Mobile dual arm robotic workers with embedded cognition for hybrid and dynamically reconfigurable manufacturing systems

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		DGH ROBOTICA, AUTOMATIZACION Y MANTENIMIENTO INDUSTRIAL SA (DGH)
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Summary:

This document provides a detailed description of the Open Production Station as a Product initial version. The preliminary set up for the automotive and the aeronautics pilot cases at LMS and TECNALIA premises is documented in detail including the hardware components' as well as the software developments' integration.

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3. Executive summary

THOMAS vision it to create a dynamically reconfigurable shopfloor utilizing autonomous, mobile dual arm robots that are able to perceive their environment and through reasoning, cooperate with each other and with other production resources including human operators. To enable the dynamic behaviour of THOMAS mobile resources, the project's partners are developing innovative individual technologies concerning human safety and interaction with mobile robots, mobile resource perception and programming as well as collaborative task planning and re-organization during execution. Along with the individual developments, the partners have joined forces on preparing the THOMAS Mobile Robot Platform (MRP) final version as well as the THOMAS Mobile Product Platform (MPP) able to cooperate with each other which are the main THOMAS mobile resources considered as enablers for THOMAS reconfiguration paradigm (Figure 1).

The main outcome of this period concerning this WP is the updated design and manufacturing of THOMAS Mobile Robot Platform focusing on addressing the safety requirements of the machine.

In parallel, integration and testing activities of the different prototypes and the required peripheral hardware components (sensors, grippers, etc.) under a common system that will allow the realization of the THOMAS resources dynamic behaviour took place during this period of the project. This common system stands for THOMAS Open Production Station as a product (OPS) and this deliverable presents the first version of THOMAS OPS as developed until the end of M24 of the project.

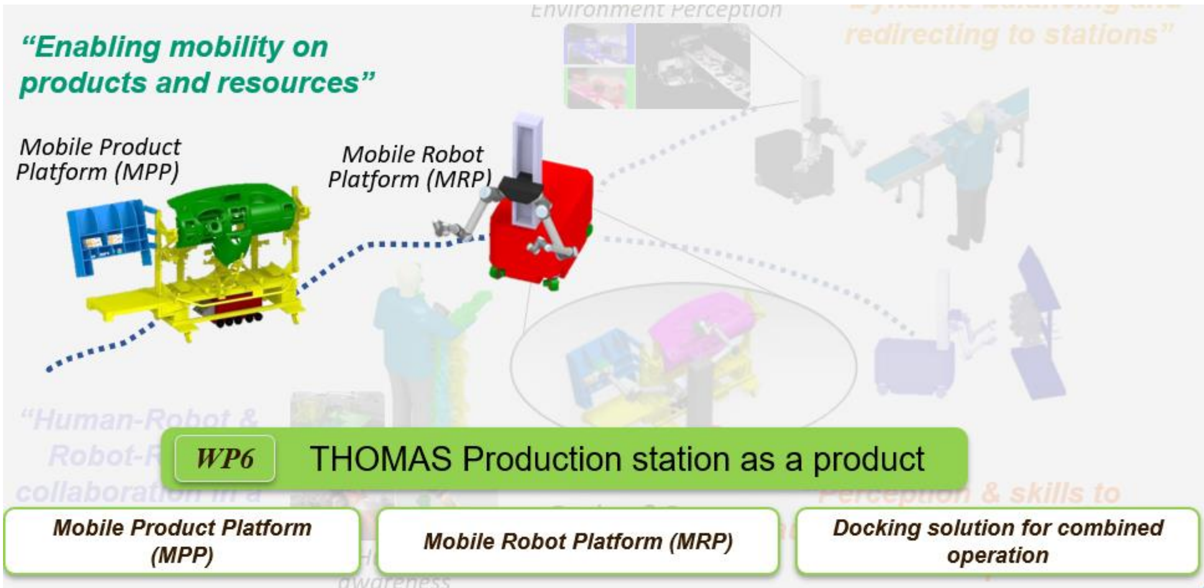


Figure 1: THOMAS Open Production Station (OPS) as a Product

THOMAS individual technologies developments have been driven from the early beginning of the project by the industrial use cases, namely the automotive and the aeronautics pilots. Thus, during the second year of the project, preliminary testbed has been set up at LMS and TECNALIA based on the automotive and the aeronautics use cases requirements respectively. These testbeds have been used for integration and testing activities of the project's technologies and are presented in detail in this document.

4. INTRODUCTION

Under the first version of THOMAS OPS, the initial version of technology prototypes derived from the following WPs have been integrated in hardware and software dimension:

- WP2: THOMAS Initial Safety Concept and Human Robot Interaction (HRI) mechanisms
- WP3: Perception methods for multiple object detection as well as for accurate navigation
- WP4: Skills based robot programming
- WP5: Station Controller for Execution control and orchestration.

Details on the individual prototypes can be found in the different WPs public deliverables available through THOMAS public website (http://www.thomas-project.eu/deliverables/).

As the main integration task DGH is responsible for majority of the hardware customization activities to provide the MRP and MPP prototype and INTRASOFT is leading the packaging of software components.

Staring from M07 of the project, the tasks performed under the THOMAS OPS preparation activities may be summarized as follows:

- Mobile Platform with dual arm Robot (MRP) – Design and development
- Sensors and tooling design and integration,
- Docking mechanisms design and test for highly accurate cooperative assembly.
- Software modules integration and packaging.

Objectives:

- **Increase reconfigurability**. The mobile resource MRP will be able to change workstations based on production needs. Time required to travel among the different workstations.
- **Reduction of programming efforts**. The MRP, integrated with skills, will be able to fast and easily learn new operations. Time to program and validate the assembly operation
- **Increase resource planning and optimization**. The MRP, integrated with the required tooling will be able to perform multiple operations. Number of different types of operations.
- **Increase Manufacturing Line flexibility**. The MRP will be able to follow the mobile product (MPP) while operating. Time save through operating while moving from one station to the next.
- **Support multiproduct Manufacturing Line**. The MRP integrated with the perception modules will be able to dynamically detect and adapt in changes in the process. Number of different product variants to be processed
- **Increase ergonomy and safety conditions of human work**. THOMA OPS, integrating the safety & interaction mechanisms will use the MRP for performing the difficult operations. Total weight handled by operator in a cycle

5. THOMAS OPEN PRODUCTION STATION AS A PRODUCT OVERVIEW

As described in the previous section, THOMAS OPS main to integrate the different hardware and software components that will allow the realization of THOMAS vision. The latter is oriented around THOMAS industrial pilot cases from the automotive (end user: PSA Group) and from the aeronautics sector (end user: AERNNOVA). Figure 2 visualizes the major components of THOMAS OPS that after customization derive the deployment and execution of the project's industrial use cases.

