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Innovation Action

Smart integrated immersive and symbiotic human-robot collaboration system controlled by Internet of Things based dynamic manufacturing processes with emphasis on worker safety

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D5.2 First system deployed at factories sites

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Abbreviations

AAEI	Automated Agent Exec Interface
AR	Augmented Reality
CC	Competence Centre
D2.1	HORSE Deliverable D2.1 “System Requirements Specification”
D5.1	HORSE Deliverable D5.1 “Validation of system components report”
DB	Database
HEG	HORSE Execution Global
HEL	HORSE Execution Local
HMI	Human Machine Interface
MPMS	Manufacturing Process Management System
N/A	Not Applicable
PC	Personal Computer
ROS	Robotic Operating System
TBD	To Be Defined
WP	Work Package

Executive Summary

This document summarises the first HORSE system deployment in different environments, for the pilot experiments. The current status of the deployment in the pilots is:

- **BOS**: The pilot experiment of BOS has been deployed in the lab environment of Eurecat, and is currently under verification testing.

- **TRI**: The P1-Unloading and P1-Tool assembly, including the use of a mobile robot, have been deployed and tested in the real factory environment. One more deployment in P2, hanging profiles on hooks is currently under final contract signing to initiate lab testing.

- **OPSA**: The solution to be deployed has been designed and the HORSE modules have been tested in lab. It is currently under final contract signing to start the lab implementation tailored to the industrial environment.

1 Introduction

1.1 Purpose and scope

This document reports the deployment of the first HORSE platform to the HORSE pilot experiments. It includes a report on the activities that have taken place towards the deployment, the detailed deployment plans, including diagrams and HORSE software components used, and demonstrations of the deployed system.

After the intermediate end-user feedback (3 months after the deployment in the pilot experiments), the HORSE system will be further improved to meet the end-user needs, and the final system will be deployed at the HORSE pilot experiments. The final system will be reported in the deliverable D5.4.

1.2 Relation with other WPs

This report is closely related with the following activities of the other Work Packages:

- WP2: the concepts and the opportunities for HORSE in the pilot experiments were identified and reported in deliverable D2.1. The use cases of the HORSE system were identified and reported in deliverable D2.2.
- WP3: the detailed features of each component and their application within the pilots have been described.
- WP4: the integration of the HORSE components and the interfacing with the environment and the external systems at the pilot sites has been defined.
- WP5: the detailed scenarios for the pilots have been analysed, and the end-users gave their first feedback as for the HORSE components.
- WP6/WP8: the application of the HORSE system to the pilot experiments will be used to better describe the features of the system and provide relevant experience for the implementation of the open call experiments.
- WP7: the application of the HORSE system to the pilot experiments was used as a baseline to define more extended and specialised demonstrations that can be implemented in the HORSE Competence Centres.
- WP9: the application of the HORSE system to pilot experiments will help to better analyse its applicability in real industrial environments and identify exploitation opportunities. The successful deployment will be also used for dissemination.

1.3 Structure of the document

- In Chapter 1, the document is introduced and the relation with the other WPs is described.
- In Chapter 2, the activities that have taken place towards the deployment are briefly described.
- In Chapter 3, the deployment plans for each pilot are included.
- In Chapter 4, demonstrators (photos, videos) of the pilot experiments can be found.
- In Chapter 5, the conclusions and the next steps are described.
- In Annex A, some example interface messages using the HORSE middleware are included.

2 Activities towards deployment

2.1 Deployment planning

This chapter includes a summary of the activities that have taken place towards the deployment of the system in the pilots.

The deployment process can be split into phases that consist of various activities and assigned teams:

I. **Operational strategy**: In this phase the operational concepts of the system and the solution that will be applied are defined. It consists of the following two core activities:
   a) Define operational concepts,
   b) Define operational scenarios.

   Both tasks are executed while taking into consideration constraints, such as costs and feasibility, while there is a continuous assessment of the deployment requirements, impacts and conformance with project's goals.

