2. The Teach Pendant console complies with parts 5.8 of EN ISO 10218-1 and 5.7 of EN ISO 10218-2.</p> <p>The impact measurement records of robots operating in PFL mode should be part of the technical documentation of the overall Aeronatic pilot application. In case of industrialisation of the application, the tests shall be adapted and documented according to the situation, environment characteristics, final trajectories, etc. of the target installation, and thus become part of the documentation of the final application.</p>	<p>EN ISO 10218-2 ISO/TS 15066</p>
Residual Risk	
<p>The training, education, experience and information that operators must have should be reflected in the instruction manual.</p> <p>This statement applies to the control of all identified risks.</p>	


Hazard Identification		Hazard No:	1.2
Title	Quasi-static contact with end effector against personnel		
Location	Operating Zone - Stakeholder		
Target	Head/Upper Limbs		
Activity	Normal Operation		
Task	Operation		
Sub Task	Control/inspection		
Hazard Type	Mechanical hazard		
Sub Type	Trapping		
Description	Trapping hazards during <ul style="list-style-type: none"> • Robot detection of part • Picking up the assembly part There is a risk that body parts of personnel could be clamped between the end effectors and the assembly part.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	1250	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • End effector's force and pressure must be set to ensure that the values do not exceed the threshold defined in the ISO/TS 15066 in case of contact. • If is not viable to set safe dynamics, then safe guarding system must be fitted to avoid contact. • Design intrinsically safe end effector (gripper). Features to take into account: • To avoid sharpening edges. Rounding surfaces with radius = 5mm minimum to reduce pressure of impact. • To fit padding on the surfaces of tool to minimize force of impact. 		ISO/TS 15066 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	7	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	5	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	3	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The movements are configured so that possible quasi-static contacts against the end-effector are performed with force and pressure levels that do not exceed the threshold defined in ISO/TS 15066 in case of contact, according to the model measurements performed.</p> <ul style="list-style-type: none"> - In the event of unintended contact, the grippers coupling to the robot wrist is disengaged to protect the tool itself. - As far as possible, the gripper has a design with a reduced number of sharp edges. <p>The impact measurement records of robots operating in PFL mode should be part of the technical documentation of the overall Aeronatic pilot application. In case of industrialisation of the application, the tests shall be adapted and documented according to the situation, environment characteristics, final trajectories, etc. of the target installation, and thus become part of the documentation of the final application.</p>		<p>EN ISO 10218-2 ISO/TR 20218-1 ISO/TS 15066</p>
Residual Risk		
<p>Padding could be placed on the tool surfaces to minimise the impact force, in case of actual final results with unsatisfactory values.</p>		


Hazard Identification		Hazard No:	1.3
Title	Impact of mobile manipulator/part against personnel during co-manipulation		
Location	Operating zone - Inspection table		
Target	Head/Upper Limbs		
Activity	Normal Operation		
Task	Manual Operation		
Sub Task	Co-manipulation of part/manual-guiding		
Hazard Type	Mechanical Hazard with the consequence of		
Sub Type	Impact		
Description	Impact hazards during the following collaborative operations: <ul style="list-style-type: none"> • Collaborative manipulation of assembly part by manual-guiding of the operator. There is a risk that the mobile manipulator or the assembly part could impact or crash against personnel during the manual-guiding of the operator when the part is placed in the inspection table.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	1250	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • The truck must include sensor devices to detect personnel and prevent collision against workers along automatic path. The length of the detection area must set according EN ISO 13855 formula: $S= 1600 \times T + (1200 - 0,4 \times H)$, where T is reaction time and H is Height of detection area. • Speed must be set according EN ISO 3691-4. • Personnel must trained and informed about the truck's automatic path and the pedestrian routes to avoid collision. 		EN ISO 3691-4 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	7	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	5	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	3	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<ul style="list-style-type: none"> - The AMR includes scanners to detect personnel and avoid collisions with workers along the automatic path. The length of the detection area is set according to EN ISO 13855. Both detection and stopping are functionally verified on site. The presence of persons during the approach to the area of operation causes the AMR travel to stop. - In any case, the displacement speed is equal or lower than 300mm/s, speed established by EN ISO 3691-4 to be able to move without means of detection of persons. - During the movement of the AMR, both robots to robots remain stationary and in their resting position within the boundaries of the AMR floor. - In the event of an approach with the robots in operation, the scanner detects it and the control system triggers a protective stop of the robots. <p>The zone classification according to EN ISO 3691-4 for the AMR system shall also be part of the technical documentation of the overall Aero pilot application. The relevant parts for the operator shall also be included in the instruction manual.</p>		ISO/TS 15066 EN ISO 10218-2 EN ISO 3691-4
Residual Risk		


Hazard Identification		Hazard No:	1.4
Title	Loss of stability during co-transport by manual guiding		
Location	Operating Zone		
Target	Entire Body		
Activity	Normal Operation		
Task	Normal Operation		
Sub Task	Co-Transport/Manual guiding		
Hazard Type	Mechanical Hazard with the consequence of		
Sub Type	Personnel loss of stability		
Description	<p>Impact hazards during the following collaborative operations:</p> <ul style="list-style-type: none"> • Collaborative transport of assembly parts by manual-guiding of the operator. <p>There is a risk that the mobile manipulator could cause loss of stability to the operator due to uncontrolled or unexpected movements (stretching, push) during the manual guidance and falling of the assembly part.</p>		
Risk Estimation and Evaluation			
Degree of Possible Harm:	5	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	312	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Manipulator's correction dynamics must be set to run in collaborative motion in order to avoid uncontrolled movements or unexpected forces to the operator. • The operators must be trained about the correct use of the robot during those manual control tasks. 		EN ISO 10218-2 ISO/TS 15066 EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:	5	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	6	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	5	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	6	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>- Operation under collaborative mode is configured to avoid uncontrolled movements or unexpected forces for the operator. Collaborative operations take into account the applicable indications of Part 5.14 of ISO/FDIS 10218-2 (integrating ISO TS 15066).</p>		<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 3691-4</p>
Residual Risk		
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Hazard Identification		Hazard No:	1.5
Title	Transient contact with end effector against personnel		
Location	Operating Zone - Stakeholder		
Target	Head/Upper Limbs		
Activity	Normal Operation		
Task	Operation		
Sub Task	Control/inspection		
Hazard Type	Mechanical hazard		
Sub Type	Impact		
Description	End effectors of robotic arms could collide with personnel during: <ul style="list-style-type: none"> • Detection of parts • Picking up the assembly part There is a risk that the end effector could collide against body parts of personnel.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	1250	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • End effector's force and pressure must be set to ensure that the values do not exceed the threshold defined in the ISO/TS 15066 in case of contact. • If is not viable to set safe dynamics, then safe guarding system must be fitted to avoid contact. • Design intrinsically safe end effector (gripper). Features to take into account: <ul style="list-style-type: none"> • To avoid sharpening edges. Rounding surfaces with radius = 5mm minimum to reduce pressure of impact. • To fit padding on the surfaces of tool to minimize force of impact. 		ISO/TS 15066 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	7	Summary Possible Level:	Negligible Risk

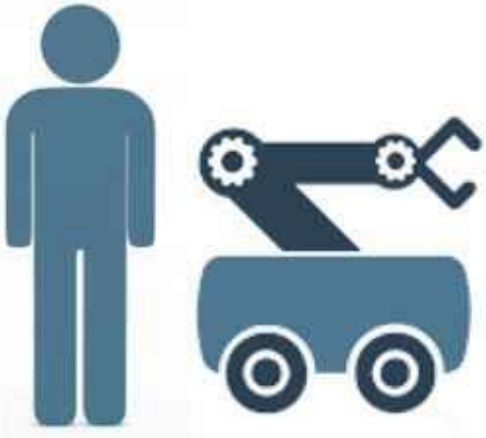
Post Measures Risk Assessment	
Assessment Date	23-oct-2024
Degree of Possible Harm	5
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	2.5
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	3
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>'- The movements are configured so that any transient contact with the end-effector is made with force and pressure levels that do not exceed the threshold defined in ISO/TS 15066 in case of contact according to the model measurements performed.</p> <p>- In the event of unintended contact, the gripper coupling to the robot wrist is disengaged to protect the tool itself - As far as possible, the gripper is presented in a design with reduced sharp edges.</p> <p>The impact measurement records of robots operating in PFL mode should be part of the technical documentation of the overall Aeronautic pilot application. In case of industrialisation of the application, the tests shall be adapted and documented according to the situation, environment characteristics, final trajectories, etc. of the target installation, and thus become part of the documentation of the final application.</p>	<p>EN ISO 10218-2 ISO/TR 20218-1 ISO/TS 15066</p>
Residual Risk	


Hazard Identification		Hazard No:	1.6
Title	Falling or ejection of assembly part during normal operation		
Location	Collaborative workplace/ Operating Zone		
Target	Upper/Lower limbs		
Activity	Normal Operation		
Task	Collaborative Operation		
Sub Task	Picking up, placing/co-transport		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Falling objects		
Description	<p>Mechanical hazards during automatic collaborative operations.</p> <ul style="list-style-type: none"> Parts could fall down or be ejected from robotic arms in case of loss of power during placing or holding the piece (up to 11kg), <p>This could cause impact, crushing or loss of stability to the personnel who manipulates the part together with the robots.</p>		
Risk Estimation and Evaluation			
Degree of Possible Harm:	5	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	156	Summary Level:	Significant Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> End effector (gripper) must be mechanically designed to support parts towards avoid ejection and uncontrolled falling of part by loss of stability. End effector's force and pressure, as well as dynamics, must be set to avoid ejection and uncontrolled falling of part. 		EN ISO 10218-2 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	5	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	3	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	5	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	6	
Summary Level		
Negligible Risk		
Risk Reduction Measures Description		Reference
<p>The end effector used in the operation should be certified by its manufacturer as part of the system integration. This ensures compliance with the applicable parts of ISO TR 20218-1 (integrated in 5.9 of ISO/FDIS 10218-2), among others:</p> <ul style="list-style-type: none"> - The mechanical link between the gripper and the robot wrist is specifically designed and constructed for the given application, including the static and dynamic limits set by the robot manufacturer. The joint is shown to be visually and/or apparently sufficient. - The mechanical link between the gripper and the workpiece is designed and built specifically for the given application. - In case of loss of power supply, the gripper does not release the workpiece. <p>Information for the use of the gripper, including inspection, maintenance and repair, shall form part of the instructions.</p>		<p>EN ISO 10218-2 ISO/TR 20218-1 EN ISO 3691-4 ISO/TS 15066</p>
Residual Risk		
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Hazard Identification		Hazard No:	1.7
Title	Loss of the end effector		
Location	Collaborative workplace/ Operating Zone		
Target	Entire Body		
Activity	Normal operation, maintenance		
Task	Operation		
Sub Task	Assembling/disassembling/Inspection		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Ejected objects		
Description	The dynamics of the robot present the risk that the end effector detach and fall out or be thrown out.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	117	Summary Level:	Significant Risk
Risk Reduction		Reference	
End effectors shall be fixed to the arms with a mechanical lockable system to avoid unexpected ejection of the tool. To train the operators about the correct procedure to lock in safety conditions the screwdriver when such tool is changed or replaced. Is also recommended to design a detection system in the robot in order to warn about an hypothetical wrong positioning of the tool.		ISO/TS 15066 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk

Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	4	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The end effector used in the operation should be certified by its manufacturer as part of the system integration. This ensures compliance with the applicable parts of ISO TR 20218-1 (integrated in 5.9 of ISO/FDIS 10218-2), among others:</p> <ul style="list-style-type: none"> - The mechanical link between the gripper and the robot wrist is specifically designed and constructed for the given application, including the static and dynamic limits set by the robot manufacturer. The joint is shown to be visually and/or apparently sufficient. - The mechanical link between the gripper and the workpiece is designed and built specifically for the given application. - In case of loss of power supply, the gripper does not release the workpiece 		<p>EN ISO 10218-2 ISO/TS 15066 ISO/TR 20218-1</p>
Residual Risk		
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Hazard Identification		Hazard No:	1.8
Title	Contact during teaching/manual mode of robotic arms (T1/T2) mode		
Location	Collaborative workspace		
Target	Head/Upper Limbs		
Activity	Maintenance		
Task	Setting/programming and/or process changeover		
Sub Task	Adjustment and setting or verification of functional parameters of the machine/programming		
Hazard Type	Mechanical Hazard with the consequence of		
Sub Type	Impact		
Description	Hazards during Setting Teaching/programming operations. <ul style="list-style-type: none"> • there is a risk that robotic arms of the mobile manipulator will collide with personnel. Most of safeguarding systems (safety Limits, sensors) could be disabled for programming purposes.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	250	Summary Level:	High Risk
Risk Reduction		Reference	
Robotic arms must have a pendant control with three-position-button to run the robot in safety conditions during such operations. Pendant control must have fitted an emergency stop button. In manual mode robots must run in slow motion (250 mm/s max). The operators must be trained about the correct use of the robot during those manual control tasks.		EN ISO 10218-2 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	5	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	5	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	2	
Pilz Hazard Rating (PHR)	1	
Summary Level		
Negligible Risk		
Risk Reduction Measures Description		Reference
<p>Both robots are certified as quasi-machine equipment by their manufacturer in accordance with EN ISO 10218-1. Teach pendant complies with the relevant parts of 5.8 of EN ISO 10218-1 and 5.7 of EN ISO 10218-2. Thus, among other relevant conditions</p> <ul style="list-style-type: none"> - Three-position pushbutton is available on the teach pendant. - The control pendant includes an emergency push button. - In manual mode, the robots operate at a maximum speed of 250 mm/s. <p>Operations under manual mode shall be restricted to specially trained personnel.</p>		<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 10218-1</p>
Residual Risk		

Hazard Identification		Hazard No:	1.9
Title	Loss of stability of the manipulator		
Location	Collaborative workplace/ Operating Zone		
Target	Entire Body		
Activity	Normal operation, maintenance		
Task	Operation		
Sub Task	Assembling/disassembling/Inspection		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Falling of robots		
Description	The movement and load of the robots cause dynamic forces on the fixing system. The robots could overturn or fall over due to a loss of stability.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	117	Summary Level:	Significant Risk
Risk Reduction		Reference	
The Fixing of the robot on the trolley's support shall be stiff enough to withstand the robot's dynamics and ensure stability. Fixing must be revised periodically to ensure the proper conditions.		ISO/TS 15066 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment	
Assessment Date	23-oct-2024
Degree of Possible Harm	25
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	0.75
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	4
Summary Level	
Negligible Risk	
Risk Reduction Measures Description	Reference
<p>The assembly, fixings and installation of each robot on board the AMR show no apparent signs of instability. The assembly is carried out according to the manufacturer's instructions and within the established limits.</p> <ul style="list-style-type: none"> - The stability of the assembly is also guaranteed during operation of the robots. - The robots do not move during the movement of the AMR, remaining in their resting zone. <p>Periodic checking of fixings shall be included in the instructions for use.</p>	<p>EN ISO 10218-2 ISO/TS 15066</p>
Residual Risk	
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Hazard Identification		Hazard No:	1.10
Title	Inability to perform an emergency stop		
Location	Collaborative workplace/ Operating Zone	<p>The diagram shows a 'Safety Devices' block containing five components: ESTOPs (red button), Mode selector (yellow button), Enable switch (black switch), Safety strip (blue sensor), and Safety Laser Scanner (yellow sensor). These are connected to a 'Safety PLC' (yellow unit). The Safety PLC is connected to a 'Process Controller' (grey unit) and a robot system (yellow and black). The robot system is shown with a yellow robot arm and a black base.</p>	
Target	People / Machine		
Activity	Operation		
Task	All tasks		
Sub Task	Driving machine		
Hazard Type	Other Hazards		
Sub Type	Loss of machine control/ Dangerous event		
Description	Unexpected situation could result in a hazardous event that could require an emergency stop from the control system.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	750	Summary Level:	Very High Risk
Risk Reduction		Reference	
The collaborative workplace and automatic path shall have at least one emergency stop push-buttons available close to the working areas and also integrated in the robot pendant control and truck manual control console. If the e-stop button is actuated the robot system stops in category 0 or 1 according to EN 60204-1. Emergency buttons shall be tested periodically to ensure the proper conditions of the circuit.		EN ISO 13850 EN ISO 10218-2 EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	30	Summary Possible Level:	Low Risk