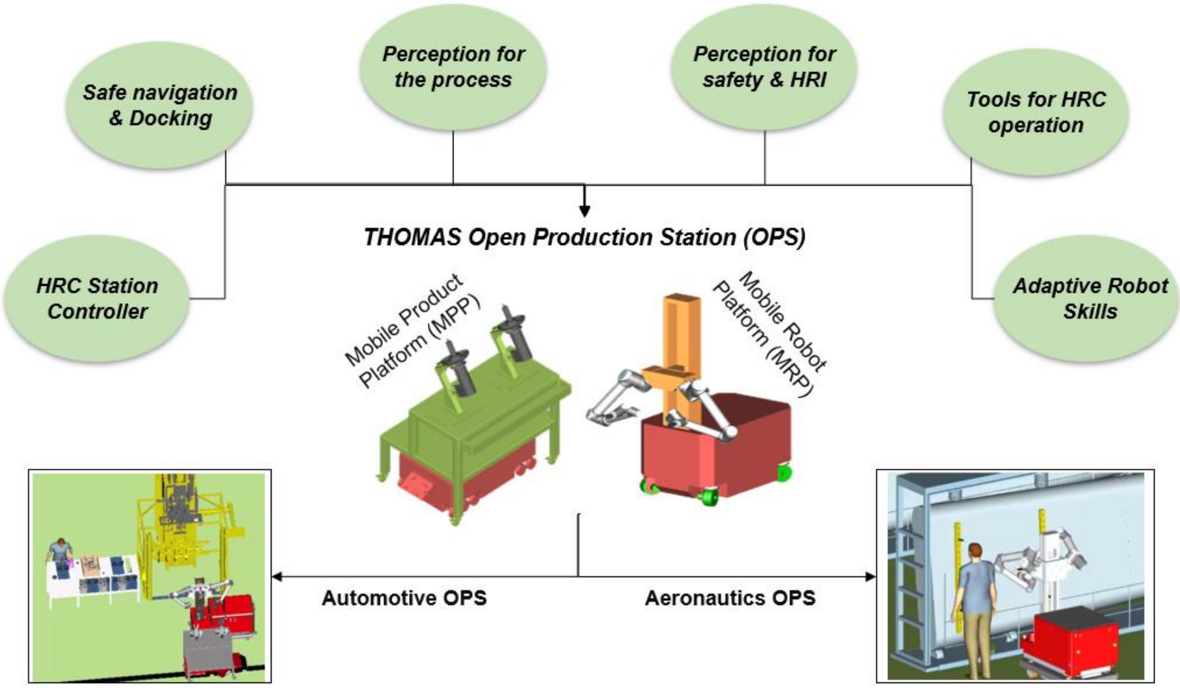


Figure 2: THOMAS Open Production Station as a Product Overview

5.1. THOMAS Mobile Resources

5.1.1. THOMAS Mobile Robot Platform (MRP)

THOMAS Open Production Station main resource is the Mobile Robot Platform (MRP) that will be used for the realization of THOMAS both industrial pilot cases. In more detail, THOMAS MRP is a mobile dual arm manipulator that may autonomously navigate in different workstations undertaking multiple operations using its 6 DOF robot arms (Universal Robot – UR 10). The main components of THOMAS MRP are visualized in the following figure.

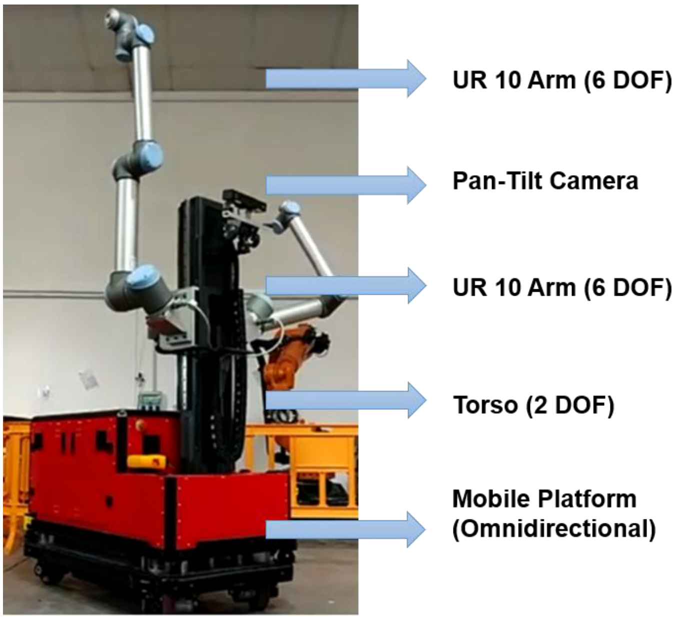


Figure 3: THOMAS MRP Main Components

Towards the effective design and development of THOMAS MRP a 2 – step approach has been following by the consortium. In the beginning of the project the MRP 1st version (Figure 4 – a) was designed by the consortium with DGH and TECNALIA leading this activity. The manufacturing of the MRP has been undertaken by an external partner. This 1st version has been used for testing the different partner's developments during the first year of the project. In parallel, DGH supported by SICK and LMS worked on the re-design of the THOMAS MRP resulting the MRP 2nd version (Figure 4 – b) performing several iterations with the manufacturer for finalizing its development.

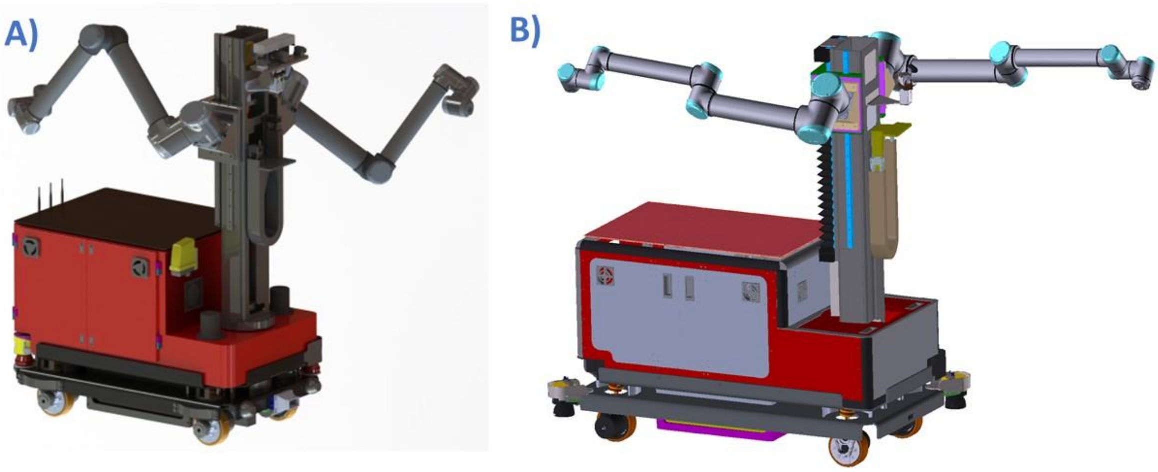


Figure 4: THOMAS MRP 3D Design a) 1st version (MRP_n1), b) 2nd version (MRP_n2)

Currently, both MRPs base components have been manufactured and fully functional available to the partners for setting up and testing the different technologies towards deploying the sue cases scenarios. The MRP 1st version will be focusing on the implementation and testing of the aeronautics pilot case. Thus, it is located at TECNALIA premises where the initial aeronautics OPS is currently under development (Figure 5).

Figure 5: THOMAS MRP 1st version at TECNALIA premises

Figure 6 visualizes the 2nd version of the MRP at LMS premises that will be used for the realization of the automotive pilot case targeting on the assembly of a vehicles suspension system.

Figure 6: THOMAS MRP 2nd version at LMS premises

Under the 2nd version of the MRP the partners related to the THOMAS application safety part has joined efforts on realizing the risk assessment for the Mobile Robot Platform (MRP) leading to the initial version of the safety concept design and safety hardware integration. Figure 7 demonstrates the main safety components selected to be added in the Mobile Robot Platform as indicated by the safety concept design. Under deliverable D2.4, submitted on M18 of the project the detailed safety concept along with the technical specifications of the selected safety hardware has been documented.

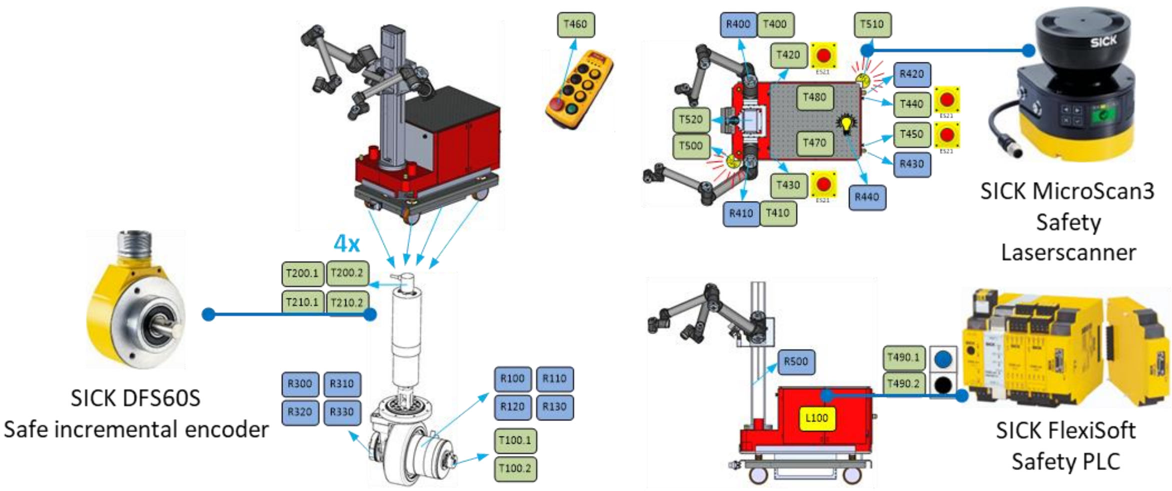


Figure 7: Safety concept design for the MRP (MRP_n2)

5.1.2. THOMAS Mobile Product Platform (MPP)

THOMAS solution considers mobility in product level along with mobile resources, towards increasing even more the production's system flexibility in terms of reconfiguration of the system's structure as well as of the performed process. To this extend, THOMAS Mobile Product Platform aims to enable product mobility. THOMAS MPP will involve an Automated Guided Vehicle (AGV) manufactured by ASTI as well as an upper mechanical structure that will be used for placing the base part (Figure 8). The goal is for the THOMAS MRP to dock on the MPP and perform assembly operations on the part that the MPP is carrying.

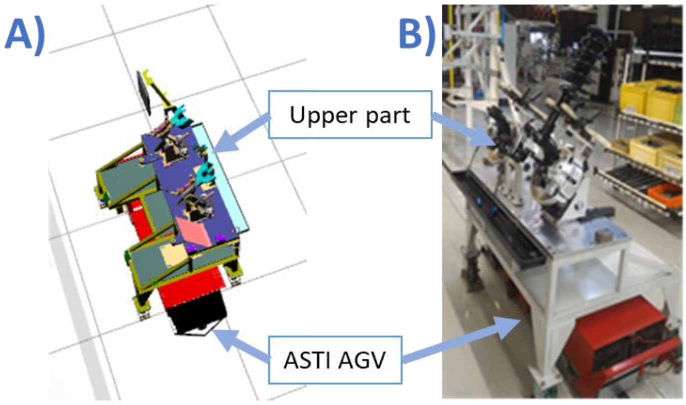


Figure 8: THOMAS MPP a) 3D Design, b) Physical part

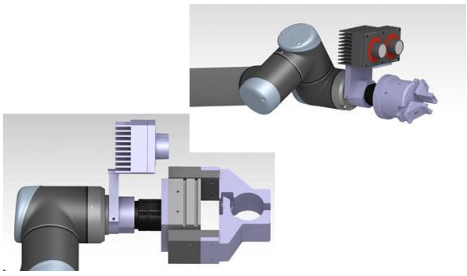
5.2. Selection of sensor and tooling for THOMAS OPS

Mobile robot platforms of THOMAS project are equipped with different sensors and tools enabling safe human robot collaboration in both use cases. In this case robots are able to navigate and perform manipulate actions with respect to other employee's safeness in the production line. Sensors and tools using under automotive and aeronautics pilot case are be listed in the following subsections.

5.2.1. Selection and testing of tools for HRC operation

Different kind of sensors and hardware components are required for both use cases of THOMAS project. Table 1 lists the major components selected for the THOMAS OPS.

Table 1: Selected tools for HRC operation

ROBOCEPTION rc_visard 65 and rc_visard 160 stereo cameras for multiple objects detection [2]	
SCHUNK Pneumatic grippers for multiple parts manipulation [3]	

Automated drilling / Screwing machines machine	
SCHUNK Tool changers for automated tool changing [4]	
OptoForce / ROBOTIQ Torque and force control device [5], [6]	
RealSense 3D sensor for human detection and accurate navigation [7]	
Kinect 2 3D sensor for human detection and accurate navigation [8]	
SICK laser scanners for human tracking and safety zones implementation [9], [10]	
Motorola MOTO 360 Smartwatch for Human side interfaces [11]	
Microsoft Hololens Augmented Reality glasses for human operator support during collaborative assembly [12]	

6. OPS Automotive Use Case

6.1. General Overview.

Under the automotive pilot case, THOMAS aims to implement a flexible robotic assembly system where mobile robots as assistants to human operators. The selected scenario concerns the assembly of the suspension system in the front axle of a passenger vehicles involving three different steps: a) damper pre-assembly, b) damper compression and c) the damper assembly on the brake disks. Starting from this scenario and its requirements, in the following sections, the automotive THOMAS OPS current status is documented.

6.2. Simulated set up of the automotive OPS at LMS simulated layout

During the first period of the project, the PSA scenario set up, including all the required hardware components was designed using 3D design tools and fully simulated using 3D simulation to validate it. Meanwhile, in parallel with the design and manufacturing of the hardware and the MRP_N2 finalization and production, in order to have a realistic environment for the software components testing the designed set up has been recreated in Robot Operating System (ROS) GAZEBO physics engine (Figure 9) using the MRP virtual controllers for the process execution.

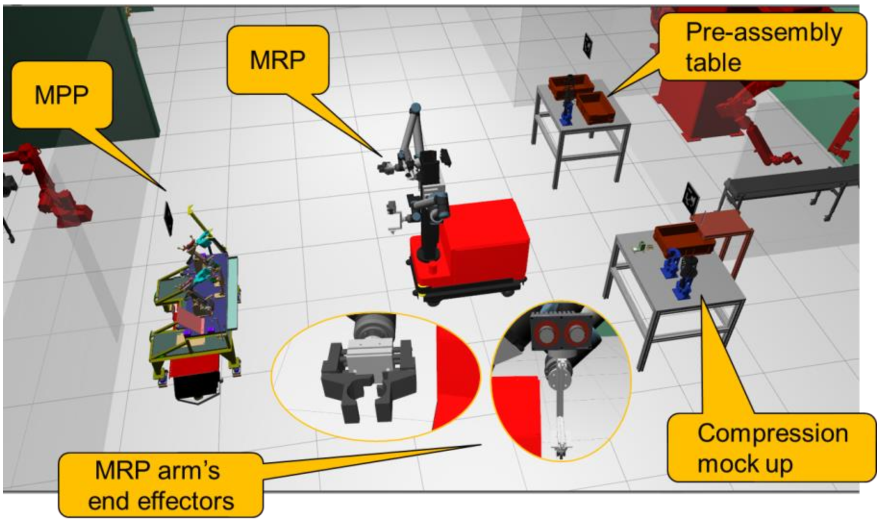
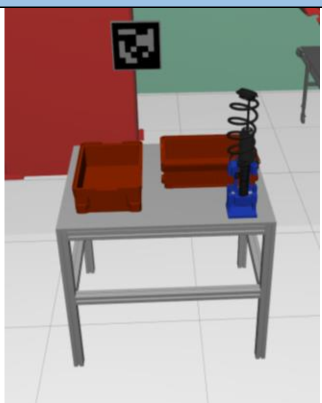
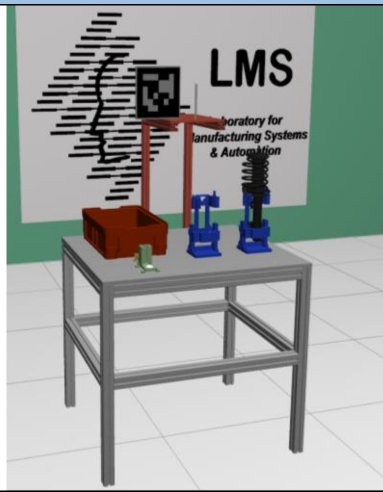
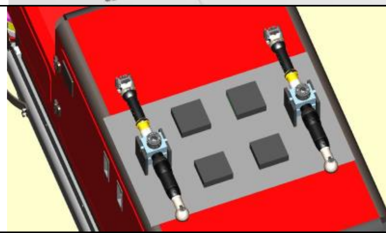
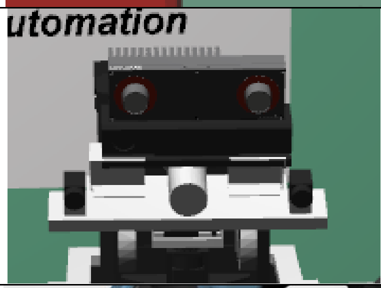
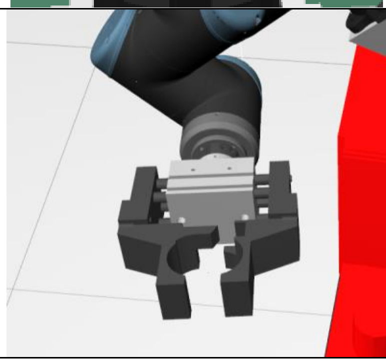