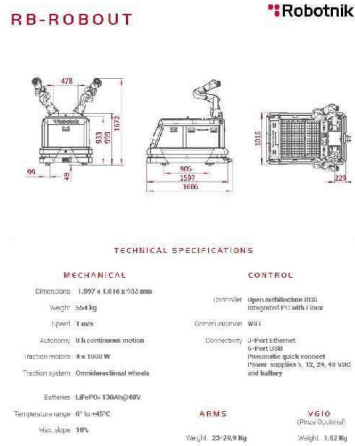
Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	3	
Pilz Hazard Rating (PHR)	9	
Summary Level		
Negligible Risk		
Risk Reduction Measures Description		Reference
<p>The application has emergency stop devices that are immediately and intuitively accessible from any operating position, including both teach pendants. The emergency stop devices meet the requirements of EN ISO 13850. Actuation of any emergency stop device triggers a category 0 or 1 stop of all actuators, both robot and AMR, in accordance with EN 60204-1. The functionality of the emergency stop has been validated</p> <p>The inclusion of additional emergency stop buttons depends on the zone classification according to EN ISO 3691-4 of the final application.</p>		EN ISO 3691-4 EN ISO 10218-2 EN ISO 13850
Residual Risk		
<p>Periodic checks shall be part of the instructions for use of the application. In addition, the obligation to check and remedy the cause of the emergency stop must be indicated in the instructions.</p>		


Hazard Identification		Hazard No:	1.11
Title	Failure of the safety related part of control system		
Location	Collaborative workplace/ Operating Zone		
Target	People / Machine		
Activity	Normal Operation/Maintenance		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other hazards		
Sub Type	Failure of the Control System		
Description	Faults in the safety control circuit of the mobile manipulator could create multiple hazards, from unexpected or uncontrolled robot movement to inability to stop the process in safety conditions.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	625	Summary Level:	Very High Risk
Risk Reduction		Reference	
The safety control system, and the components that integrate it, must be designed and connected to achieve the reliability levels required for human robot collaborative applications.		EN ISO 3691-4 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	25	Summary Possible Level:	Low Risk

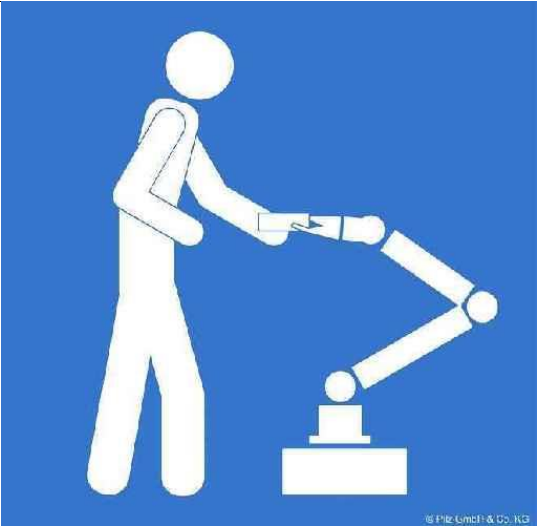
Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	15	
Summary Level	Very Low Risk	
Risk Reduction Measures Description		Reference
<p>The safety functions involved in the integration of the Aeronautic pilot application have been designed under appropriate architectures and components in order to comply with performance level PL=d and category 3, in accordance with EN ISO 10218-2.</p> <p>Functional and installation validation of safety functions and associated equipment has been performed.</p> <p>The safety functions incorporated individually in the sub-assemblies (AMR and robots) are validated by their manufacturer, by means of the declaration of conformity or declaration of incorporation.</p> <p>The documentation of the design, implementation and validation of the safety functions of the pilot application in compliance with EN ISO 13849-1 should be part of the technical documentation.</p> <p>Relevant information on safety functions intended for the user is listed in EN ISO 13849-1 and shall be included in the instruction manual.</p>		<p>EN ISO 10218-1 EN ISO 3691-4 ISO/TS 15066 ANSI/RIA R15.08-1</p>
Residual Risk		


Hazard Identification		Hazard No:	1.12
Title	Hazards generated from operation by unauthorized personnel		
Location	Collaborative workplace/ Operating Zone		
Target	Upper Limbs		
Activity	Normal operation, setup, maintenance, servicing and repair		
Task	Setting Teaching/programming and/or process changeover		
Sub Task	Automatic mode, programming/testing		
Hazard Type	Operation by unauthorised personnel		
Sub Type	Unintended/unexpected start-up		
Description	Operation of the robot by unauthorized personnel can lead to mechanical hazards due to unexpected movements when operators are close the mobile manipulator.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	250	Summary Level:	High Risk
Risk Reduction		Reference	
Use appropriate safeguards in order to prevent unauthorized (remote) access as: <ul style="list-style-type: none"> • password protection to access to the safety settings of robot. • Use of key in order to select manual or remote work modes. The key must be in possession of authorized personnel. Programming or teaching (remote or not) must be barred to all untrained personnel.		EN ISO 12100 IEC 62443-3-3 IEX 62443-2-4	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	10	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment	
Assessment Date	23-oct-2024
Degree of Possible Harm	25
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	5
Frequency And / Or Duration of Exposure	1
Pilz Hazard Rating (PHR)	6
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>Each machine or sub-assembly that makes up the application has its own keyed mode selector switch for 'automatic' control as part of the overall application or 'manual' control for individual operation (settings or maintenance). The teach pendants for control in manual mode have an access code. Remote operation is not provided for.</p> <p>Cybersecurity is addressed in another section of the pilot, for the achievement of measures to prevent unauthorised access to control systems, hardware, software, configuration data and application software.</p>	<p>ISO/TS 15066 EN ISO 10218-2 EN ISO 3691-4</p>
Residual Risk	
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Hazard Identification		Hazard No:	1.13
Title	Hazards generated by foreseeable misuse due to lack of technical documentation		
Location	Collaborative workplace/ Operating Zone/ electrical and pneumatic systems	 <p>RB-ROBOUT Robotnik</p> <p>TECHNICAL SPECIFICATIONS</p> <p>MECHANICAL</p> <p>Dimensions: 1.297 x 1.616 x 533 mm Weight: 55.4 kg Speed: 1 mm/s Actuators: 8 in continuous motion Traction motors: 4 x 1000 W Traction system: Omnidirectional wheels Batteries: LiFePO₄ 13.8Ah@90V Temperature range: 0° to +60°C Max. slope: 10%</p> <p>CONTROL</p> <p>Control: Open architecture IEC61131-3 integrated PLC with I/O Communication: Wi-Fi Connectivity: 2-Port Ethernet, 4x RS-485 Pneumatic: quick connect hose assembly, 1/2, 3/8, 1/4" NPT and battery</p> <p>ARMS</p> <p>Weight: 23-26.9 kg</p> <p>V.G.I.O. (Plus-Quadrant) Weight: 1.52 kg</p>	
Target	People / Machine		
Activity	All activities		
Task	All tasks		
Sub Task	Driving the machine/Fault-findings/Assembly/setting and commissioning		
Hazard Type	Mechanical hazards/Electrical hazards		
Sub Type	Inadequate training/Documentation		
Description	Operator could carry out inadequate actions due to inability to get an instruction manual to consult in order to run the application properly or to solve technical problems.		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Not Acceptable
Risk Reduction		Reference	
<ul style="list-style-type: none"> The instruction manual of the machine must be provided to make possible put it in service the robot system and use it in safety manner, covering all the work modes. Manual must specify the prohibition to expose head to robot system parts. The instruction manual also must detail procedure to assemble and disassemble the complete operating workplace equipment, and relevant data as noise level, residual risks and PPE required. Additionally, awareness introduction training is required to work within the collaborative workplace and truck automatic path. 		EN ISO 12100	
Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable

Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level		
Further Review		
Risk Reduction Measures Description		Reference
<p>The application instruction manual is pending, with the minimum contents established in parts 1.7.3 of 2006/42/EC and type C applicable standards. The manuals of the AMR and robots will become part of the application instruction manual</p>		<p>ISO/TS 15066 EN ISO 3691-4</p>
Residual Risk		
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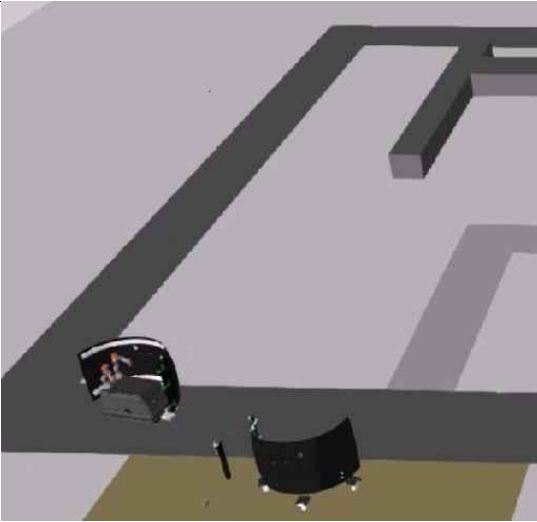
Hazard Identification		Hazard No:	1.14
Title	Lack of marking of robot Collaborative workplace and Operating Zone		
Location	Workplace area/ Operating zones		
Target	Upper Limbs/ Head		
Activity	Normal Operation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other Hazards		
Sub Type	Inadequate identification		
Description	Collaborative workplace and operating zone where the operator can interact directly with the mobile manipulator is not clearly defined or warned.		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Not Acceptable
Risk Reduction		Reference	
<ul style="list-style-type: none"> The collaborative area must be identified with a label, as required by EN ISO 10218-2. The robot collaborative workplace and truck automatic path must be marked on the ground/floor, as required by standards. This actions must be supported with warning signs and awryness training to the personnel.		ISO/TS 15066 EN ISO 10218-2 EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable

Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level		
Not Acceptable		
Risk Reduction Measures Description		Reference
<p>Pending identification and marking of collaboration zones according to 5.11 of EN ISO 10218-2, as well as AMR routes and pedestrian crossings according to 6.3 of EN ISO 3691-4 in accordance with the classification of the zones.</p> <p>The zone classification according to EN ISO 3691-4 for the AMR system shall also be part of the technical documentation of the overall Aero pilot application. The relevant parts for the operator shall also be included in the instruction manual.</p>		<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 3691-4</p>
Residual Risk		
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Hazard Identification		Hazard No:	1.15
Title	Hazards generated by electrical components and electromagnetic radiation		
Location	Robot control system		
Target	Entire Body		
Activity	Normal operation, setup, maintenance, servicing and repair		
Task	Operation/maintenance		
Sub Task	Normal operation, setup, maintenance, servicing and repair		
Hazard Type	Hazards associated with the environment in which the machine is used		
Sub Type	Electromagnetic disturbances		
Description	The industrial environment where the application runs can result in electromagnetic fields. These fields can influence control systems and control signals of the robot. The interference can lead to malfunctions that trigger potentially dangerous movements due to the robot system has been not designed to withstand electromagnetic radiation of the environment.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	390	Summary Level:	High Risk
Risk Reduction		Reference	
The elements that integrate the control system of the robot and truck, as axis actuators or logic controllers must be CE marked that have already been tested for EM compatibility are to be used (European Directive 2014/30/EU).		EN ISO 12100 EN 60204-1	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	15	Summary Possible Level:	Very Low Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	15	
Summary Level	Very Low Risk	
Risk Reduction Measures Description		Reference
<p>The partially complete machine certification of AMR and on-board robots includes compliance with the applicable parts of the EMC directive 2014/30/EU.</p> <p>Although no EMC defects have been identified, justification of the assembly's compliance with the 2014/30/EU directive is pending, by means of a technical report that endorses the use of good engineering practices in relation to electromagnetic compatibility performance.</p>		<p>EN ISO 3691-4 EN 1175-1 EN 12895</p>
Residual Risk		
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9.2.2.2. Mechanical Hazards: AERO-BUC-02

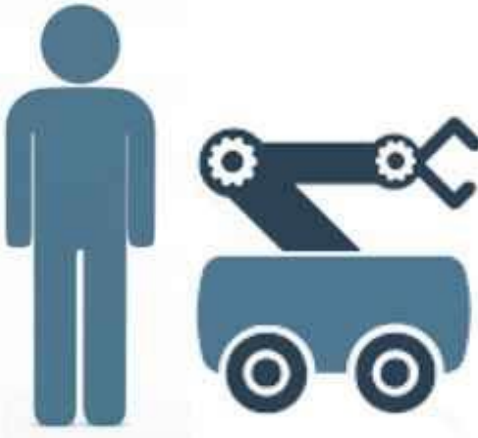
Hazard Identification		Hazard No:	2.1
Title	Impact between mobile manipulator/part and operator during autonomous navigation		
Location	Operating zone		
Target	Head		
Activity	Normal Operation		
Task	Automatic Operation		
Sub Task	Autonomous Navigation		
Hazard Type	Mechanical Hazard with the consequence of		
Sub Type	Impact		
Description	Impact hazards during autonomous Navigation. There is a risk that the mobile manipulator could impact or crash against personnel during the autonomous navigation within the operating zone.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	1250	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> The truck must include sensor devices to detect personnel and prevent collision against workers along automatic path. The length of the detection area must set according EN ISO 13855 formula: $S= 1600 \times T + (1200 - 0,4 \times H)$, where T is reaction time and H is Height of detection area. Speed must be set according EN ISO 3691-4: Personnel must trained and informed about the truck's automatic path and the pedestrian routes to avoid collision. 		EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5


Pilz Hazard Rating (PHR):	7	Summary Possible Level:	Negligible Risk
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Post Measures Risk Assessment	
Assessment Date	23-oct-2024
Degree of Possible Harm	5
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	0.75
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	1
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<ul style="list-style-type: none"> - The AMR includes scanners to detect personnel and avoid collisions with workers along the automatic path. The length of the detection area is set according to EN ISO 13855. Both detection and stopping are functionally verified on site. The presence of persons during the approach to the area of operation causes the AMR travel to stop. - In any case, the displacement speed is equal or lower than 300mm/s, speed established by EN ISO 3691-4 to be able to move without means of detection of persons. - During the movement of the AMR, both robots to robots remain stationary and in their resting position within the boundaries of the AMR floor. - In the event of an approach with the robots in operation, the scanner detects it and the control system triggers a protective stop of the robots. <p>The zone classification according to EN ISO 3691-4 for the AMR system shall also be part of the technical documentation of the overall Aero pilot application. The relevant parts for the operator shall also be included in the instruction manual.</p>	<p>EN ISO 3691-4 IEC 62046</p>
Residual Risk	


Hazard Identification		Hazard No:	2.2
Title	Clamping between the mobile manipulator/part and fixed structures		
Location	Operating hazardous zone: stakeholder or inspection area		
Target	Operator Body/Head		
Activity	Normal operation		
Task	Operation		
Sub Task	Autonomous navigation		
Hazard Type	Mechanical hazard		
Sub Type	Clamping		
Description	Clamping hazard during autonomous navigation: • There is a risk that personnel could stay trapped between platform and fixed structures of the operating zone as stakeholder or inspection table.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	8	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	125	Summary Level:	Significant Risk
Risk Reduction		Reference	
To provide 500 mm wide corridors in expected pass areas. To program robot trajectories in order to prevent approach to this pass areas. Means and procedure to release a trapped operator's limb must be provided, in case of clamping between personnel and fixed structures of the collaborative cell.		EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:	8	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	5	Summary Possible Level:	Negligible Risk

Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	11	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	2	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The pilot has 500 mm wide and 2100 mm high zones in the passage areas, outside the robot operating zones. The robots remain inert, without movement, while the AMR moves. The moving platform travel speed is less than 300 mm/s. AMR detection ensures the absence of people in the vicinity when the robot is about to operate.</p> <p>The zone classification of the final (industrialised) application to be carried out according to EN ISO 3691-4 will determine additional measures if necessary.</p>		EN ISO 3691-4 IEC 62046
Residual Risk		