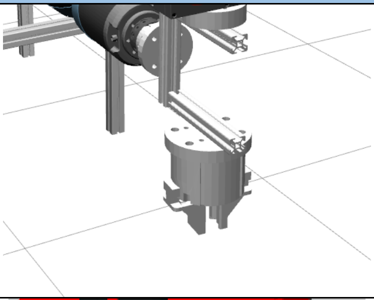
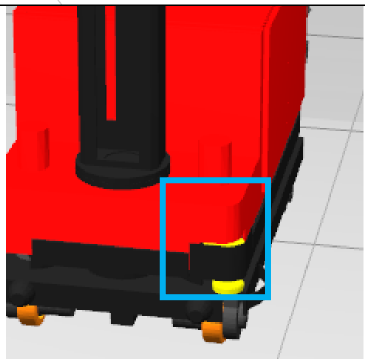
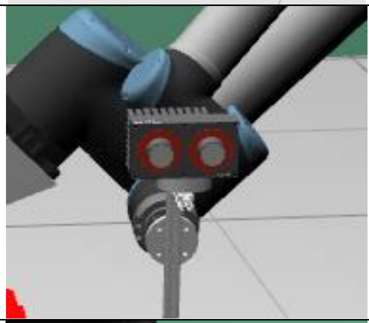
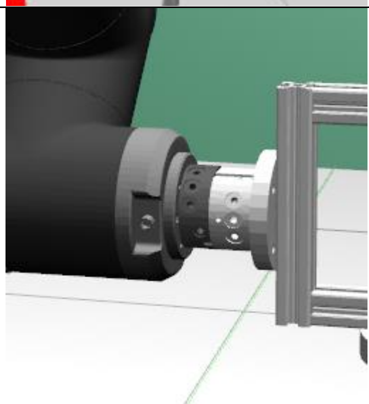
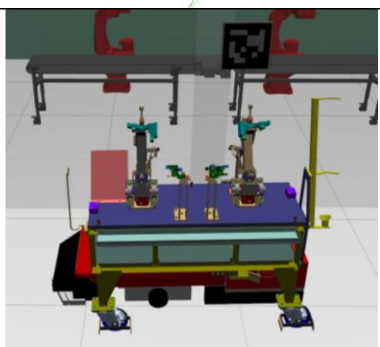
Figure 9: General Overview of THOMAS automotive pilot case scenario

lists in detail all the hardware components that are included in the automotive use case scenario and are required for its execution.

Table 2: Hardware components in THOMAS Automotive pilot case

Hardware Components	
Pre-assembly table	

Hardware Components	
Compression table mock up	
Tool changer stand on the MRP	
Apriltags	
Kinect and ROBOCEPTION rc_visard_160 stereo camera	
Pneumatic gripper for damper's manipulation	

Hardware Components	
Pneumatic gripper for nut's and alignment rod's manipulation	
SICK MicroScan 3 sensor	
ROBOCEPTION rc_visard 65 stereo camera	
Tool changers	
Mobile Product Platform (MPP)	

6.2.1. Navigation in automotive pilot case's scenario

Using the virtual MRP's controller through the GAZEBO simulation environment the different navigation modules were tested in the automotive pilot case set up.

6.2.1.1. 2D based SLAM navigation

Under the first implementation of the scenario the conventional 2D laser scanner based navigation using the SICK S300 laser scanner simulated data was tested (Figure 10). The deployment of a dedicated navigation planner, the MRP was able to reach the final goals though optimized and collision free trajectories. In this way, MRP's reachability in scenario's workstations but also object's manipulation has been successfully tested. Planned navigation trajectory can be visualized using ROS RViz.

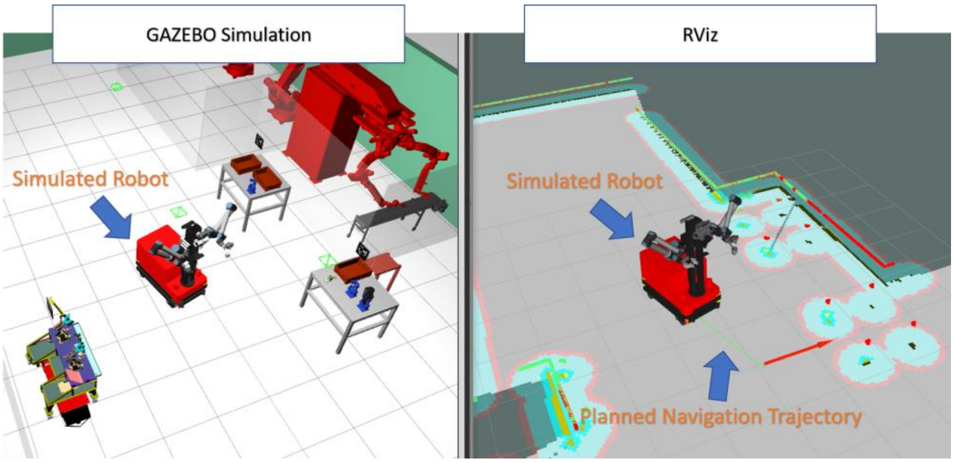


Figure 10: Navigation action using simulated MRP model

6.2.1.2. 3D sensor data based accurate localization

During the testing of the conventional navigation algorithm several navigation errors were detected not allowing the robot to reach with accuracy its final goal. A strategy for compensating these errors were needed concluding in the usage of 3D sensor data and the localization based on apriltag detection. Apriltags have been placed inside the simulation environment, on each of the three working areas. In this way it is ensured that the MRP will reach the final navigation goal without any navigation errors. The only requirement is that after each navigation action, the respective apriltag needs to be inside robot camera's view (Figure 11). A 3D sensor has been used for the implantation of this module.

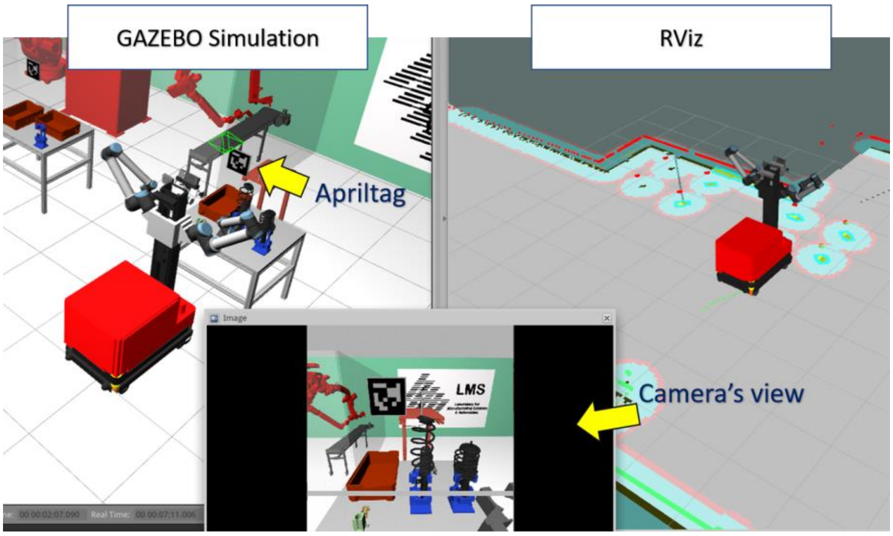


Figure 11: MRP accurate localization process

6.3. Physical set up of the automotive OPS at LMS

As mentioned in the previous sections, in parallel with the simulation testing of the automotive OPS the hardware with the MRP as a major component has been under preparation. Thus, preliminary testbeds using alternative robot resources were needed for starting physical testing before the complete hardware preparation.

6.3.1. Preliminary stationary testbed

In the very beginning of the development period, a stationary set up has been created at LMS to test the detection and manipulation of the damper, the main part involved in the assembly operations of the PSA case. This set up is presented in detail on Figure 12 having a UR 10 as robot resource.

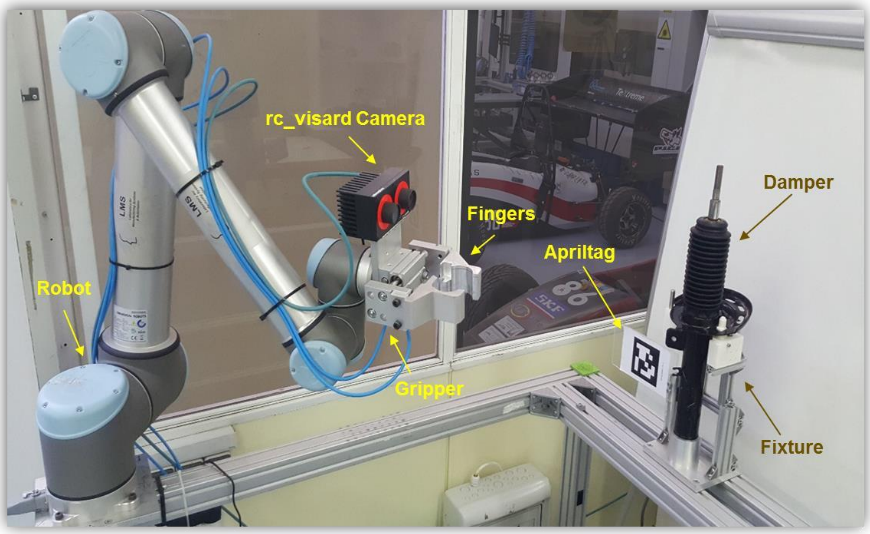


Figure 12: Automotive pilot case preliminary test bed at LMS premises

A SCHUNK pneumatic gripper, integrated on the UR10, has been used for testing various custom 3D – printed fingers towards optimizing their design to be used in the final demonstrator. The selected and manufactured fingers are visualized in Figure 13. The rc_visard camera has been deployed for testing the April tag and object detection modules achieving the accurate damper pose estimation for grasping.

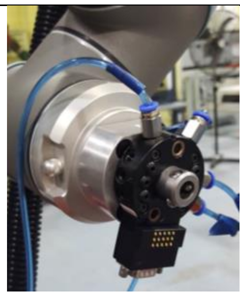
Figure 13: Damper's Manipulation

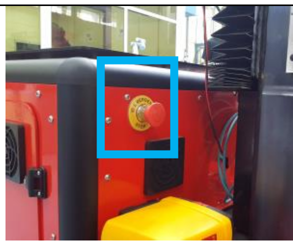
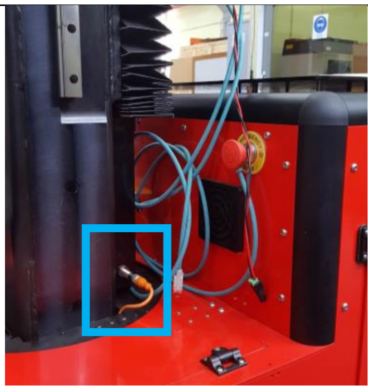
The following video shows the demonstrator: [Link to THOMAS YouTube Channel]

6.3.2. Actual physical set up of the automotive OPS at LMS

Following the finalization of MRP_n2, a first version of THOMAS PSA case set up is already prepared at LMS Machine Shop where the first full version of the pilot will be demonstrated. Developed technologies of THOMAS project such as object's detection and moving human avoidance have been tested using this setup. The already existing components are presented in the following table (Table 3):

Table 3: Available components in LMS premises for THOMAS automotive pilot case

Apriltags	Apriltags are used for the detection process of the damper and the MRP platform localization using the ROBOCEPTION rc_visard cameras.	
Tool changers	A SCHUNK SWK 011 male tool changer is installed on each robot's arm in order to automate robot's tools change (grippers and screwdrivers). Each tool uses One SCHUNK SWA 011 female ool changer to be attached in robots' arm.	
SICK MicroScan 3 sensor	Two SICK MicroScan 3 sensors are installed on MRP's platform in such a way so to cover the complete perimeter of the robots. Safety and human tracking are the main applications where the MicroScan3 data are used.	
Pneumatic gripper for nuts / alignment rod's manipulation and ROBOCEPTION rc_visard 65 stereo camera	rc_visard_65 camera is responsible for detecting the nut and alignment rod and publishing the detected grasping point on the THOMAS world model. The MRP uses the SMC MHS 2 63D pneumatic gripper with one pair of custom designed fingers to grasp and manipulate both the nut and alignment rod.	
Pneumatic gripper for damper's manipulation and ROBOCEPTION rc_visard 160 stereo camera	rc_visard_160 camera is responsible for detecting the uncompressed / compressed damper and publishing the detected grasping point on the THOMAS world model. The SMC MHL 2 25D pneumatic gripper and another pair of fingers is capable to grasp and manipulate each damper's model.	

Kinect	Kinect sensor is used in THOMAS automotive pilot case in order to detect human motion and Human Robot Interaction (HRI) through gesture's recognition	
MOTO 360 Smartwatch	The smartwatch is used as the human side interface allowing the human to provide feedback on the Station Controller	
Safe Incremental Encoders	Automotive pilot case's MRP is equipped with one safe incremental encoder per each motor inside the robot. MRP includes 2 motors for each wheel. In this case, MRP consist of 8 encoders responsible for the motion of the robot in a safety certified way.	
Emergency buttons	Four safety buttons have been installed around the MRP in case of malfunction.	
Remote Emergency button	One remote safety button has been integrated in MRP's controller allowing operator to stop MRP's navigation and its arms motion without approaching its machine.	
Safe position sensor	Used for monitoring position in a safety certified way.	

SICK FlexiSoft safety PLC	This safe PLC is used for integrating the inputs / outputs from all the involved safety related hardware on the robot. The safe logic configuration will be deployed on this PLC so to regulate the safety functions during execution.	

6.3.2.1. Integration of Process level perception modules

THOMAS project focuses on the manipulation of small and big objects using detection processes. Both rc_visard_65 and rc_visard_160 cameras are capable to perform these actions. In the current automotive set up, rc_visard_65 camera has been mounted on the MRP's left arm for testing the detection of the nuts producing successful results (Figure 14).

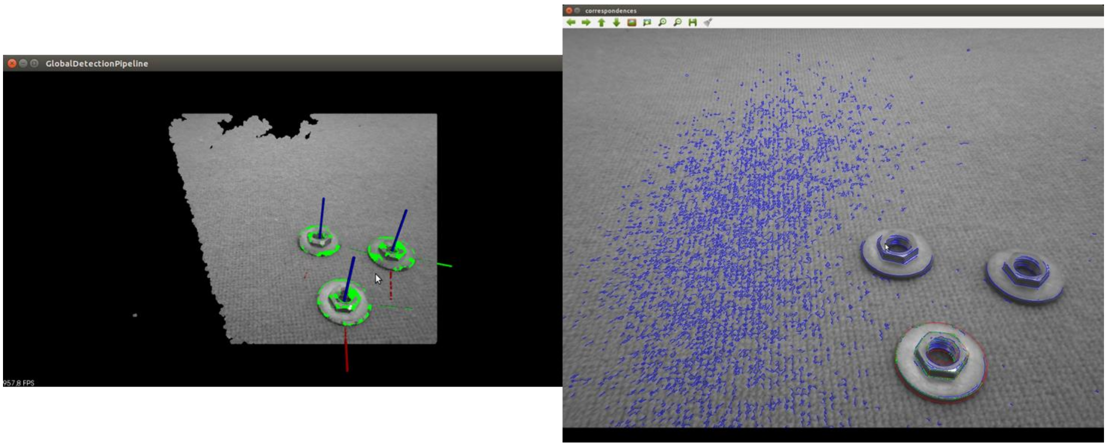


Figure 14: Detection of nuts using rc_visard_65 mounted on the MRP

The detection process of both compressed and pre-compressed damper's model is implemented using the rc_visard_160 camera (Figure 15).

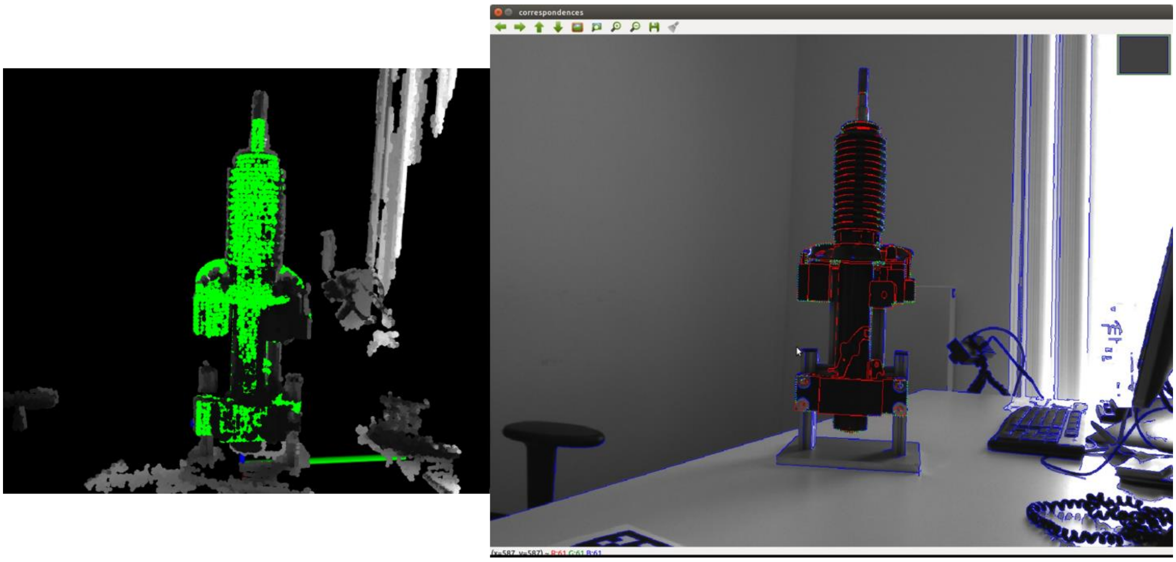


Figure 15: Detection of pre-compressed damper using rc_visard_160 mounted on the MRP

6.3.2.2. Deployment of THOMAS Station Controller initial prototype

THOMAS Station controller is a high-level mechanism responsible for the communication between all sensors and hardware components included in the execution (Figure 16). In this way, station controller is able to send commands regarding navigation, object detection and robot arm motion actions relative to the detected models. Under the station controller the human operator is also integrated through specially designed human side interfaces. In the current set up, MOTO 360 smartwatch has been used as the human side hardware device. Two functionalities have been deployed and tested under this device: a) task completed button, through which the human informs the system for the status of his operations and b) task take over button from which the human can request to take over a task from the from the robot. Using this mechanism, operators are able to change scenario's task sequence by executing robot actions. Mobile robot platform waits until operator press the completed button from the smartwatch in order to continue with the next task respectively to the task sequence.