Hazard Identification		Hazard No:	2.3
Title	Contact during teaching/manual mode of robotic arms (T1/T2) mode		
Location	Collaborative workspace		
Target	Head/Upper Limbs		
Activity	Maintenance		
Task	Setting/programming and/or process changeover		
Sub Task	Adjustment and setting or verification of functional parameters of the machine/programming		
Hazard Type	Mechanical Hazard with the consequence of		
Sub Type	Impact		
Description	Hazards during Setting Teaching/programming operations. <ul style="list-style-type: none"> • there is a risk that robotic arms of the mobile manipulator will collide with personnel. Most of safeguarding systems (safety Limits, sensors) could be disabled for programming purposes.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	250	Summary Level:	High Risk
Risk Reduction		Reference	
Robotic arms must have a pendant control with three-position-button to run the robot in safety conditions during such operations. Pendant control must have fitted an emergency stop button. In manual mode robots must run in slow motion (250 mm/s max). The operators must be trained about the correct use of the robot during those manual control tasks.		EN ISO 10218-2 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	5	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment	
Assessment Date	23-oct-2024
Degree of Possible Harm	11
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	2.5
Frequency And / Or Duration of Exposure	2
Pilz Hazard Rating (PHR)	2
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>Both robots are certified as quasi-machine equipment by their manufacturer in accordance with EN ISO 10218-1. Teach pendant complies with the relevant parts of 5.8 of EN ISO 10218-1 and 5.7 of EN ISO 10218-2. Thus, among other relevant conditions</p> <ul style="list-style-type: none"> - Three-position pushbutton is available on the teach pendant. - The control pendant includes an emergency push button. - In manual mode, the robots operate at a maximum speed of 250 mm/s. <p>Operations under manual mode shall be restricted to specially trained personnel.</p>	<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 10218-1</p>
Residual Risk	

Hazard Identification		Hazard No:	2.4
Title	Remote access for manual intervention		
Location	Collaborative workplace		
Target	Entire Body		
Activity	Normal Operation - Maintenance		
Task	Operation		
Sub Task	Minor adjustments and setting of functional parameters of the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Moving elements		
Description	The robot system can be connected to the network and remotely accessed. Manipulation of the control system by remote access can present hazards for the personnel standing close by.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	500	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Where possible, the robot control system must not be connected to the general network • Protect software with password protection in order to prevent unauthorised remote access • Provide an indication to show that the robot system is being remotely controlled • Not teaching or manual operations shall be permitted or possible when the robot system is remotely controlled 		EN ISO 10218-2 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	10	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	1	
Pilz Hazard Rating (PHR)	3	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The change of parameters in the application software is password protected. Remote access for manual interventions is not foreseen. If necessary, part 5.6.5 of EN ISO 10218-2 shall be followed.</p> <p>Cybersecurity is addressed in another section of the pilot, for the achievement of measures to prevent unauthorised access to control systems, hardware, software, configuration data and application software.</p>		<p>ISO/TS 15066 EN ISO 10218-2</p>
Residual Risk		


Hazard Identification		Hazard No:	2.5
Title	Failure of the safety related part of control system		
Location	Collaborative workplace/ Operating Zone		
Target	People / Machine		
Activity	Normal Operation/Maintenance		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other hazards		
Sub Type	Failure of the Control System		
Description	Faults in the safety control circuit of the mobile manipulator could create multiple hazards, from unexpected or uncontrolled robot movement to inability to stop the process in safety conditions.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	625	Summary Level:	Very High Risk
Risk Reduction		Reference	
The safety control system, and the components that integrate it, must be designed and connected to achieve the reliability levels required for human robot collaborative applications.		EN ISO 3691-4 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	25	Summary Possible Level:	Low Risk

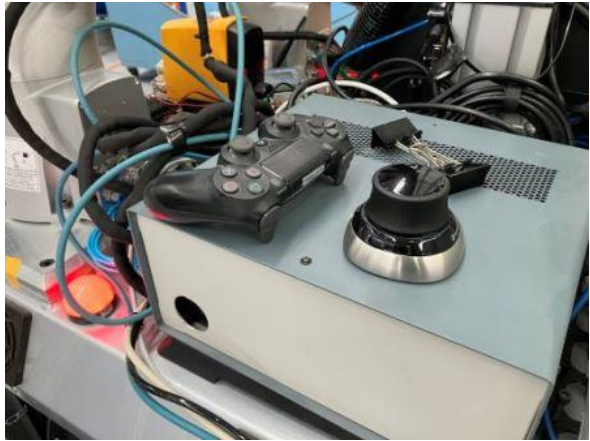
Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	15	
Summary Level	Very Low Risk	
Risk Reduction Measures Description		Reference
<p>The safety functions involved in the integration of the Aeronautic pilot application have been designed under appropriate architectures and components in order to comply with performance level PL=d and category 3, in accordance with EN ISO 10218-2.</p> <p>Functional and installation validation of safety functions and associated equipment has been performed.</p> <p>The safety functions incorporated individually in the sub-assemblies (AMR and robots) are validated by their manufacturer, by means of the declaration of conformity or declaration of incorporation.</p> <p>The documentation of the design, implementation and validation of the safety functions of the pilot application in compliance with EN ISO 13849-1 should be part of the technical documentation.</p> <p>Relevant information on safety functions intended for the user is listed in EN ISO 13849-1 and shall be included in the instruction manual.</p>		<p>EN ISO 10218-1 EN ISO 3691-4 ISO/TS 15066</p>
Residual Risk		
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Hazard Identification		Hazard No:	2.6
Title	Unexpected movements due to new start-up		
Location	Collaborative workplace/ Operating Zone		
Target	Head/Upper Limbs		
Activity	Normal Operation		
Task	Automatic Operation		
Sub Task	Autonomous Navigation/Collaborative applications/Co-transport		
Hazard Type	Other Hazards		
Sub Type	Unintended/unexpected start-up		
Description	<p>Impact hazards during the following operations:</p> <ul style="list-style-type: none"> • Autonomous navigation • Picking assembly part <p>The sudden start-up or movement of the mobile manipulator can present a hazard to persons in the immediate vicinity of the Robot system.</p>		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	500	Summary Level:	High Risk
Risk Reduction		Reference	
<p>To ensure protection against unexpected start-up, after a stop position, operation shall not resume until reset by a deliberate restart action with the operator outside of the collaborative workspace or automatic path. Reset must be placed in a location with proper visibility of the robot system. E.g. On the mobile base.</p> <p>Reset buttons should be provided to prevent automatic restarting of the robot system after either:</p> <ul style="list-style-type: none"> • Actuation of a safeguarding function • Emergency/operative stop • Detection of failure in the safety-related part of the control system • Change in operating mode of the robot system <p>REMARK: The detection of personnel sensor devices is an exception. Automatic reset of scanners to avoid collision could be acceptable once personnel is out of hazardous area.</p>		<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 3691-4</p>	
Possible Residual Ris			


Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	20	Summary Possible Level:	Very Low Risk

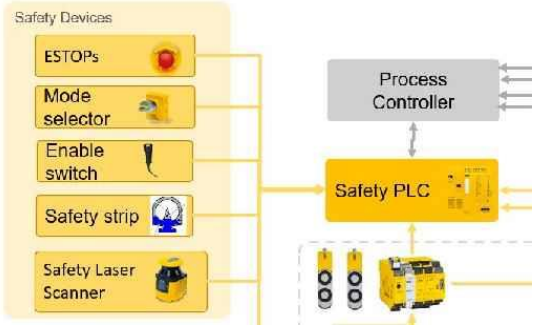
Post Measures Risk Assessment	
Assessment Date	23-oct-2024
Degree of Possible Harm	25
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	2.5
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	15
Summary Level	
Very Low Risk	
	
Risk Reduction Measures Description	Reference
<p>The application has a manual reset function by push button operation located on the mobile platform, to avoid unexpected or unauthorised start-up with persons in the danger zone. Manual reset is therefore necessary:</p> <ul style="list-style-type: none"> - Actuation of a protective function. - Emergency stop. - Detection of control system faults. - Change of operating mode selection. <p>As an exception, the resetting of the safety function associated with the set of scanners that equips the AMR is automatic and is carried out when there is no presence in its detection area.</p>	<p>ISO/TS 15066 EN ISO 3691-4 EN ISO 10218-2</p>
Residual Risk	

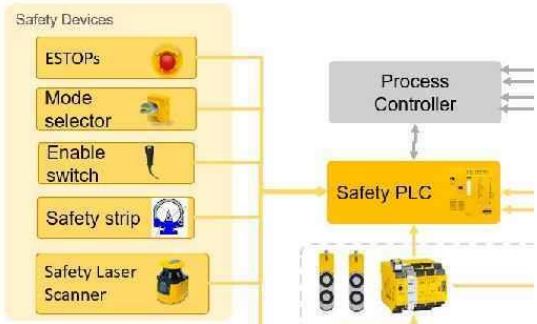
Hazard Identification		Hazard No:	2.7
Title	Inability to warn about status of Robot system - Inadequate design of interface Human-machine		
Location	Collaborative workplace/ Operating Zone		
Target	People / Machine		
Activity	Normal Operation/maintenance/teaching		
Task	Operation		
Sub Task	Normal operation/maintenance/Teaching		
Hazard Type	Ergonomic Hazard		
Sub Type	Inadequate design of interface Human - Robot		
Description	Hazards due to inadequate interface Human - machine. Collaborative mobile platform has not available visual warning devices to inform about the status of the robot and mobile base.		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Not Acceptable
Risk Reduction		Reference	
Warning device should be fitted on the mobile robot system to warn about the status of the device. <ul style="list-style-type: none"> • failure status (red) • safe stop (red) • Normal mode (green) • Manual mode (yellow) • waiting for a reset validation (Blue) Personnel must be informed about the meaning of the colour code.		EN ISO 10218-2 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable

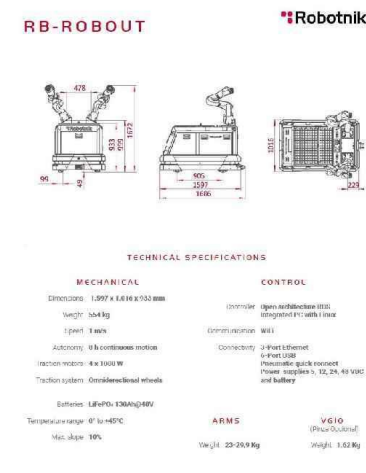
Post Measures Risk Assessment	
Assessment Date	23-oct-2024
Degree of Possible Harm	
Probability of Occurrence of a Hazardous Event	
Possibility of Avoidance	
Frequency And / Or Duration of Exposure	
Pilz Hazard Rating (PHR)	N/A
Summary Level	
Acceptable	
	
Risk Reduction Measures Description	Reference
There is a pilot light on the mobile platform that informs about the overall status.	EN ISO 3691-4 EN ISO 12100 EN ISO 10218-1
Residual Risk	
Operators shall be trained and informed about the colour codes. The meaning of the colours of the light device shall be part of the instructions.	


Hazard Identification		Hazard No:	2.8
Title	Hazards generated from operation by unauthorized personnel		
Location	Collaborative workplace/ Operating Zone		
Target	Upper Limbs		
Activity	Normal operation, setup, maintenance, servicing and repair		
Task	Setting Teaching/programming and/or process changeover		
Sub Task	Automatic mode, programming/testing		
Hazard Type	Operation by unauthorised personnel		
Sub Type	Unintended/unexpected start-up		
Description	Operation of the robot by unauthorized personnel can lead to mechanical hazards due to unexpected movements when operators are close the mobile manipulator.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	250	Summary Level:	High Risk
Risk Reduction		Reference	
Use appropriate safeguards in order to prevent unauthorized (remote) access as: <ul style="list-style-type: none"> • password protection to access to the safety settings of robot. • Use of key in order to select manual or remote work modes. The key must be in possession of authorized personnel. Programming or teaching (remote or not) must be barred to all untrained personnel.		EN ISO 12100 IEC 62443-3-3 IEX 62443-2-4	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	10	Summary Possible Level:	Negligible Risk

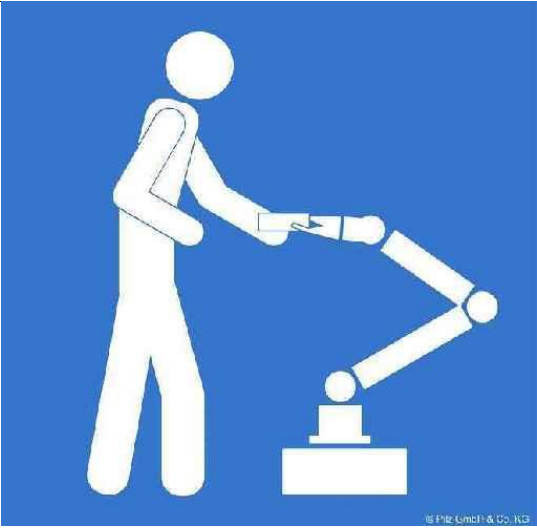
Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	11	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	1	
Pilz Hazard Rating (PHR)	1	
Summary Level		
Negligible Risk		
Risk Reduction Measures Description		Reference
<p>Each machine or sub-assembly that makes up the application has its own keyed mode selector for 'automatic' control as part of the overall application or 'manual' control for individual operation (adjustments or maintenance).</p> <p>The teach pendants comply with the relevant parts of 5.8 of EN ISO 10218-1 and 5.7 of EN ISO 10218-2.</p> <p>Teach pendants for control in manual mode have an access code.</p> <p>Operations under manual mode shall be restricted to specially trained personnel.</p>		<p>ISO/TS 15066 EN ISO 10218-2 EN ISO 3691-4</p>
Residual Risk		
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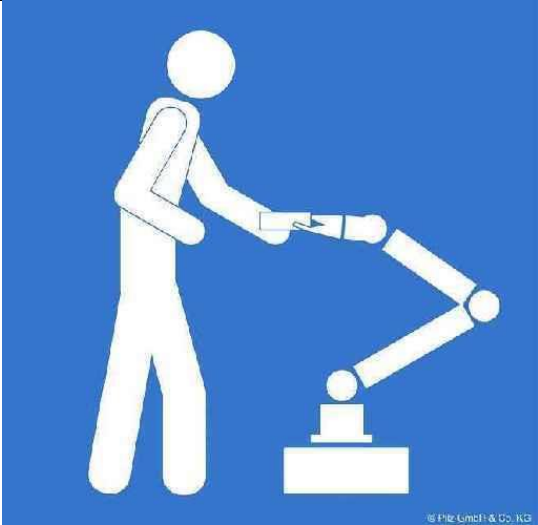
Hazard Identification		Hazard No:	2.9
Title	Inability to perform an emergency stop		
Location	Collaborative workplace/ Operating Zone	 <p>The diagram illustrates the safety system architecture. On the left, a box labeled 'Safety Devices' contains five components: ESTOPs (Emergency Stop Push-Buttons), Mode selector, Enable switch, Safety strip, and Safety Laser Scanner. Each component is connected via a yellow line to a central 'Safety PLC' (Programmable Logic Controller). The Safety PLC is connected to a 'Process Controller' above it. Below the Safety PLC, there is a representation of a collaborative robot system, including a robot arm and a truck, indicating the safety system's application in a collaborative environment.</p>	
Target	People / Machine		
Activity	Operation		
Task	All tasks		
Sub Task	Driving machine		
Hazard Type	Other Hazards		
Sub Type	Loss of machine control/ Dangerous event		
Description	Unexpected situation could result in a hazardous event that could require an emergency stop from the control system.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	750	Summary Level:	Very High Risk
Risk Reduction		Reference	
The collaborative workplace and automatic path shall have at least one emergency stop push-buttons available close the working areas and also integrated in the robot pendant control and truck manual control console. If the e-stop button is actuated the robot system stops in category 0 or 1 according EN 60204-1. Emergency buttons shall be tested periodically to ensure the proper conditions of the circuit.		EN ISO 13850 EN ISO 10218-2 EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	30	Summary Possible Level:	Low Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	 <p>The diagram illustrates the safety system architecture. On the left, a box labeled 'Safety Devices' contains five components: ESTOPs (Emergency Stop buttons), Mode selector, Enable switch, Safety strip, and Safety Laser Scanner. These devices are connected via yellow lines to a central 'Safety PLC' (Programmable Logic Controller). The Safety PLC is also connected to a 'Process Controller' above it and to various actuators (represented by icons of cylinders and a gripper) below it.</p>
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	3	
Pilz Hazard Rating (PHR)	9	
Summary Level		
Negligible Risk		
Risk Reduction Measures Description		Reference
<p>The application has emergency stop devices that are immediately and intuitively accessible from any operating position, including both teach pendants. The emergency stop devices meet the requirements of EN ISO 13850. Actuation of any emergency stop device triggers a category 0 or 1 stop of all actuators, both robot and AMR, in accordance with EN 60204-1. The functionality of the emergency stop has been validated</p> <p>The inclusion of additional emergency stop buttons depends on the zone classification according to EN ISO 3691-4 of the final application.</p>		<p>EN ISO 3691-4 EN ISO 10218-2 EN ISO 13850</p>
Residual Risk		
<p>Periodic checks shall be part of the instructions for use of the application. In addition, the obligation to check and remedy the cause of the emergency stop must be indicated in the instructions.</p>		


Hazard Identification		Hazard No:	2.10																						
Title	Hazards generated by foreseeable misuse due to lack of technical documentation																								
Location	Collaborative workplace/ Operating Zone/ electrical and pneumatic systems	 <p>RB-ROBOUT Robotnik</p> <p>TECHNICAL SPECIFICATIONS</p> <table border="0"> <tr> <td>MECHANICAL</td> <td>CONTROL</td> </tr> <tr> <td>Dimensions: 1.597 x 1.616 x 933 mm</td> <td>Control: Open architecture (PLC) integrated PC with I base</td> </tr> <tr> <td>Weight: 554 kg</td> <td>Communication: Wi-Fi</td> </tr> <tr> <td>Speed: 1 m/s</td> <td>Connectivity: 2-Port Ethernet, 4x RS-485</td> </tr> <tr> <td>Actuators: 8 in continuous motion</td> <td>Positioning: quick connect, those equipped with 24, 28, 40 VDC and battery</td> </tr> <tr> <td>Traction motors: 4 x 1000 W</td> <td></td> </tr> <tr> <td>Traction system: Omnidirectional wheels</td> <td></td> </tr> <tr> <td>Batteries: LiFePO4 130Ah@90V</td> <td>ARMS</td> </tr> <tr> <td>Temperature range: 0° to +60°C</td> <td>Weight: 23-26.9 kg</td> </tr> <tr> <td>Max. slope: 10%</td> <td>V.G.I.O. (Plus-Optional)</td> </tr> <tr> <td></td> <td>Weight: 1.52 kg</td> </tr> </table>		MECHANICAL	CONTROL	Dimensions: 1.597 x 1.616 x 933 mm	Control: Open architecture (PLC) integrated PC with I base	Weight: 554 kg	Communication: Wi-Fi	Speed: 1 m/s	Connectivity: 2-Port Ethernet, 4x RS-485	Actuators: 8 in continuous motion	Positioning: quick connect, those equipped with 24, 28, 40 VDC and battery	Traction motors: 4 x 1000 W		Traction system: Omnidirectional wheels		Batteries: LiFePO4 130Ah@90V	ARMS	Temperature range: 0° to +60°C	Weight: 23-26.9 kg	Max. slope: 10%	V.G.I.O. (Plus-Optional)		Weight: 1.52 kg
MECHANICAL	CONTROL																								
Dimensions: 1.597 x 1.616 x 933 mm	Control: Open architecture (PLC) integrated PC with I base																								
Weight: 554 kg	Communication: Wi-Fi																								
Speed: 1 m/s	Connectivity: 2-Port Ethernet, 4x RS-485																								
Actuators: 8 in continuous motion	Positioning: quick connect, those equipped with 24, 28, 40 VDC and battery																								
Traction motors: 4 x 1000 W																									
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Batteries: LiFePO4 130Ah@90V	ARMS																								
Temperature range: 0° to +60°C	Weight: 23-26.9 kg																								
Max. slope: 10%	V.G.I.O. (Plus-Optional)																								
	Weight: 1.52 kg																								
Target	People / Machine																								
Activity	All activities																								
Task	All tasks																								
Sub Task	Driving the machine/Fault-finders/Assembly/setting and commissioning																								
Hazard Type	Mechanical hazards/Electrical hazards																								
Sub Type	Inadequate training/Documentation																								
Description	Operator could carry out inadequate actions due to inability to get an instruction manual to consult in order to run the application properly or to solve technical problems.																								
Risk Estimation and Evaluation																									
Degree of Possible Harm:		Possibility of Avoidance:																							
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:																							
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Not Acceptable																						
Risk Reduction		Reference																							
<ul style="list-style-type: none"> The instruction manual of the machine must be provided to make possible put it in service the robot system and use it in safety manner, covering all the work modes. Manual must specify the prohibition to expose head to robot system parts. The instruction manual also must detail procedure to assemble and disassemble the complete operating workplace equipment, and relevant data as noise level, residual risks and PPE required. Additionally, awareness introduction training is required to work within the collaborative workplace and truck automatic path. 		EN ISO 12100																							
Possible Residual Risk																									
Degree of Possible Harm:		Possibility of Avoidance:																							
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:																							
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable																						

Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level		
Further Review		
Risk Reduction Measures Description		Reference
<p>The application instruction manual is pending, with the minimum contents established in parts 1.7.3 of 2006/42/EC and type C applicable standards. The manuals of the AMR and robots will become part of the application instruction manual.</p>		<p>ISO/TS 15066 EN ISO 3691-4</p>
Residual Risk		
Empty space for Residual Risk content		


Hazard Identification		Hazard No:	2.11
Title	Lack of marking of robot Collaborative workplace and Operating Zone		
Location	Workplace area/ Operating zones		
Target	Upper Limbs/ Head		
Activity	Normal Operation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other Hazards		
Sub Type	Inadequate identification		
Description	Collaborative workplace and operating zone where the operator can interact directly with the mobile manipulator is not clearly defined or warned.		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Not Acceptable
Risk Reduction		Reference	
<ul style="list-style-type: none"> The collaborative area must be identified with a label, as required by EN ISO 10218-2. The robot collaborative workplace and truck automatic path must be marked on the ground/floor, as required by standards. This actions must be supported with warning signs and awareness training to the personnel.		ISO/TS 15066 EN ISO 10218-2 EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level		
Not Acceptable		
Risk Reduction Measures Description		Reference
<p>Pending identification and marking of collaboration zones according to 5.11 of EN ISO 10218-2, as well as AMR routes and pedestrian crossings according to 6.3 of EN ISO 3691-4 in accordance with the zone classification.</p> <p>The zone classification according to EN ISO 3691-4 for the AMR system shall also be part of the technical documentation of the overall Aero pilot application. The relevant parts for the operator shall also be included in the instruction manual</p>		<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 3691-4</p>
Residual Risk		
Empty space for Residual Risk		

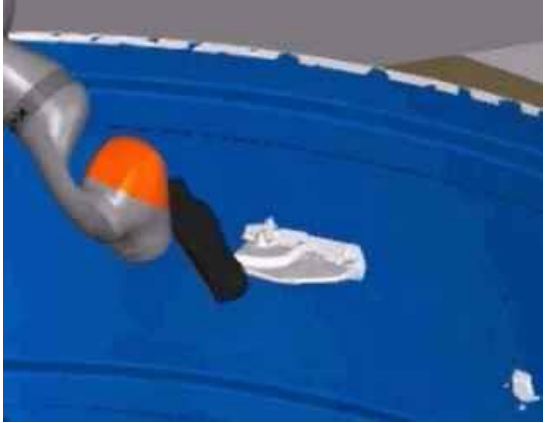
Hazard Identification		Hazard No:	2.12
Title	Hazards generated by electrical components and electromagnetic radiation		
Location	Robot control system		
Target	Entire Body		
Activity	Normal operation, setup, maintenance, servicing and repair		
Task	Operation/maintenance		
Sub Task	Normal operation, setup, maintenance, servicing and repair		
Hazard Type	Hazards associated with the environment in which the machine is used		
Sub Type	Electromagnetic disturbances		
Description	The industrial environment where the application runs can result in electromagnetic fields. These fields can influence control systems and control signals of the robot. The interference can lead to malfunctions that trigger potentially dangerous movements due to the robot system has been not designed to withstand electromagnetic radiation of the environment.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	390	Summary Level:	High Risk
Risk Reduction		Reference	
The elements that integrate the control system of the robot and truck, as axis actuators or logic controllers must be CE marked that have already been tested for EM compatibility are to be used (European directive 2014/30/EU).		EN ISO 12100 EN 60204-1	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	15	Summary Possible Level:	Very Low Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	15	
Summary Level	Very Low Risk	
Risk Reduction Measures Description		Reference
<p>The machine certification of AMR and on-board robots includes compliance with the applicable parts of the EMC directive 2014/30/EU.</p> <p>Although no EMC defects have been identified, justification of the assembly's compliance with the 2014/30/EU directive is pending, by means of a technical report that endorses the use of good engineering practices in relation to electromagnetic compatibility performance.</p>		<p>EN ISO 3691-4 EN 1175-1 EN 12895</p>
Residual Risk		

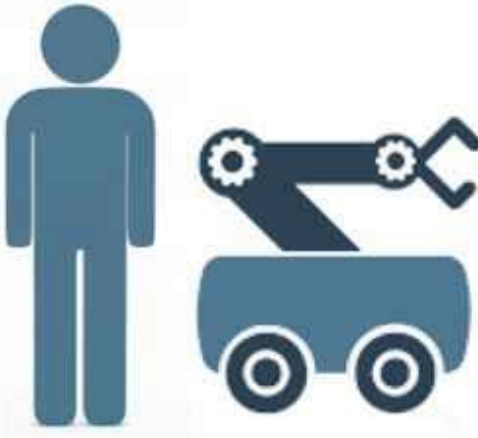
9.2.2.3. Mechanical Hazards: AERO-BUC-03


Hazard Identification		Hazard No:	3.1
Title	Unexpected contact between robot and operator parts during hand-guiding		
Location	Operating zone - Stakeholder		
Target	Head/Upper Limbs		
Activity	Normal Operation		
Task	Setting Teaching/programming by hand-guiding		
Sub Task	Adjustment and setting of functional parameters of the robotic arms		
Hazard Type	Mechanical Hazard with the consequence of		
Sub Type	Impact		
Description	<p>Impact hazards during the following collaborative operations:</p> <ul style="list-style-type: none"> • Hand guiding teaching. • Transition from hand guiding to automatic movements <p>There is a risk that the robot system could collide against body parts of personnel due to uncontrolled dynamics or transitions from automatic to hand-guiding mode</p>		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	1500	Summary Level:	Very High Risk
Risk Reduction		Reference	
<p>Transitions between hand guiding operations and other types of collaborative operations shall not introduce additional risk. The operator shall control such transitions by deliberate actions. Transitions between automatic operating mode and hand guiding mode shall not lead unexpected motion.</p>		EN ISO 10218-2 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	30	Summary Possible Level:	Low Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	8	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	5	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The transition between automatic operation and collaborative mode is done automatically, through the detection capabilities of the AMR's on-board safety scanner.</p>		<p>EN ISO 10218-2 ISO/TS 15066</p>
Residual Risk		
Empty space for Residual Risk description		

Hazard Identification		Hazard No:	3.2
Title	Loss of the end effector		
Location	Collaborative workplace/ Operating Zone		
Target	Entire Body		
Activity	Normal operation, maintenance		
Task	Operation		
Sub Task	Assembling/disassembling/Inspection		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Ejected objects		
Description	The dynamics of the robot present the risk that the end effector detach and fall out or be thrown out.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	117	Summary Level:	Significant Risk
Risk Reduction		Reference	
End effectors shall be fixed to the arms with a mechanical lockable system to avoid unexpected ejection of the tool. To train the operators about the correct procedure to lock in safety conditions the screwdriver when such tool is changed or replaced. Is also recommended to design a detection system in the robot in order to warn about an hypothetical wrong positioning of the tool.		ISO/TS 15066 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk

Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	4	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The end effector used in the operation should be certified by its manufacturer as part of the system integration. This ensures compliance with the applicable parts of ISO TR 20218-1 (integrated in 5.9 of ISO/FDIS 10218-2), among others:</p> <ul style="list-style-type: none"> - The mechanical link between the gripper and the robot wrist is specifically designed and constructed for the given application, including the static and dynamic limits set by the robot manufacturer. The joint is shown to be visually and/or apparently sufficient. - The mechanical link between the gripper and the workpiece is designed and built specifically for the given application. - In case of loss of power supply, the gripper does not release the workpiece. <p>Information for the use of the gripper, including inspection, maintenance and repair, shall form part of the instructions.</p>		<p>EN ISO 10218-2 ISO/TS 15066</p>
Residual Risk		

Hazard Identification		Hazard No:	3.3
Title	Contact during teaching/manual mode of robotic arms (T1/T2) mode		
Location	Collaborative workspace		
Target	Head/Upper Limbs		
Activity	Maintenance		
Task	Setting/programming and/or process changeover		
Sub Task	Adjustment and setting or verification of functional parameters of the machine/programming		
Hazard Type	Mechanical Hazard with the consequence of		
Sub Type	Impact		
Description	Hazards during Setting Teaching/programming operations. <ul style="list-style-type: none"> • there is a risk that robotic arms of the mobile manipulator will collide with personnel. Most of safeguarding systems (safety Limits, sensors) could be disabled for programming purposes.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	250	Summary Level:	High Risk
Risk Reduction		Reference	
Robotic arms must have a pendant control with three-position-button to run the robot in safety conditions during such operations. Pendant control must have fitted an emergency stop button. In manual mode robots must run in slow motion (250 mm/s max). The operators must be trained about the correct use of the robot during those manual control tasks.		EN ISO 10218-2 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	5	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment	
Assessment Date	23-oct-2024
Degree of Possible Harm	25
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	2.5
Frequency And / Or Duration of Exposure	1
Pilz Hazard Rating (PHR)	3
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>Both robots are certified as quasi-machine equipment by their manufacturer in accordance with EN ISO 10218-1. Teach pendant complies with the relevant parts of 5.8 of EN ISO 10218-1 and 5.7 of EN ISO 10218-2. Thus, among other relevant conditions</p> <ul style="list-style-type: none"> - Three-position pushbutton is available on the teach pendant. - The control pendant includes an emergency push button. - In manual mode, the robots operate at a maximum speed of 250 mm/s. <p>Operations under manual mode shall be restricted to specially trained personnel.</p>	<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 10218-1</p>
Residual Risk	

Hazard Identification		Hazard No:	3.4
Title	Loss of stability of the manipulator		
Location	Collaborative workplace/ Operating Zone		
Target	Entire Body		
Activity	Normal operation, maintenance		
Task	Operation		
Sub Task	Assembling/disassembling/Inspection		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Falling of robots		
Description	The movement and load of the robots cause dynamic forces on the fixing system. The robots could overturn or fall over due to a loss of stability.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	117	Summary Level:	Significant Risk
Risk Reduction		Reference	
The Fixing of the robot on the trolley's support shall be stiff enough to withstand the robot's dynamics and ensure stability. Fixing must be revised periodically to ensure the proper conditions.		ISO/TS 15066 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment	
Assessment Date	23-oct-2024
Degree of Possible Harm	25
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	0.75
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	4
Summary Level	
Negligible Risk	
Risk Reduction Measures Description	Reference
<p>The assembly, fixings and installation of each robot on board the AMR show no apparent signs of instability. The assembly is carried out according to the manufacturer's instructions and within the established limits.</p> <ul style="list-style-type: none"> - The stability of the assembly is also guaranteed during operation of the robots. - The robots do not move during the movement of the AMR, remaining in their resting zone within the limits of the AMR plant. <p>Periodic checking of fixings shall be included in the instructions for use.</p>	<p>EN ISO 10218-2 ISO/TS 15066</p>
Residual Risk	
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Hazard Identification		Hazard No:	3.5
Title	Inability to perform an emergency stop		
Location	Collaborative workplace/ Operating Zone		
Target	People / Machine		
Activity	Operation		
Task	All tasks		
Sub Task	Driving machine		
Hazard Type	Other Hazards		
Sub Type	Loss of machine control/ Dangerous event		
Description	Unexpected situation could result in a hazardous event that could require an emergency stop from the control system.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	750	Summary Level:	Very High Risk
Risk Reduction		Reference	
The collaborative workplace and automatic path shall have at least one emergency stop push-buttons available close to the working areas and also integrated in the robot pendant control and truck manual control console. If the e-stop button is actuated the robot system stops in category 0 or 1 according to EN 60204-1. Emergency buttons shall be tested periodically to ensure the proper conditions of the circuit.		EN ISO 13850 EN ISO 10218-2 EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	30	Summary Possible Level:	Low Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	3	
Pilz Hazard Rating (PHR)	9	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The application has emergency stop devices that are immediately and intuitively accessible from any operating position, including both teach pendants. The emergency stop devices meet the requirements of EN ISO 13850. Actuation of any emergency stop device triggers a category 0 or 1 stop of all actuators, both robot and AMR, in accordance with EN 60204-1. The functionality of the emergency stop has been validated.</p> <p>The inclusion of additional emergency stop buttons depends on the zone classification according to EN ISO 3691-4 of the final application.</p>		EN ISO 3691-4 EN ISO 10218-2 EN ISO 13850
Residual Risk		
<p>Periodic checks shall be part of the instructions for use of the application. In addition, the obligation to check and remedy the cause of the emergency stop must be indicated in the instructions.</p>		