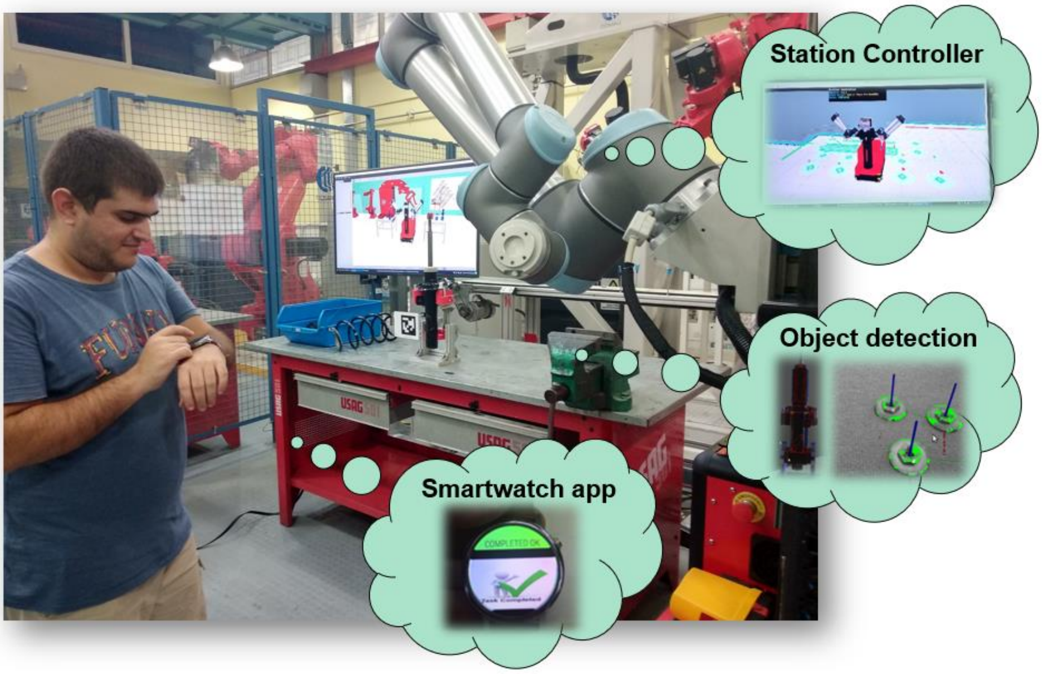


Figure 16: Station Controller developed under THOMAS project

7. OPS AERONAUTICS USE CASE

In this paragraph explain the status of OPS Aeronautics Use Case in the way Navigation, docking, tools control, and perception device needed.

7.1. General Overview

The Aeronautics Use Case will be developed at AERNNOVA to test and validate the THOMAS Open Production Station concept for aeronautics. Three aeronautics processes will be addressed at this Use Case (See D1.1 for details):

- **Drilling process:** It will consist of making the joining holes of both skins to the inner structure (ribs and spar) by means of drilling templates that will be positioned and removed by the operator / robot. The drilling will be performed by the operator / robot using the semi-automatic semi-tec drill-machine. **This is THOMAS main Aeronautics scenario and it will be developed to a TRL6 level.**
- **Inspection of rivers process:** The Robot will inspect the height of the rivets with a scanner in one arm, if any rivet is not in the correct height, robot will mark it on the skin product, which must be repaired and inspected again, until 100% of defects have disappeared. The goal on this scenario is to show the flexibility of the THOMAS approach. Rivet inspection accuracy will rely on the performance of the sensor being tested in AERNNOVA, it will not be an evaluation KPI of THOMAS. **THOMAS will add the value of automating the rivet inspection process.**
- **Paint sanding process:** It will consist of the required operations for preparing the products by sanding their surface for the subsequent application of paints. Once the sanded operation is finished, a quality inspector will check the correct work. The goal on this scenario is to show the flexibility of the Thomas approach. The quality of the sanding will not be an evaluation KPI of THOMAS. **The final process to be shown in THOMAS will depend on further research of available sanding grippers and quality measurement sensors.** With the results of this research, THOMAS will show a demonstration of sanding and/or quality inspection as prove of concept.

For testing the THOMAS concept, the three processes will be developed on different parts of the same wing. The robot, to perform one process, will navigate to the tool table, will get the required tool and will work on the process. When the task is finished it will move again to the tool table, it will release the tool and will navigate following a path that brings the robot out of the wing and back again to the wing to the next process´s tool table. Then will repeated the sequence to perform the new process. Figure 17 shows a drawing of the Use Case space.

Figure 17: Design of the final use-case at AERNNOVA

7.2. Navigation

Cell to cell navigation is required at AERNNOVA use-case as well as the static docking capability of in cell navigation. The THOMAS navigation system initial prototype is presented in the D3.4. Refer to this deliverable for more details of the implementation.

7.2.1. Standard 2D based SLAM navigation

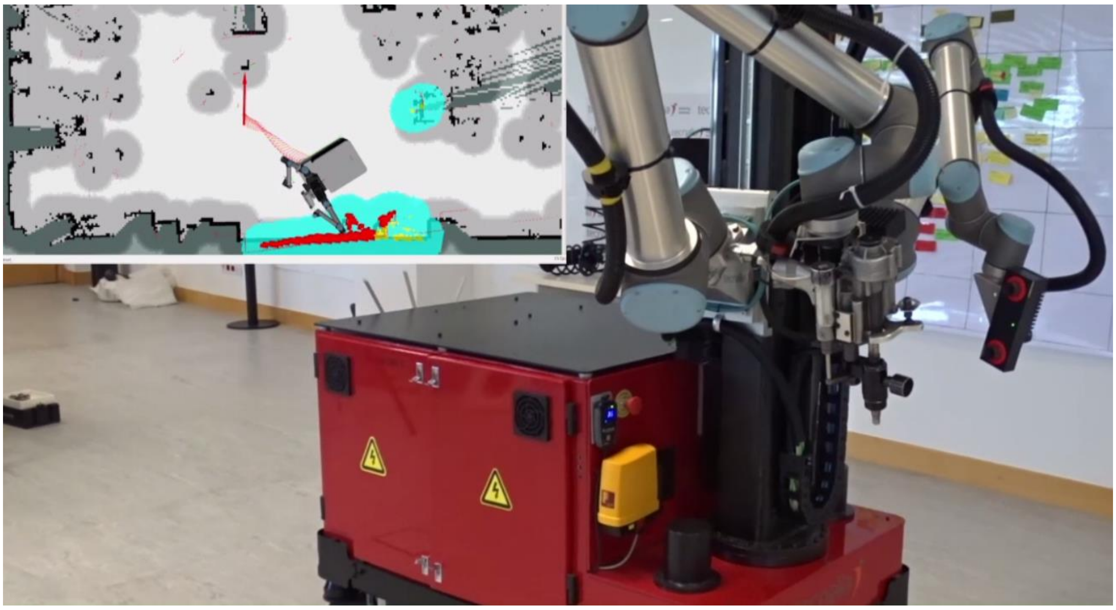


Figure 18: MRP navigation test

The navigation of the first prototype of the MRP is composed of standard 2D laser-based navigation. Besides the navigation and localization methods implemented, some other actions where necessary to

improve navigation efficiency and safety, namely the improvement of the wheel low level management and the use of dynamically adaptable robot’s footprint to have into account the robot’s arm configuration while navigating.

7.2.2. 3D Perception based navigation

The laser-based navigation has its limitations. The main limitations are, robot re-localization problems (robots must start navigation always at a known point in their map) and the limited 2D information about the obstacles that we get from lasers. To address these problems 3D perception is being integrated to the THOMAS navigation. In addition, the viability of using 3D semantic maps will be studied.

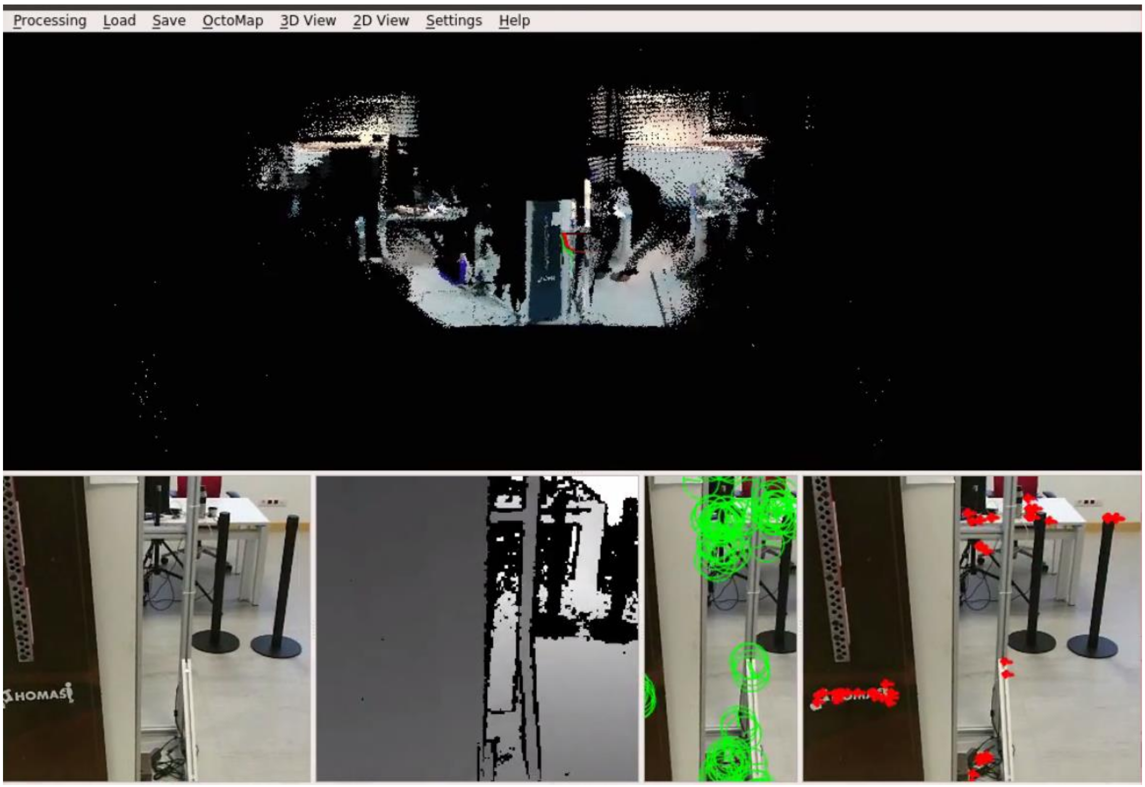


Figure 19: vSLAM initialization view

Figure 20: Final 3D map of the environment and robot trajectory

7.2.3. Static Docking: Accurate positioning with respect to a static reference

The static docking is achieved by visual servoing a reference marker. The system is based on a proportional control that maintains and ensures, with the desired tolerance, the position of the robot with respect to the marker. To obtain a good response of fluid movements of the robot it has been decided to use a closed loop system with a sampling frequency of 20 Hz. A frame transformation is performed to validate the position and orientation from the image of the marker seen from the camera to the base of the robot.

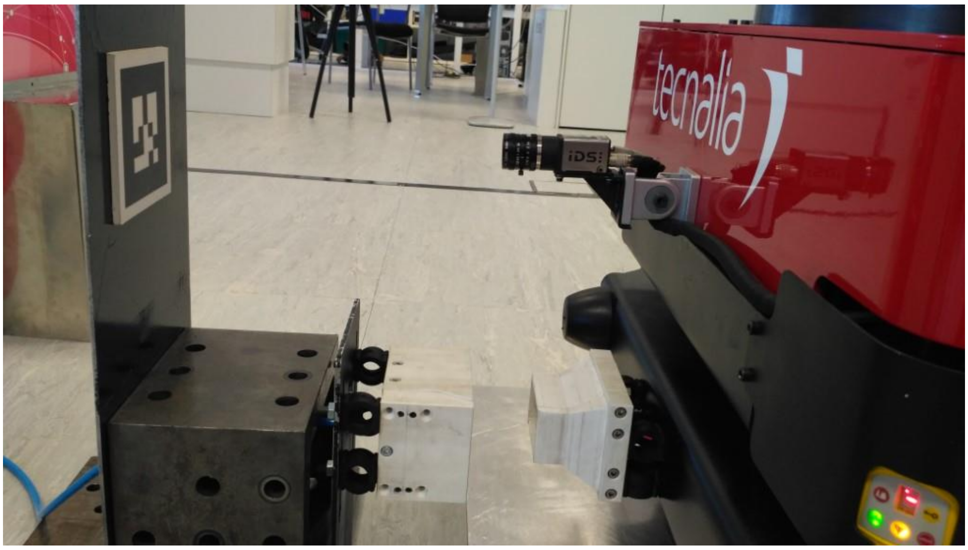


Figure 21: Final docking system with charge station and marker installed

7.3. Processes

7.3.1. Tool exchanging system

One of the main features of the aeronautics case is the ability of THOMAS MRP to travel to different workstations for performing different type of operations. In this particular use case, three different use cases are investigated: a) drilling, b) inspection of rivers and c) paint sanding. To enable this flexible behaviour from a hardware and tooling point of view, a tool exchanging system is being designed to enable tool exchanging at the AERNNOVA use-case. Figure 22 shows the mechanical design of the tool exchanging table.

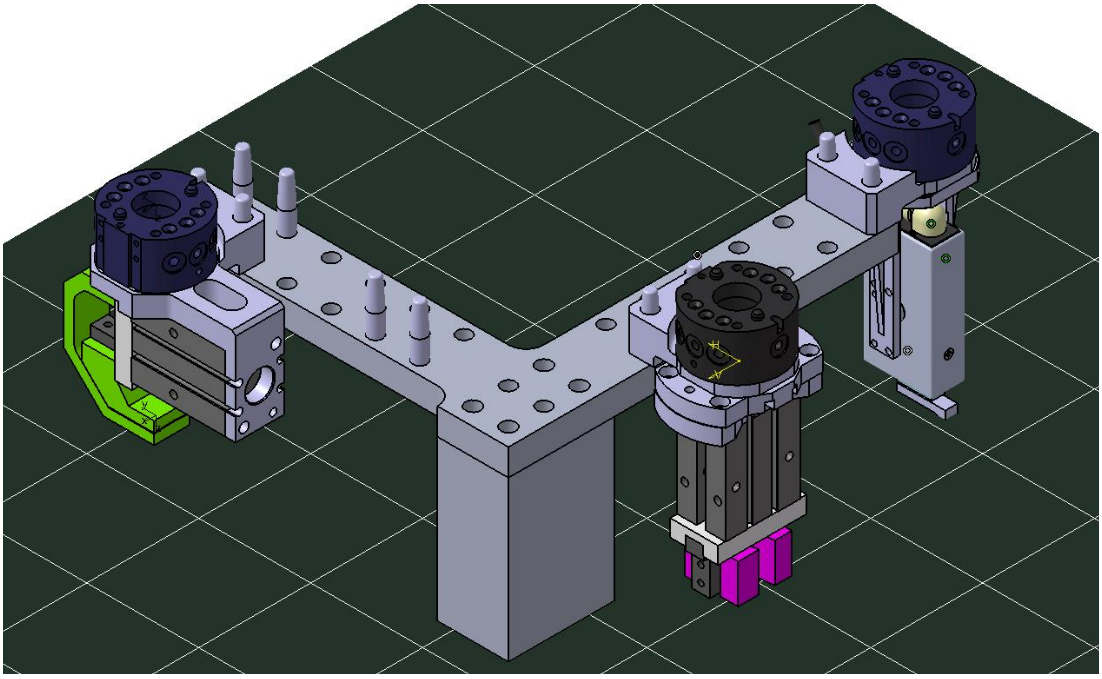


Figure 22: Mechanical design of the tool exchanging table

7.3.2. Drilling

A first prototype of the drilling process has been developed and was demonstrated at both TECNALIA's and AERNNOVA's premises. This prototype solves the problem of navigation to the operation station, drilling template detection using ROBOCEPTION rc_visard stereo cameras and drilling machine insertion at the template holes.