Hazard Identification		Hazard No:	3.6
Title	Failure of the safety related part of control system		
Location	Collaborative workplace/ Operating Zone		
Target	People / Machine		
Activity	Normal Operation/Maintenance		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other hazards		
Sub Type	Failure of the Control System		
Description	Faults in the safety control circuit of the mobile manipulator could create multiple hazards, from unexpected or uncontrolled robot movement to inability to stop the process in safety conditions.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	625	Summary Level:	Very High Risk
Risk Reduction		Reference	
The safety control system, and the components that integrate it, must be designed and connected to achieve the reliability levels required for human robot collaborative applications.		EN ISO 3691-4 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	25	Summary Possible Level:	Low Risk

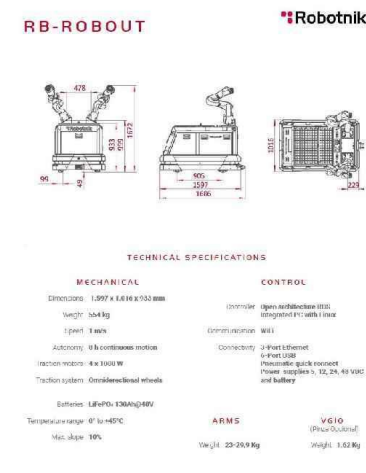
Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	15	
Summary Level	Very Low Risk	
Risk Reduction Measures Description		Reference
<p>The safety functions involved in the integration of the Aeronautic pilot application have been designed under appropriate architectures and components in order to comply with performance level PL=d and category 3, in accordance with EN ISO 10218-2.</p> <p>Functional and installation validation of safety functions and associated equipment has been performed.</p> <p>The safety functions incorporated individually in the sub-assemblies (AMR and robots) are validated by their manufacturer, by means of the declaration of conformity or declaration of incorporation.</p> <p>The documentation of the design, implementation and validation of the safety functions of the pilot application in compliance with EN ISO 13849-1 should be part of the technical documentation.</p> <p>Relevant information on safety functions intended for the user is listed in EN ISO 13849-1 and shall be included in the instruction manual.</p>		<p>EN ISO 10218-1 EN ISO 3691-4 ISO/TS 15066 ANSI/RIA R15.08-1</p>
Residual Risk		
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Hazard Identification		Hazard No:	3.7
Title	Falling or ejection of assembly part during normal operation		
Location	Collaborative workplace/ Operating Zone		
Target	Upper/Lower limbs		
Activity	Normal Operation		
Task	Collaborative Operation		
Sub Task	Picking up, placing/co-transport		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Falling objects		
Description	<p>Mechanical hazards during automatic collaborative operations.</p> <ul style="list-style-type: none"> Parts could fall down or be ejected from robotic arms in case of loss of power during placing or holding the piece (up to 11kg), <p>This could cause impact, crushing or loss of stability to the personnel who manipulates the part together with the robots.</p>		
Risk Estimation and Evaluation			
Degree of Possible Harm:	5	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	156	Summary Level:	Significant Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> End effector (gripper) must be mechanically designed to support parts towards avoid ejection and uncontrolled falling of part by loss of stability. End effector's force and pressure, as well as dynamics, must be set to avoid ejection and uncontrolled falling of part. 		EN ISO 10218-2 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	5	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	3	Summary Possible Level:	Negligible Risk

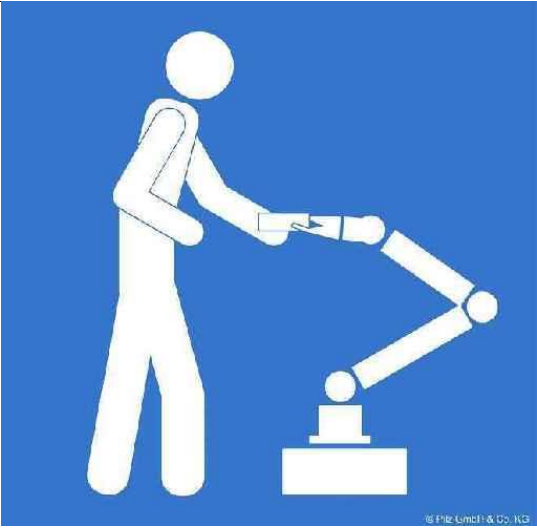
Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	5	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	6	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The end effector used in the operation should be certified by its manufacturer as part of the system integration. This ensures compliance with the applicable parts of ISO TR 20218-1 (integrated in 5.9 of ISO/FDIS 10218-2), among others:</p> <ul style="list-style-type: none"> - The mechanical link between the gripper and the robot wrist is specifically designed and constructed for the given application, including the static and dynamic limits set by the robot manufacturer. The joint is shown to be visually and/or apparently sufficient. - The mechanical link between the gripper and the workpiece is designed and built specifically for the given application. - In case of loss of power supply, the gripper does not release the workpiece. <p>Information for the use of the gripper, including inspection, maintenance and repair, shall form part of the instructions.</p>		<p>EN ISO 10218-2 ISO/TR 20218-1 EN ISO 3691-4</p>
Residual Risk		


Hazard Identification		Hazard No:	3.8
Title	Hazards generated from operation by unauthorized personnel		
Location	Collaborative workplace/ Operating Zone		
Target	Upper Limbs		
Activity	Normal operation, setup, maintenance, servicing and repair		
Task	Setting Teaching/programming and/or process changeover		
Sub Task	Automatic mode, programming/testing		
Hazard Type	Operation by unauthorised personnel		
Sub Type	Unintended/unexpected start-up		
Description	Operation of the robot by unauthorized personnel can lead to mechanical hazards due to unexpected movements when operators are close the mobile manipulator.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	250	Summary Level:	High Risk
Risk Reduction		Reference	
Use appropriate safeguards in order to prevent unauthorized (remote) access as: <ul style="list-style-type: none"> • password protection to access to the safety settings of robot. • Use of key in order to select manual or remote work modes. The key must be in possession of authorized personnel. Programming or teaching (remote or not) must be barred to all untrained personnel.		EN ISO 12100 IEC 62443-3-3 IEX 62443-2-4	
Possible Residual Risk			
Degree of Possible Harm:	40	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	1
Pilz Hazard Rating (PHR):	10	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	5	
Frequency And / Or Duration of Exposure	1	
Pilz Hazard Rating (PHR)	6	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>Each machine or sub-assembly that makes up the application has its own keyed mode selector for 'automatic' control as part of the overall application or 'manual' control for individual operation (adjustments or maintenance). The teach pendants comply with the relevant parts of 5.8 of EN ISO 10218-1 and 5.7 of EN ISO 10218-2. Teach pendants for control in manual mode have an access code. Operations under manual mode shall be restricted to specially trained personnel.</p>		ISO/TS 15066 EN ISO 10218-2 EN ISO 3691-4
Residual Risk		
<p>Misuse of machine or lack of care.</p> <ul style="list-style-type: none"> • Only trained operators could manage machine in manual mode. Programming or teaching (remote or not) must be barred to all untrained personnel. 		


Hazard Identification		Hazard No:	3.9																						
Title	Hazards generated by foreseeable misuse due to lack of technical documentation																								
Location	Collaborative workplace/ Operating Zone/ electrical and pneumatic systems	 <p>RB-ROBOUT Robotnik</p> <p>TECHNICAL SPECIFICATIONS</p> <table border="0"> <tr> <td>MECHANICAL</td> <td>CONTROL</td> </tr> <tr> <td>Dimensions: 1.297 x 1.616 x 533 mm</td> <td>Control: Open architecture (PLC) integrated F1 with I base</td> </tr> <tr> <td>Weight: 55.4 kg</td> <td>Communication: Wi-Fi</td> </tr> <tr> <td>Speed: 1 m/s</td> <td>Connectivity: 2-Port Ethernet, RS-485, USB</td> </tr> <tr> <td>Actuators: 8 in continuous motion</td> <td>Positioning: quick connect, those equipped with 12, 24, 48 VDC and battery</td> </tr> <tr> <td>Traction motors: 4 x 1000 W</td> <td></td> </tr> <tr> <td>Traction system: Omnidirectional wheels</td> <td></td> </tr> <tr> <td>Batteries: LiFePO4 130Ah@90V</td> <td>ARMS</td> </tr> <tr> <td>Temperature range: 0° to +60°C</td> <td>Weight: 23-26.9 kg</td> </tr> <tr> <td>Max. slope: 10%</td> <td>V.G.I.O. (Plus-Optional)</td> </tr> <tr> <td></td> <td>Weight: 1.52 kg</td> </tr> </table>		MECHANICAL	CONTROL	Dimensions: 1.297 x 1.616 x 533 mm	Control: Open architecture (PLC) integrated F1 with I base	Weight: 55.4 kg	Communication: Wi-Fi	Speed: 1 m/s	Connectivity: 2-Port Ethernet, RS-485, USB	Actuators: 8 in continuous motion	Positioning: quick connect, those equipped with 12, 24, 48 VDC and battery	Traction motors: 4 x 1000 W		Traction system: Omnidirectional wheels		Batteries: LiFePO4 130Ah@90V	ARMS	Temperature range: 0° to +60°C	Weight: 23-26.9 kg	Max. slope: 10%	V.G.I.O. (Plus-Optional)		Weight: 1.52 kg
MECHANICAL	CONTROL																								
Dimensions: 1.297 x 1.616 x 533 mm	Control: Open architecture (PLC) integrated F1 with I base																								
Weight: 55.4 kg	Communication: Wi-Fi																								
Speed: 1 m/s	Connectivity: 2-Port Ethernet, RS-485, USB																								
Actuators: 8 in continuous motion	Positioning: quick connect, those equipped with 12, 24, 48 VDC and battery																								
Traction motors: 4 x 1000 W																									
Traction system: Omnidirectional wheels																									
Batteries: LiFePO4 130Ah@90V	ARMS																								
Temperature range: 0° to +60°C	Weight: 23-26.9 kg																								
Max. slope: 10%	V.G.I.O. (Plus-Optional)																								
	Weight: 1.52 kg																								
Target	People / Machine																								
Activity	All activities																								
Task	All tasks																								
Sub Task	Driving the machine/Fault-finders/Assembly/setting and commissioning																								
Hazard Type	Mechanical hazards/Electrical hazards																								
Sub Type	Inadequate training/Documentation																								
Description	Operator could carry out inadequate actions due to inability to get an instruction manual to consult in order to run the application properly or to solve technical problems.																								
Risk Estimation and Evaluation																									
Degree of Possible Harm:		Possibility of Avoidance:																							
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:																							
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Not Acceptable																						
Risk Reduction		Reference																							
<ul style="list-style-type: none"> The instruction manual of the machine must be provided to make possible put it in service the robot system and use it in safety manner, covering all the work modes. Manual must specify the prohibition to expose head to robot system parts. The instruction manual also must detail procedure to assemble and disassemble the complete operating workplace equipment, and relevant data as noise level, residual risks and PPE required. Additionally, awareness introduction training is required to work within the collaborative workplace and truck automatic path. 		EN ISO 12100																							
Possible Residual Risk																									
Degree of Possible Harm:		Possibility of Avoidance:																							
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:																							
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable																						

Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level		
Further Review		
Risk Reduction Measures Description		Reference
<p>The application instruction manual is pending, with the minimum contents established in parts 1.7.3 of 2006/42/EC and type C applicable standards. The manuals of the AMR and robots will become part of the application instruction manual.</p>		<p>ISO/TS 15066 EN ISO 3691-4</p>
Residual Risk		
Empty space for Residual Risk content		

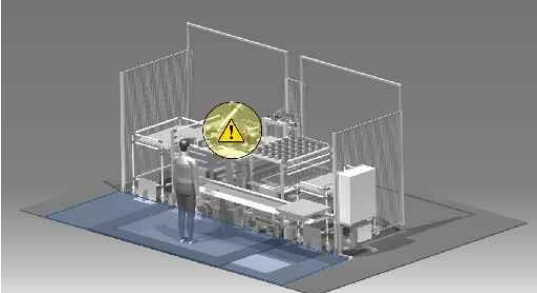
Hazard Identification		Hazard No:	3.10
Title	Lack of marking of robot Collaborative workplace and Operating Zone		
Location	Workplace area/ Operating zones		
Target	Upper Limbs/ Head		
Activity	Normal Operation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other Hazards		
Sub Type	Inadequate identification		
Description	Collaborative workplace and operating zone where the operator can interact directly with the mobile manipulator is not clearly defined or warned.		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Not Acceptable
Risk Reduction		Reference	
<ul style="list-style-type: none"> The collaborative area must be identified with a label, as required by EN ISO 10218-2. The robot collaborative workplace and truck automatic path must be marked on the ground/floor, as required by standards. This actions must be supported with warning signs and awareness training to the personnel.		ISO/TS 15066 EN ISO 10218-2 EN ISO 3691-4	
Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable

Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level		
Not Acceptable		
Risk Reduction Measures Description		Reference
<p>Pending identification and marking of collaboration zones according to 5.11 of EN ISO 10218-2, as well as AMR routes and pedestrian crossings according to 6.3 of EN ISO 3691-4 in accordance with the zone classification.</p> <p>The zone classification according to EN ISO 3691-4 for the AMR system shall also be part of the technical documentation of the overall Aero pilot application. The relevant parts for the operator shall also be included in the instruction manual.</p>		<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 3691-4</p>
Residual Risk		
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Hazard Identification		Hazard No:	3.11
Title	Hazards generated by electrical components and electromagnetic radiation		
Location	Robot control system		
Target	Entire Body		
Activity	Normal operation, setup, maintenance, servicing and repair		
Task	Operation/maintenance		
Sub Task	Normal operation, setup, maintenance, servicing and repair		
Hazard Type	Hazards associated with the environment in which the machine is used		
Sub Type	Electromagnetic disturbances		
Description	The industrial environment where the application runs can result in electromagnetic fields. These fields can influence control systems and control signals of the robot. The interference can lead to malfunctions that trigger potentially dangerous movements due to the robot system has been not designed to withstand electromagnetic radiation of the environment.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	390	Summary Level:	High Risk
Risk Reduction		Reference	
The elements that integrate the control system of the robot and truck, as axis actuators or logic controllers must be CE marked that have already been tested for EM compatibility are to be used (European Directive 2014/30/EU).		EN ISO 12100 EN 60204-1	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	15	Summary Possible Level:	Very Low Risk

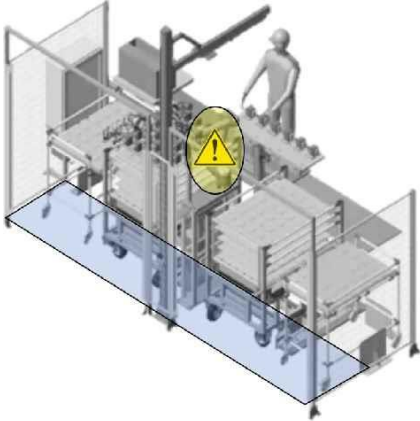
Post Measures Risk Assessment		
Assessment Date	23-oct-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	15	
Summary Level	Very Low Risk	
Risk Reduction Measures Description		Reference
<p>The partially complete machine certification of AMR and on-board robots includes compliance with the applicable parts of the EMC directive 2014/30/EU.</p> <p>Although no EMC defects have been identified, justification of the assembly's compliance with the 2014/30/EU directive is pending, by means of a technical report that endorses the use of good engineering practices in relation to electromagnetic compatibility performance</p>		<p>EN ISO 3691-4 EN 1175-1 EN 12895</p>
Residual Risk		
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9.2.3. White Goods pilot Risk assessment conducted

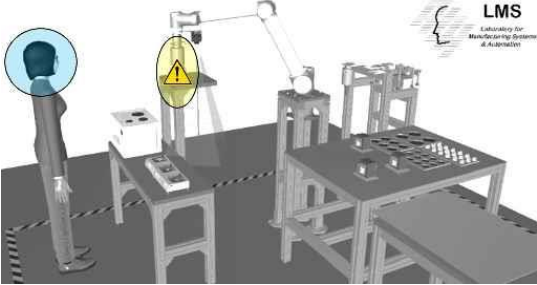
Hazard Identification		Hazard No:	1.1
Title	Impact with the Robot in operator area		
Location	Operator Area		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Pick and Place		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Mechanical hazards due to the exposed risk of impact with the robot structure while the robot is performing the place operation of the process parts. This area is where the operator will always be performing the manual operation of transformer placement. Due to space constrains, it is not possible to install a light sensing device in the frontal area of the robot.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	781	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Reduce the speed of the robot when in close contact with the operator. • Slow speed robot movements when is working near the operator. • Robot path programmed to avoid crossing torso and head areas. • Training and information for use about residual risk. 		EN ISO 10218-2 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5


Pilz Hazard Rating (PHR):	15	Summary Possible Level:	Very Low Risk
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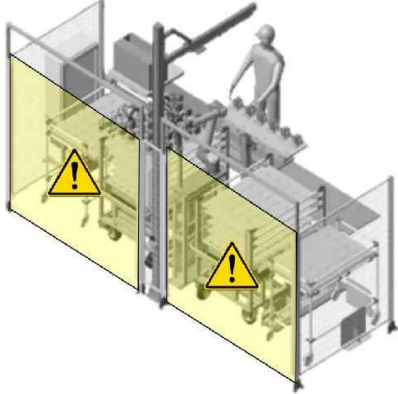
Post Measures Risk Assessment	
Assessment Date	14-nov-2024
Degree of Possible Harm	8
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	0.75
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	1
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>A vertical plane safety scanner is provided which detects access to the operating table and the position of the robot is dual monitored. When the robot is in proximity to or on the operating table and upper limb access is detected by the scanner, the control system commands the robot to slow down and enter collaborative mode.</p> <p>The distance from the detection plane of the scanner to the nearest point of the robot path is sufficient.</p> <p>Robot paths are programmed to remain out of reach of the operator's head, face or neck. The distance due to the width of the conveyor helps to keep these parts out of the robot's reach.</p> <p>The final configuration of the scanner detection field shall be recorded and shall be part of the technical documentation of the overall application in case of final industrialisation.</p>	<p>EN ISO 10218-2 ISO/TS 15066</p>
Residual Risk	
<p>The training, education, experience and information that operators must have should be reflected in the instruction manual. This statement applies to the control of all identified risks.</p>	


Hazard Identification		Hazard No:	1.2
Title	Impact with the Robot in back area		
Location	Back Area		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Pick and Place		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Mechanical hazards due to the exposed risk of impact with the robot structure while the robot is working in the back area. The back area is where the tool changing mechanism and also where the pallets with the product for the robot to pick are located.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	625	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Install light sensing devices (scanner or light barriers) in accordance to the EN ISO 13855 to protect the access to the hazard area. • Install fixed guards in accordance to EN ISO 14130 and EN ISO 13857 to protect the access to the back area. • Slow speed robot movements near foreseeable access points. • Training and information for use about residual risk. 		EN ISO 13855 EN ISO 10218-2 EN ISO 14120	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	3	Summary Possible Level:	Negligible Risk

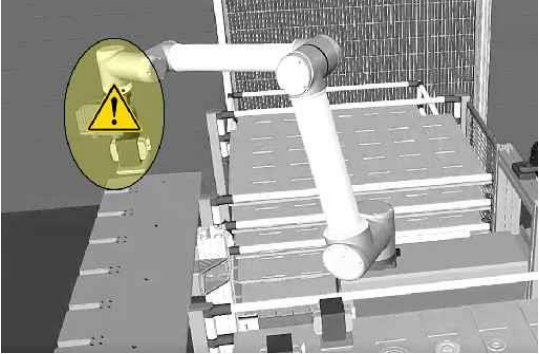
Post Measures Risk Assessment	
Assessment Date	14-nov-2024
Degree of Possible Harm	5
Probability of Occurrence of a Hazardous Event	1.25
Possibility of Avoidance	2.5
Frequency And / Or Duration of Exposure	4
Pilz Hazard Rating (PHR)	62
Summary Level	
Significant Risk	
	
Risk Reduction Measures Description	Reference
<p>A combination of fixed commercial mechanical locking on both sides and two immaterial safety curtains for body access detection is provided at the openings provided for material trolley storage and retrieval.</p> <p>Access through the detection planes of the curtains, which is the operational way of access, causes the following safety reactions of the robot:</p> <ul style="list-style-type: none"> - Protective stop, if operating with the vacuum gripper. - Speed reduction changing to collaborative mode, otherwise <p>The front arrangement of the conveyor (1 metre high) makes it difficult for the operator to pass over it. The robot trajectories are programmed to remain out of reach of the operator's head, face or neck. After exiting the protected area, it is necessary to manually reset the function to continue the operating cycle. The reset button is located outside the protected area, however, due to the space conditions of the pilot it is verified that:</p> <ul style="list-style-type: none"> - The distance of the light curtains to the nearest danger point is not sufficient (160mm). The end-effector storage is too close to the detection plane of the light curtain. It does not comply with EN ISO 13855 - The position of the reset button is in such a position that it is possible to reset from the protected area. <p>The commissioning of the application that provides for an increase in the internal dimensions of the robot's operating enclosure, in combination with the use of a higher resolution curtain, could allow the above two points to be solved.</p> <p>Physical guards must be used to prevent the operator from passing under the conveyor.</p>	<p>EN ISO 13855 EN ISO 10218-2 EN ISO 14120</p>
Residual Risk	
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Hazard Identification		Hazard No:	1.3
Title	Impact with the process part during placement		
Location	Operator Area		
Target	Head/Upper Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Placement of the Process Part		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Mechanical hazards due to the exposed risk of impact with the process part while the operator robot is performing the placing of the process part. The head of the operator is the most crucial area for the impact measurement reductions and the robot is working very near to it.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	781	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Use additional covers with soft material for the grippers that come in close contact with operator. • Possibility to cover the process part in order to reduce the impact with the sharp edges. • Slow speed robot movements when is working near the operator. • Robot path programmed to avoid crossing torso and head areas. • Perform impact measurements to define the maximum speed for impact in accordance to the EN ISO 15066. • Training and information for use about residual risk. 		EN ISO 12100 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	15	Summary Possible Level:	Very Low Risk

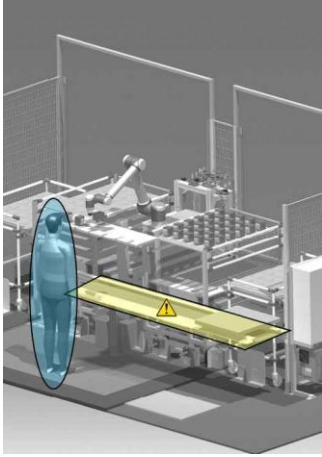
Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm	3	
Probability of Occurrence of a Hazardous Event	1.25	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	14	
Summary Level	Very Low Risk	
Risk Reduction Measures Description		Reference
<p>The end effector should be certified by its manufacturer as part of the system integration, thus ensuring compliance with the applicable parts of ISO TR 20218-1 (integrated in 5.9 of ISO/FDIS 10218-2).</p> <ul style="list-style-type: none"> - Movements are configured so that possible contacts against the end effector are made with force and pressure levels that do not exceed the threshold defined in ISO/TS 15066 in case of contact. - The design of edges, surfaces or corners are designed as far as possible to eliminate or reduce contact hazards or suitably protected to prevent cuts or lacerations. <p>The contact tests records of robots operating in PFL mode should be part of the technical documentation of the overall White Goods pilot application. If the application is industrialised, the tests must be adapted and documented according to the situation, final layout, robot paths, etc. of the destination installation, and thus become part of the documentation of the final application.</p>		<p>EN ISO 12100 ISO/TS 15066</p>
Residual Risk		


Hazard Identification		Hazard No:	1.4
Title	Impact during the pallet change operation		
Location	Back Area		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Feeding, filling, loading of raw material		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Mechanical hazards due to the exposed risk of impact with the robot when the operator is changing the pallets manually. It is expected that the pallet change operation is performed manually by the operator.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	625	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Use a light indicator to warn about the status of the back zone. • Disable the robot movement inside the area that the operator is performing the pallet change operation. • Reduce the robot speed when the light barrier is interrupted. • Training and information for use about residual risk. 		EN ISO 13855 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	3	Summary Possible Level:	Negligible Risk

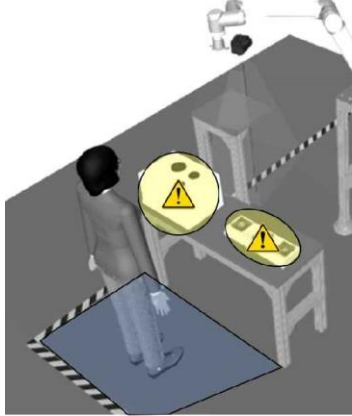
Post Measures Risk Assessment	
Assessment Date	14-nov-2024
Degree of Possible Harm	5
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	2.5
Frequency And / Or Duration of Exposure	4
Pilz Hazard Rating (PHR)	2
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>Access to the pallet area is via the optoelectronic curtains, whose operation has been described above.</p> <p>There is a light beacon that warns of the activation of the access control function, by means of a standardised colour code.</p> <p>Operators shall be trained and informed about the colour codes. The meaning of the colours of the illuminating devices shall be part of the instructions.</p>	<p>EN ISO 13855 EN ISO 10218-2</p>
Residual Risk	
Empty space for residual risk assessment	


Hazard Identification		Hazard No:	1.5
Title	Falling or ejection of the process part		
Location	Robot Perimeter		
Target	People / Machine		
Activity	Normal Operation		
Task	Operation		
Sub Task	Clamping/fastening the workpiece		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Falling or ejected objects		
Description	Mechanical hazards due to the exposed risk of impact with the process part while the robot is performing the pick and place operation of the process part. The part can be dropped by gravity, loss of power excessive speed of manipulation or wrong intrinsically design of the fixation mechanism. It is expected that a magnetic gripper will be used.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	390	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • The gripper requirements must be in accordance with the ISO TR 20218-1 • Use a intrinsically safe mechanical locking system in the gripper to hold the part in place. • Robots shall be designed and constructed so that loss or change of electrical, pneumatic or vacuum energy does not result in a hazardous situation. • Proper positioning and closing of the gripper should be monitored before allowing robot movements. • Speed reduction when reaching outer areas will help to reduce kinetic energies in case the product gets detached. • Warning pictograms, training and information for use about residual risk. 		EN ISO 12100 EN ISO 10218-2 ISO TR 20218-1	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk

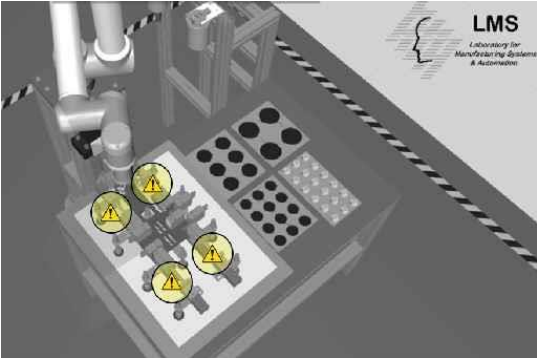
Post Measures Risk Assessment	
Assessment Date	14-nov-2024
Degree of Possible Harm	5
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	2.5
Frequency And / Or Duration of Exposure	5
Pilz Hazard Rating (PHR)	3
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>The end effector used should be certified by its manufacturer as part of the system integration, ensuring compliance with the applicable parts of ISO TR 20218-1 (integrated in 5.9 of ISO/FDIS 10218-2).</p> <ul style="list-style-type: none"> - The mechanical link between the gripper and the robot wrist is designed and constructed specifically for the given application, including the static and dynamic limits set by the robot manufacturer. The joint is shown to be visually and/or apparently sufficient. - The mechanical link between the gripper and the workpiece is designed and built specifically for the given application. - In case of loss of power supply, the gripper does not release the workpiece (falling of the cardboard sheet from the vacuum lifter does not pose a risk). - When the collaborative space is reached, the speed is reduced, so that the workpiece will not be projected onto the operator in the event of a fall. <p>Information for the use of the gripper, including inspection, maintenance and repair, shall form part of the instructions.</p>	<p>EN ISO 12100 EN ISO 10218-2 ISO TR 20218-1</p>
Residual Risk	
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Hazard Identification		Hazard No:	1.6
Title	Drawing in or trapping with the linear conveyor		
Location	Conveyor		
Target	Hands/Fingers		
Activity	Normal Operation		
Task	Operation		
Sub Task	Minor interventions during operation		
Hazard Type	Mechanical Hazard with the consequence of		
Sub Type	Drawing-in or Trapping		
Description	Drawing-in hazard between the traction or carrying elements and supporting rollers of the conveyor. The drawing-in points need to be guarded to avoid the access with fingers. Also, trapping hazard between the conveyor and the fixed supports, the conveyor height can be adjusted depending on the application. The trapping points need to be guarded to avoid access with the hands or fingers.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	4	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	150	Summary Level:	Significant Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Install fixed guards in accordance to EN ISO 14120 and EN ISO 13857 to prevent the access to the trapping points. • Block the adjustment of the conveyor permanently if this is not needed. • Drawing-in points shall be guarded by the use of nip guards directly at the drawing-in point. • The maximum gap between the openings need to be 5 mm at the most. 		EN 619 EN ISO 13857 EN ISO 14120	
Possible Residual Risk			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	1	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm	3	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	1	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The conveyor is designed and built in accordance with EN 619 as certified by its manufacturer. It does not offer any hazardous points with mechanical risk.</p> <p>The conveyor manufacturer's declaration of incorporation should be part of the technical documentation of the overall application. See hazard 1.2</p>		<p>EN 619 EN ISO 13857 EN ISO 14120</p>
Residual Risk		
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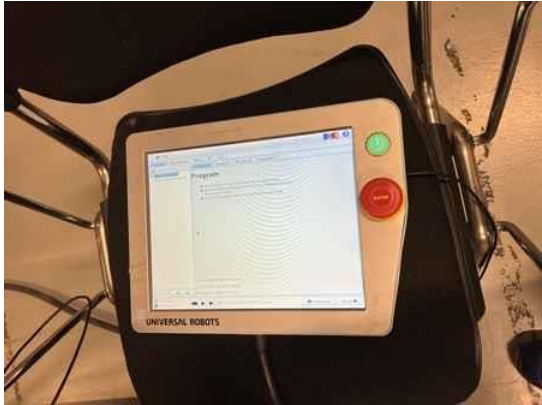
Hazard Identification		Hazard No:	1.7
Title	Falling of the process part in the conveyor		
Location	Conveyor		
Target	Lower Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Clamping the process part		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Falling objects		
Description	Mechanical hazards due to the exposed risk of falling of the process part while moving in the conveyor. If the microwave or the oven is not properly placed in the conveyor, an abrupt stop can create this hazard.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	93	Summary Level:	Significant Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Use a intrinsically safe mechanical locking system to hold the part in place in the conveyor. • Assure the design of the part holder is resistant to small impacts and vibrations. • Use a mechanism to lock the part in place during the movement of the conveyor. 		EN 619 EN ISO 13857 EN 62061	
Possible Residual Risk			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	1	Summary Possible Level:	Negligible Risk