The following video shows the demonstrator: Link to THOMAS You Tube Channel, Link to TECNALIA YouTube Channel

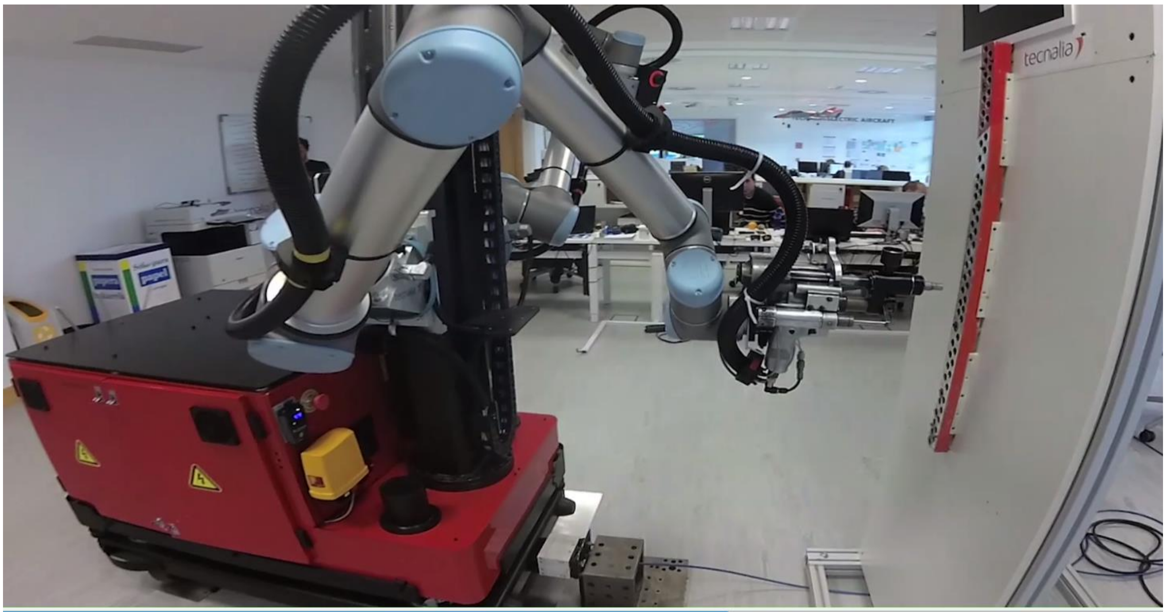


Figure 23: Drilling process demonstrator at TECNALIA Laboratory

Figure 24: Drilling process demonstrator at AERNNOVA workshop

As next steps, drilling quality tests must be done to validate the drilling process. Also, robustness for the vision system must be demonstrated for multiple template detection.

7.3.3. Inspection of rivets

A bunch of tests have been done with different types of sensors to select the one that best fits the THOMAS project goals in terms of cost, reliability, precision and connectivity with the THOMAS system. Figure 25, Figure 26 and Figure 27 show three of the tested systems. Precision and reliability wise the Gap Gun device (Figure 27) is the most suitable solution but its high price and lower connectivity with THOMAS systems make the choice to be less attractive. One of the two vision based solutions will be most probably the selected option for THOMAS.

Figure 25: Measurement tests with standard stereo camera

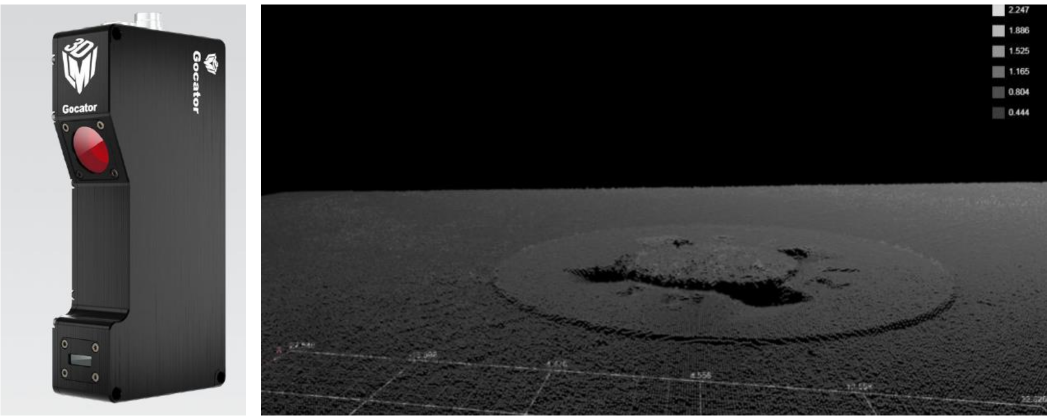


Figure 26: Measurement tests using the Gocator 3D Smart Sensor

Figure 27: Rivet measurement using the Gap Gun device

Independently of the sensor selection, the skill system that will make the robot able to integrate rivet inspection at AERNNOVA will be developed in the following period.

7.3.4. Paint sanding

The development of this process is on-going during this period of the project. The tool to be used by the robot to perform the paint sanding operation has been selected and it is visualized in the following figure.

Figure 28: Sanding device used in Aeronautic use case

Currently, this pneumatic device is used by human operators to manually perform the sanding process. Under the scope of THOMAS project, a mounting system will be design and integrated towards the automatic use of the device by the THOMAS MRP. In particular, THOMAS MRP will be equipped with a gripping system for sanding device with the possibility by the tool changer installed in MRP change directly device and gripping system if is necessary use in other operation simultaneously.

7.4. Safety concept

AERNNOVA use-case will be used to partially demonstrate safety. The full safety concept will be implemented at the PSA use-case.

7.4.1. Safety during operation

The AERNNOVA use-case MRP is equipped with two safety laser scanners (SICK S 300 laser scanners) placed at two robot corners. They provide a field of view of 360º together. They are connected to a general safety relay that can switch the robot down on person detection.

No humans will be able to work near the robot during operation. If a person enters the security limit field of the robot the system will stop in an emergency stop.

7.4.2. Safety during navigation

Given the safety configuration of the robot hardware. Navigation, from the point of view of safety, is restricted to open areas where humans are a fair distance far from the moving area of the robot.

For practicality reasons in the AERNNOVA use-case. Navigation safety fields will be modified by software following the dynamic safety zone paradigm where the zones are made wider in the direction of movement of the robot and dependent on the speed of the robot and narrower in the rest of the directions. This makes the robot able to navigate in workshop areas of AERNNOVA safely for the demonstration purposes of the project, but this is not a certifiable solution. For being certifiable the robot should have safe encoders added to the laser system and the dynamic safety zone paradigm would need to be programmed on a safe PLC device. This will be demonstrated at the PSA MRP.

8. Conclusions

This document has presented the current version of THOMAS Open Production Station (OPS) as a Product as developed up the end of the second year of the project. The main activities of the consortium have been oriented around: a) Finalizing the design and development of the THOMAS Mobile Resources – MRP and MPP and b) Integrating the initial prototype of the individual resources under the preliminary testbeds set up at LMS and at TECNALIA for the automotive and the aeronautics pilot case respectively.

Following the presented results for THOMAS OPS, the project partners have achieved the defined technical milestones concerning the expected features to be implemented by M24 as listed following table.

Table 4: Technical Milestones for THOMAS OPS.

Project Technical Milestones	M24
Mobile dual arm manipulator for flexible operations – **1st prototype**	■
System for enabling docking and collaborative operation of mobile units – **1st prototype**	■
Generic Perception skill library providing Application-ready solutions for flexible robotics guiding: **a) Object & Process, b) Navigation**	■
Mobile platform navigation software library, complementing the traditional SLAM with vision-based accurate localization – **1st prototype**	■
Fenceless environment monitoring and robot control software library : **Human Tracking**	■
Automatic programming software library providing an easy operation programming for product-variants – **1 Skill Set and 1 framework prototype**	■
Global communication & synchronization framework - Network of services **a) Resource Shared Perception, b)Resource Level Reasoning**	■
Dual arm robot autonomy and cooperation level: **a) Navigation, b) Static Operation**	■
Task sharing level between human and robot in the same workspace: **Separation**	■

The fine tuning and extension of integration activities for further enhancing THOMAS OPS are already in progress targeting on the second version that will be delivered at the end of M36 of the project.

9. GLOSSARY

MRP	Mobile Robot Platform
OPS	Open production Station
MPP	Mobile Product Platform
ROS	Robot Operating System

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