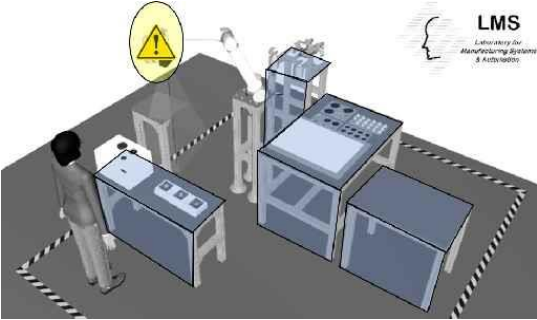
Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm	3	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	1	
Summary Level		
Negligible Risk		
Risk Reduction Measures Description		Reference
The parts flow on trays that occupy the width of the conveyor and provide sufficient stability.		EN 619 EN ISO 13857 EN 62061
Residual Risk		


Hazard Identification		Hazard No:	1.8
Title	Crushing with the pneumatic gripper actuators		
Location	Pneumatic Gripper		
Target	Hands/Fingers		
Activity	Normal Operation		
Task	Operation		
Sub Task	Interlayer Picking or Tool Change		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Crushing		
Description	Crushing hazard with the linear actuators installed in the pneumatic gripper. The pneumatic gripper can be adjusted to different interlayers by moving a set of four pneumatic cylinders.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	4	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	120	Summary Level:	Significant Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • A combination of different guards or of guards with other devices should be installed according to EN ISO 14120 and EN ISO 13857. • Disable the actuators movement if there is an operator inside the back area of the cell. • For the pneumatic power supply a shut-off device shall be provided and needs to be lockable in the OFF (isolated) position. • The device shall also dissipate pressure from the system. 		EN ISO 13857 EN ISO 13855 EN ISO 4414	
Possible Residual Risk			
Degree of Possible Harm:	3	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	1	Summary Possible Level:	Negligible Risk

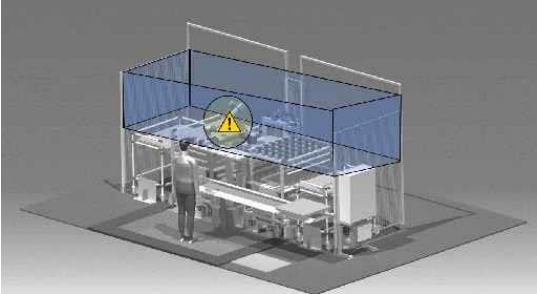
Post Measures Risk Assessment	
Assessment Date	14-nov-2024
Degree of Possible Harm	3
Probability of Occurrence of a Hazardous Event	1.25
Possibility of Avoidance	2.5
Frequency And / Or Duration of Exposure	4
Pilz Hazard Rating (PHR)	37
Summary Level	
Low Risk	
	
Risk Reduction Measures Description	Reference
<p>The end-effector used should be certified by its manufacturer as part of the system integration, thus ensuring compliance with the applicable parts of ISO TR 20218-1 (integrated in 5.9 of ISO/FDIS 10218-2).</p> <p>The response of the rear area access detection has been described above and also reaches the end effectors.</p> <p>However, the pneumatic installation is provisionally installed and does not meet the requirements of EN ISO 4414. The final installation, in case of commissioning, must comply with good practice, including lockable pneumatic disconnecter (with dissipation), soft-start valve and separation between electrical and pneumatic circuits in different enclosures.</p>	<p>EN ISO 13857 EN ISO 13855 EN ISO 4414</p>
Residual Risk	
Empty space for residual risk assessment	


Hazard Identification		Hazard No:	1.9
Title	Impact with the robot during teaching operation		
Location	Robot Perimeter		
Target	People / Machine		
Activity	Normal Operation - Maintenance		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Impact		
Description	Impact hazard caused by either the robotic arm or the work-piece attached to the end effector caused by the movement of various electrically actuated elements when programming the robot. There is the need to use teaching mode in the application. During this mode, the robot will be working without additional safety equipment (scanners or barriers) and this can generate an hazard for the operator.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	0.5
Pilz Hazard Rating (PHR):	78	Summary Level:	Significant Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Use a mode selector and an enable switch to control the robot manually in teaching mode. • Speed limitation so that Tool Centre Point shall not exceed 250 mm/s controlled by a safe enabling function. • Work-piece characteristics to be reviewed to ensure rotational speed is not greater than 250 mm/s. • The end-effector characteristic and the pneumatic movement also require speeds lower than the 250 mm/s speed limit. 		EN ISO 12100 EN ISO 10218-1 EN ISO 13849-1	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	0.5
Pilz Hazard Rating (PHR):	3	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment	
Assessment Date	14-nov-2024
Degree of Possible Harm	5
Probability of Occurrence of a Hazardous Event	0.05
Possibility of Avoidance	0.75
Frequency And / Or Duration of Exposure	2
Pilz Hazard Rating (PHR)	1
Summary Level	
Negligible Risk	
	
Risk Reduction Measures Description	Reference
<p>The robot is certified as a partial complete machine by its manufacturer in accordance with EN ISO 10218-1. The teach pendant complies with the relevant parts of 5.8 of EN ISO 10218-1 and 5.7 of EN ISO 10218-2. Thus, among other relevant conditions:</p> <ul style="list-style-type: none"> - Selection Automatic or manual low-speed (T1) operating modes in teach pendant. High-speed manual mode (T2) is not available. - Three-position pushbutton is available on the teach pendant. - The control pendant includes an emergency push button. - In manual mode (T1), the robot operates at a maximum speed of 250 mm/s <p>The robot manufacturer's declaration of incorporation should be part of the technical documentation of the overall application.</p>	<p>EN ISO 12100 EN ISO 10218-1 EN ISO 13849-1</p>
Residual Risk	
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Hazard Identification		Hazard No:	1.10
Title	Impact of robot moving parts against a fixed part		
Location	Robot Perimeter	 <p>The illustration shows a 3D perspective of a robotic work cell. A worker in a white lab coat is standing near a control panel. A yellow warning sign with a black exclamation mark is positioned above the worker. The robot cell is enclosed by a blue and grey structure. The LMS logo is visible in the top right corner of the illustration.</p>	
Target	Entire Body		
Activity	Normal Operation		
Task	Setting Teaching/programming and/or process changeover		
Sub Task	Adjustment and setting or verification of functional parameters of the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Approach of a moving element to a fixed part		
Description	Impact hazard with other elements present in the working radius of the robot such as the conveyor, the pallets with the process parts and the structure of the machine. This and other fixed machine elements within the working space of the robot may present a crushing hazards between fixed and moving parts for personnel. This is especially true in the event of a machine unexpected start-up when personnel are conducting operations within the robotic work space envelope, for example teaching.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	343	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Perimeter guard installation to take safety distances specified in EN ISO 13854 into account. • Definition of a restricted space within a limit robot envelope area • Mechanical hard stop and/or safety-rated soft limits to reduce and monitor operating space • Provide information and warning in relation to maximum space which can be swept by moving parts of the robot including the robot's end-effector and work-piece. 		EN ISO 14120 EN ISO 13857 EN 842 EN ISO 13854 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	11	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	6	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm	11	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	2	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>Robot spaces are defined in accordance with ISO TS 15066. Robot paths pass at a sufficient distance from the fixed side guards. Operator contact, if it occurs, shall be under collaborative mode, with acceptable force and pressure values, see descriptions above.</p> <p>Information regarding maximum, operational, restricted and collaborative spaces shall be part of the instructions.</p> <p>The contact tests records of robots operating in PFL mode should be part of the technical documentation of the overall White Goods pilot application. If the application is industrialised, the tests must be adapted and documented according to the situation, final layout, robot paths, etc. of the destination installation, and thus become part of the documentation of the final application.</p>		<p>EN ISO 14120 EN ISO 13857 EN 842 EN ISO 13854 EN ISO 10218-2</p>
Residual Risk		
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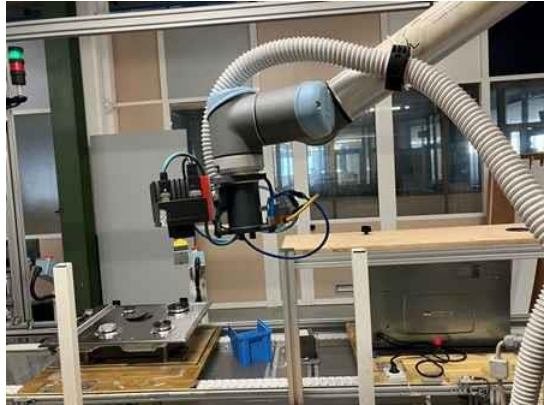
Hazard Identification		Hazard No:	1.11
Title	Robot movements beyond the expected boundaries		
Location	Robot Perimeter		
Target	Entire Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Moving elements		
Description	During normal operation the robot and other associated machine elements and products stay inside a limited (and typically safeguarded) area. If due to an operational or control fault the robot or work-piece extends beyond the distance guard there is a potential impact risk for personnel in the vicinity.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	0.5
Pilz Hazard Rating (PHR):	78	Summary Level:	Significant Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Definition of a restricted space within a limit robot envelope area • Mechanical hard stop and/or safety-rated soft limits to reduce and monitor operating space • Perimeter guards installed are able to contain and withstand robot impact forces • Provide information about established limits in "Information for Use" 		EN ISO 14120 EN ISO 10218-1	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	0.5
Pilz Hazard Rating (PHR):	3	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm	11	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	2	
Pilz Hazard Rating (PHR)	1	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The robot operates within the restricted area by means of software-controlled axis limiters. This is a function integrated in the robot and certified by the robot manufacturer as part of the declaration of incorporation. This prevents the robot, the end effector or the workpiece from leaving the operating space or beyond the safety space. It is therefore not necessary for the physical enclosure to be strong enough to withstand impacts.</p> <p>Information regarding maximum, operational, restricted and collaborative spaces shall be part of the instructions.</p>		<p>EN ISO 14120 EN ISO 10218-1</p>
Residual Risk		
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Hazard Identification		Hazard No:	1.12
Title	Hazards due the stability of the robot		
Location	Robot Perimeter		
Target	People / Machine		
Activity	Assembly and Installation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Instability		
Description	Mechanical hazards or other hazards due to lack of stability of the robot during operation.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	390	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Mass and/or weight of robot to be marked on machine • Information for use to contain adequate mounting, anchorage / foundations details of the robot • Consideration to be given to tools, work-pieces • Frequency of inspections of robot fixings / anchorage to be specified as part of maintenance schedule 		EN ISO 12100	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	5
Pilz Hazard Rating (PHR):	4	Summary Possible Level:	Negligible Risk

Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm	11	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	5	
Pilz Hazard Rating (PHR)	2	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The assembly, fastenings and installation of the robot show no apparent signs of instability. The assembly should be carried out in accordance with the manufacturer's instructions and taking into account the established limits.</p> <p>The mass of the robot is 17 kg, according to its nameplate.</p> <p>The industrialisation of the application could require a specific mechanical validation in accordance with the manufacturer's recommendations.</p>		EN ISO 12100
Residual Risk		

Hazard Identification		Hazard No:	1.13
Title	Hazards generated by the loss of end effector		
Location	Robot Perimeter		
Target	Entire Body		
Activity	Normal Operation - Maintenance		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Mechanical Hazard as a result of		
Sub Type	Kinetic energy		
Description	The movement of the robot presents the risk that the tool may detach and fall or as a result of the dynamic forces involved be ejected at speed. This can put personnel within range of the robot in danger.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	0.5
Pilz Hazard Rating (PHR):	78	Summary Level:	Significant Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Ensure that the fixing systems of the end effector is secured mechanically • Position of end effector shall be monitored • Information for use shall contain details of end effector and inspection intervals for connection details 		EN ISO 12100 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	0.5
Pilz Hazard Rating (PHR):	3	Summary Possible Level:	Negligible Risk

Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm	11	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	0.75	
Frequency And / Or Duration of Exposure	0.5	
Pilz Hazard Rating (PHR)	1	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The end effectors used in the pilot should be certified by their manufacturers as part of the system integration. This ensures compliance with the applicable parts of ISO TR 20218-1 (integrated in 5.9 of ISO/FDIS 10218-2), among others:</p> <ul style="list-style-type: none"> - The mechanical links between the grippers and the robot wrist are specifically designed and constructed for the given application, including the static and dynamic limits set by the robot manufacturer. The joints is shown to be visually and/or apparently sufficient. <p>Information for the use of the gripper, including inspection, maintenance and repair, shall form part of the instructions.</p>		<p>EN ISO 12100 EN ISO 10218-2</p>
Residual Risk		
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Hazard Identification		Hazard No:	1.14
Title	Lack of marking of collaborative workplace		
Location	Robot Perimeter - Collaborative Area		
Target	Upper Limbs		
Activity	Normal Operation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Mechanical hazards		
Sub Type	Inadequate identification		
Description	The collaborative space of the robot cell is not identified with a label, as required by EN ISO 10218-2. On the other hand, the collaborative workplace where the operator can interact directly with the robot, is not clearly defined or warned.		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Not Acceptable
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Robot shall be labelled with the signal above attached. • Additionally, a mark or sign must be fitted on the workbench, to warn about the possibility to interact directly with robot. 		ISO/TS 15066 EN ISO 10218-2	
Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable

Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level		
Not Acceptable		
Risk Reduction Measures Description		Reference
<p>Cell and robot labelling, conforming to 5.11 of EN ISO 10218-2 is pending</p> <p>The final signage, positioning and appropriate size will depend on the characteristics of the target location.</p>		<p>ISO/TS 15066 EN ISO 10218-2</p>
Residual Risk		
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WHR-BUC-01/02 & 03

Safety Signal

Standard Signal

Safety Devices

ESTOPs

Light Barriers

Safety Laser Scanners

Mode selector

Enable switch

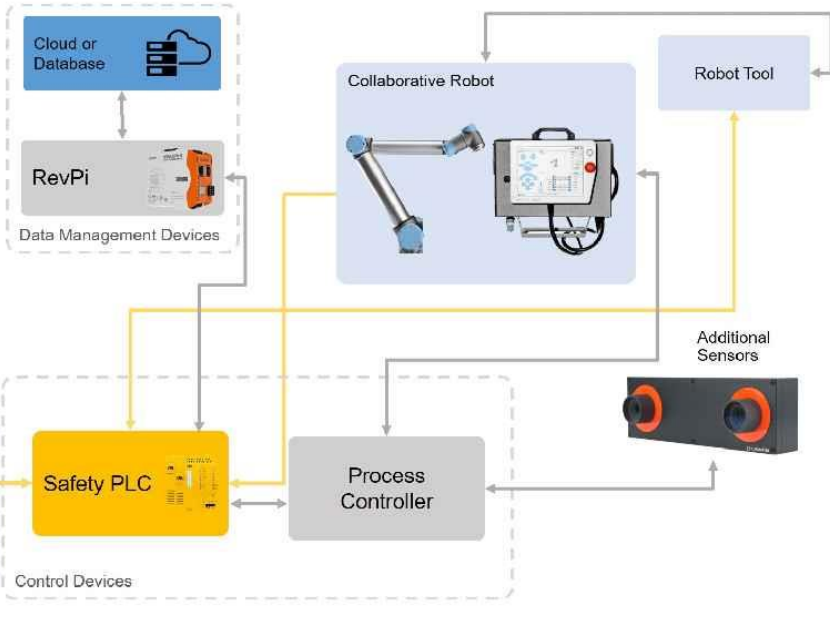
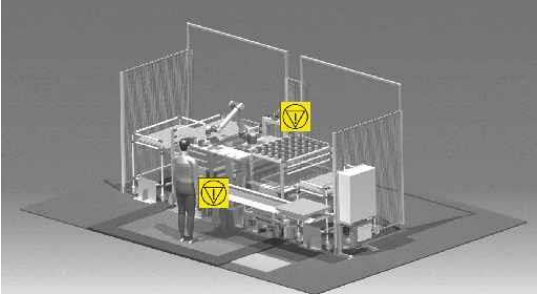

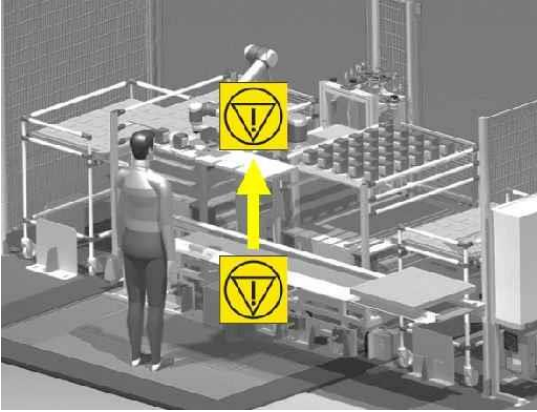




Figure 129: Failure of the Control System

Hazard Identification		Hazard No:	2.1
Title	Inability to perform an emergency stop		
Location	Perimeter of the Machine		
Target	People / Machine		
Activity	People / Machine		
Task	Operation		
Sub Task	All tasks		
Hazard Type	--		
Sub Type	Failure of the Control System		
Description	<p>Unexpected situation could result in a hazardous event that could require an emergency stop from the control system.</p> <p>There are multiple locations that need an emergency stop push button:</p> <ul style="list-style-type: none"> • Operator area • Back area 		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	937	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • The machine shall have emergency stop push-buttons available near every area where a possible hazard can happen. • If the ESTOP push-button is actuated the robot stops in category 0 or 1 according EN 60204-1. • Emergency buttons shall be tested periodically to ensure the proper conditions of the circuit. 		EN ISO 12100 EN ISO 13850	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	9	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	5	
Frequency And / Or Duration of Exposure	3	
Pilz Hazard Rating (PHR)	18	
Summary Level	Very Low Risk	
Risk Reduction Measures Description		Reference
<p>The application has multiple emergency stop devices that are immediately and intuitively accessible from any operating position.</p> <p>The emergency stop devices comply with the requirements of EN ISO 13850.</p> <p>Actuation of any emergency stop device triggers a category 0 or 1 stop of the actuators within its operating range, in accordance with EN 60204-1.</p> <p>The functionality of the emergency stop has been validated.</p>		<p>EN ISO 12100</p> <p>EN ISO 13850</p>
Residual Risk		
<p>Periodic checks shall be part of the instructions for use of the application. In addition, the obligation to check and remedy the cause of the emergency stop must be indicated in the instructions.</p>		


Hazard Identification		Hazard No:	2.2
Title	Inability to perform a simultaneously emergency stop between the conveyor and the robot		
Location	AGV - Conveyor		
Target	Full Body		
Activity	Normal Operation		
Task	Operation		
Sub Task	Minor interventions during operation		
Hazard Type	Mechanical Hazard with the consequence of		
Sub Type	Impact or projection		
Description	Mechanical hazard due to the impossibility of stopping the robot when the emergency stop push button of the conveyor is pressed. In the real application there is an emergency stop rope installed just for the conveyor, this needs to be linked to the robot.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	5
Probability of Occurrence of a Hazardous Event:	2.5	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	937	Summary Level:	Very High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • If an emergency stop situation is generated in the conveyor, the robot must stop the movement. • This is only valid for the real application, in the laboratory there is no need to install an emergency stop rope. 		EN ISO 12100 EN ISO 13849-1 EN ISO 13850	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	9	Summary Possible Level:	Negligible Risk


Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level		
Not Acceptable		
Risk Reduction Measures Description		Reference
<p>A mushroom pushbutton for the emergency stop of the robot is accessible at the main operator station and at the teach pendant. Further emergency stop pushbuttons are located around the cell, whose operating range also includes the conveyor. However, as there are different operating ranges, these must be visibly marked on the emergency stop device.</p>		<p>EN ISO 12100 EN ISO 13849-1 EN ISO 13850</p>
Residual Risk		
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Hazard Identification		Hazard No:	2.3
Title	Failure of the safety related part of control system - Robot		
Location	Robots Perimeter		
Target	People / Machine		
Activity	Normal Operation/Maintenance		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other hazards		
Sub Type	Failure of the Control System		
Description	<p>Faults in the safety control circuit of the robot system could create multiple hazards, from unexpected or uncontrolled robot movement to inability to stop the process in safety conditions.</p> <p>Models used for the application:</p> <ul style="list-style-type: none"> • 1x UNIVERSAL ROBOTS CB Series Robot <p>According the technical documentation available, the robot has safety features. In accordance with the robot documentation, the performance level for all the safety functions is PL=d according EN ISO 13849-1.</p>		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Further Review
Risk Reduction		Reference	
<p>The safety control system, and the components that integrate it, must be designed and connected to achieve the reliability levels required for human robot collaborative applications. According the C-standard, it should be a Performance Level PL=d with a circuit architecture Category 3, according EN ISO 13849-1. The following safety functions must fulfill this requirement:</p> <ul style="list-style-type: none"> • Emergency stop • Safe stop • Power and force limiting • Axis limiting • Speed and standstill monitoring 		<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 13849-1</p>	


Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable


Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level	Acceptable	
Risk Reduction Measures Description		Reference
<p>The safety functions involving the integration of the White Goods pilot application have been designed under appropriate architectures and components in order to comply with performance level PL = d and category 3, according to EN ISO 10218-2. Functional and installation validation of the safety functions and associated equipment has been performed.</p> <p>The safety functions incorporated individually in the sub-assemblies (IMR and AURA robot) are validated by their manufacturer by means of the declaration of conformity or declaration of incorporation.</p> <p>The documentation of the design, implementation and validation of the safety functions of the pilot application in compliance with EN ISO 13849-1 should be part of the technical documentation. Relevant information on safety functions intended for the user is listed in EN ISO 13849-1 and shall be included in the instruction manual.</p>		<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 13849-1</p>
Residual Risk		


Hazard Identification		Hazard No:	2.4
Title	Failure of the safety related part of control system - End Effector		
Location	Robots Perimeter - End Effectors		
Target	People / Machine		
Activity	Normal Operation/Maintenance		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other hazards		
Sub Type	Failure of the Control System		
Description	<p>Faults in the safety control circuit of the end effectors could create multiple hazards, from unexpected or uncontrolled part manipulation movement or the inability to stop the process in safety conditions.</p> <p>Models used for the application:</p> <ul style="list-style-type: none"> • 1x SCHUNK EMH036-B (Transformer Gripper) • 1x FESTO DHEF-20 (Knobs and Cooktops Gripper) • 1x SWK-011 (Tool Changer) • 1x Personalized Pneumatic Gripper (Interlayers) 		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Further Review
Risk Reduction		Reference	
The end effectors movement must be associated to safety control system of the robots. The performance level required is PLd.		EN ISO 10218-2 ISO/TS 15066 EN ISO 13849-1 ISO TR 20218-1	
Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable


Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level		
Acceptable		
Risk Reduction Measures Description		Reference
<p>The safety functions affecting the integration of the end effectors in the robot have been designed under appropriate architectures and components in order to comply with performance level PL = d and category 3, according to EN ISO 10218-2. Functional and installation validation has been performed.</p> <p>The documentation of the design, implementation and validation of the safety functions of the pilot application in compliance with EN ISO 13849-1 should be part of the technical documentation. Relevant information on safety functions intended for the user is listed in EN ISO 13849-1 and shall be included in the instruction manual.</p>		<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 13849-1 ISO TR 20218-1</p>
Residual Risk		
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Hazard Identification		Hazard No:	2.5
Title	Failure of the safety related part of control system - Conveyor		
Location	Conveyor Area		
Target	People / Machine		
Activity	Normal Operation/Maintenance		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other hazards		
Sub Type	Failure of the Control System		
Description	Faults in the safety control circuit of the conveyor system could create multiple hazards, from unexpected or uncontrolled process part movement or the inability to stop the process in safety conditions.		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Further Review
Risk Reduction		Reference	
The conveyor movement must be associated to safety control system of mobile platform and the robots. The performance level required is PLd.		EN ISO 10218-2 ISO/TS 15066 EN ISO 13849-1	
Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable


Post Measures Risk Assessment	
Assessment Date	14-nov-2024
Degree of Possible Harm	
Probability of Occurrence of a Hazardous Event	
Possibility of Avoidance	
Frequency And / Or Duration of Exposure	
Pilz Hazard Rating (PHR)	N/A
Summary Level	
Acceptable	
	
Risk Reduction Measures Description	Reference
<p>The safety functions involving the integration of the Automotive pilot application have been designed under appropriate architectures and components in order to comply with performance level PL = d and category 3, according to EN ISO 10218-2.</p> <p>Functional and installation validation of the safety functions and associated equipment has been performed.</p> <p>The safety functions incorporated individually in the sub-assemblies (IMR and AURA robot) are validated by their manufacturer by means of the declaration of conformity or declaration of incorporation.</p> <p>The documentation of the design, implementation and validation of the safety functions of the pilot application in compliance with EN ISO 13849-1 should be part of the technical documentation. Relevant information on safety functions intended for the user is listed in EN ISO 13849-1 and shall be included in the instruction manual.</p>	<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 13849-1</p>
Residual Risk	

Hazard Identification		Hazard No:	2.6
Title	Failure of the safety related part of control system - Pneumatic System		
Location	Conveyor Area		
Target	People / Machine		
Activity	Normal Operation/Maintenance		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other hazards		
Sub Type	Failure of the Control System		
Description	Faults in the safety control circuit of the pneumatic system could create multiple hazards, from unexpected or uncontrolled process part movement or the inability to stop the process in safety conditions.		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Further Review
Risk Reduction		Reference	
The performance level required for the pneumatic system of the application is PLd.		EN ISO 4414 EN ISO 13849-1	
Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable

Post Measures Risk Assessment	
Assessment Date	14-nov-2024
Degree of Possible Harm	
Probability of Occurrence of a Hazardous Event	
Possibility of Avoidance	
Frequency And / Or Duration of Exposure	
Pilz Hazard Rating (PHR)	N/A
Summary Level	
Acceptable	
	
Risk Reduction Measures Description	Reference
Pneumatic actuators are part of the safety functions mentioned in previous references. See also hazard 1.8	EN ISO 4414 EN ISO 13849-1
Residual Risk	

Hazard Identification		Hazard No:	2.7
Title	Unexpected movements due to new start-up		
Location	Perimeter		
Target	Head/Upper Limbs		
Activity	Normal Operation		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other Hazards		
Sub Type	Unintended/unexpected start-up		
Description	The sudden start-up or movement of the robot arm can present a hazard to persons in the immediate vicinity of the HRC system. The collaborative application has not a reset button to prevent automatic restarting of robot after a safe stop.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	234	Summary Level:	High Risk
Risk Reduction		Reference	
To ensure protection against unexpected start-up. Operation shall not resume until reset by a deliberate restart action with the operator outside of the collaborative workspace. A reset button should be provided to prevent automatic restarting of the robot after either: <ul style="list-style-type: none"> • Actuation of a safeguarding function • Detection of failure in the safety-related part of the control system • A change in operating mode of the robot 		EN ISO 10218-2 ISO/TS 15066 EN ISO 14118	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	3
Pilz Hazard Rating (PHR):	2	Summary Possible Level:	Negligible Risk

Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	3	
Pilz Hazard Rating (PHR)	9	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>After any safety stop, prior to start-up or after changing the robot's operating mode, it is necessary to manually operate a reset button, located outside the protected areas and the collaborative space, which has been functionally tested; safety stop that include the conveyor in their control range require the conveyor to be manually reset for restarting, by means of a specific and particular button.</p> <p>Reset pushbutton must be blue.</p>		<p>EN ISO 10218-2 ISO/TS 15066 EN ISO 14118</p>
Residual Risk		
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Hazard Identification		Hazard No:	2.8
Title	Unexpected movements due to mode selection		
Location	Robot Perimeter		
Target	People / Machine		
Activity	Normal Operation - Maintenance		
Task	Operation		
Sub Task	Driving the machine		
Hazard Type	Other Hazards		
Sub Type	Unintended/unexpected start-up		
Description	The robot needs to run in various operating modes (e.g. automatic mode, teaching mode, etc.). There is the need to include a mode selector which can be lockable in accordance with relevant standards to prevent unauthorized access.		
Risk Estimation and Evaluation			
Degree of Possible Harm:	25	Possibility of Avoidance:	2.5
Probability of Occurrence of a Hazardous Event:	1.25	Frequency And / Or Duration of Exposure:	4
Pilz Hazard Rating (PHR):	312	Summary Level:	High Risk
Risk Reduction		Reference	
<ul style="list-style-type: none"> • Each position of the selector is clearly identifiable and shall allow only one control or operating mode • Procedures shall identify that the key for the mode selector shall be held by an authorised competent person only • Operating mode selector switch shall attain the same required PL, as the safeguarding measures associated with the modes • Functions allowed in each mode selected shall be in accordance with the requirements of EN ISO 10218-1&2 		EN ISO 13849-1 EN 60204-1 EN ISO 12100 EN ISO 10218-1	
Possible Residual Risk			
Degree of Possible Harm:	25	Possibility of Avoidance:	0.75
Probability of Occurrence of a Hazardous Event:	0.05	Frequency And / Or Duration of Exposure:	4


Pilz Hazard Rating (PHR):


3

Summary Possible Level:

Negligible Risk

Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm	25	
Probability of Occurrence of a Hazardous Event	0.05	
Possibility of Avoidance	2.5	
Frequency And / Or Duration of Exposure	3	
Pilz Hazard Rating (PHR)	9	
Summary Level	Negligible Risk	
Risk Reduction Measures Description		Reference
<p>The robot is certified as a partially complete machine by its manufacturer in accordance with EN ISO 10218-1. The teach pendant complies with the relevant parts of 5.8 of EN ISO 10218-1 and 5.7 of EN ISO 10218-2. The selection of automatic or manual reduced speed (T1) operating mode is made on the teach pendant, with the possibility of control by means of a password. See hazard 1.9</p> <p>The robot manufacturer's declaration of incorporation should be part of the technical documentation of the overall application.</p>		<p>EN ISO 13849-1 EN 60204-1 EN ISO 12100 EN ISO 10218-1</p>
Residual Risk		
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Hazard Identification		Hazard No:	2.9
Title	Inability to warn about status of Robot		
Location	Collaborative workplace		
Target	People / Machine		
Activity	Normal Operation/maintenance/teaching		
Task	Operation		
Sub Task	Normal operation/maintenance/teaching		
Hazard Type	Other Hazards		
Sub Type	Unintended/unexpected start-up		
Description	Collaborative robot cell has not available visual warning devices to inform about the status of the robot.		
Risk Estimation and Evaluation			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Level:	Not Acceptable
Risk Reduction		Reference	
Warning device should be fitted on the mobile robot system to warn about the status of the device. <ul style="list-style-type: none"> • Failure status (red) • Safe stop (red) • Normal mode (green) • Manual mode (yellow) • Waiting for a reset validation (Blue) 		EN ISO 10218-2 ISO/TS 15066	
Possible Residual Risk			
Degree of Possible Harm:		Possibility of Avoidance:	
Probability of Occurrence of a Hazardous Event:		Frequency And / Or Duration of Exposure:	
Pilz Hazard Rating (PHR):	N/A	Summary Possible Level:	Acceptable

Post Measures Risk Assessment		
Assessment Date	14-nov-2024	
Degree of Possible Harm		
Probability of Occurrence of a Hazardous Event		
Possibility of Avoidance		
Frequency And / Or Duration of Exposure		
Pilz Hazard Rating (PHR)	N/A	
Summary Level		
Acceptable		
Risk Reduction Measures Description		Reference
<p>There is a colour-coded light beacon, which provides information on the overall status of the application. The colours comply with the recommendations of EN 60204-1. There are other beacons that inform about the status of the rest of the line (the application is intended for online operation).</p> <p>Operators shall be trained and informed about the colour codes. The meaning of the colours of the illuminating devices shall be part of the instructions.</p>		<p>EN ISO 10218-2 ISO/TS 15066</p>
Residual Risk		
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