   The outcomes of this phase have been incrementally (in more detail) elaborated in the following HORSE deliverables:

   1. D2.1 (Concepts in high level)
   2. D2.2 (Concepts in technical level - Use cases)
   3. D5.1 (Scenarios)
   4. WP3 deliverables (Scenarios in technical level - features per component)

II. **Transition:** This phase is concerned with performing the relevant tasks that are needed for the transition[1] preparation. This includes preparing the transition strategy/plan and performing the tasks needed for the actual preparation of the transition. Activities in this phase include:

   a) Define technical requirements and detailed designs for the deployment (includes re-visits to the pilot facilities and involvement of external suppliers)

   b) Make arrangements and preparations for the deployment (e.g. prepare contracts with external suppliers, order parts etc.)

   c) Assess readiness for deployment (e.g. ensure that all parts, facilities and equipment are ready before going to the facility and perform the deployment, perform lab verification of the solution etc.)

III. **Deployment**: This phase consists of three main activities:

   a) Deploy hardware to the facility

   b) Deploy software (HORSE and other software that may be needed)

   c) Perform qualification testing to ensure that the system works as expected and is accepted by the pilot end-user.

IV. **Post-deployment**: This phase include activities to take place after the deployment, such as training, maintenance and support. Outputs to be considered for further exploitation.

[1] "Transition" refers to the transition from the old situation (without HORSE) to the new situation (with HORSE)

V. **Final system deployment**: This phase refers to the deployment of the final system, to be reported in deliverable D5.3. It consists of the same activities as in phases II and III, but in a more tightened schedule, as only required changes are concerned for the transition from early system to final system.

Table 1 reports the teams and the responsibilities in each phase. Multi-disciplinary teams have been composed where needed. EUR (Eurecat), ETRA and Gibas organisations have been also involved as robotic system integrators for BOS, OPSA and TRI respectively.

Table 1: Roles and responsibilities in each deployment phase

Phase	BOS	OPSA	TRI
I. Operational strategy	ED, TUM, PROS	CEA, TUE	KUKA, TNO, TUE, FZI
II. Transition	TUM, PROS, KUKA, TUE, EUR, CET, ED	CEA, KUKA, ETRA	PROS, KUKA, TNO, TUE, FZI, ED, Gibas
III. Deployment	TUM, TUE, EUR, PROS	CEA, ETRA	TNO, TUE, FZI, CET, KUKA, PROS, Gibas
IV. Post-deployment	TBD		
V. Final system deployment	To be reported in D5.3		

2.2 Current status

The current status with the outputs of the afore-mentioned activities, along with the additional administrative activities taking place, is summarised in Table 2.

In brief the status for each pilot is as follows:

- **BOS**: A contract with Eurecat has been signed. Eurecat will become a HORSE partner. Needed equipment has already been transferred to the Eurecat Lab and the development and testing of the solution has been initiated.
- **OPSA**: The HORSE modules that will be used in the OPSA case have been tested in lab, with a different robot (Staubli). A KUKA industrial robot will be used in the real pilot experiment. Negotiations with ETRA as an external robotics integrator have been concluded and agreed. The contract signing is in progress.
- **TRI**: In TRI 3 experiments take place.
    - In P1 Loading, the solution has been deployed and tested by the HORSE Consortium, and is ready for the real production.
    - In P1 Tool assembly, the solution has been deployed and tested by the HORSE Consortium, and is ready for the real production.
    - In P2 Hanging profiles, a demo has been shown by an external robotics integrator, Gibas, and an offer has been made. Negotiations on finalizing the contract details (scope of services, costs etc.) are initiated.

Table 2: Current status of deployment

Outputs	BOS	OPSA	TRI – P1 Loading	TRI – P1 Tool Assembly	TRI – P2 Hanging profiles
(Phase I) Operational concepts & scenarios	✓	✓	✓	✓	✓
(Phase II) Detailed technical design / Simulation – final offer document by the robotic integrator	✓	✓	✓	✓	✓
(Phase II) Arrangements & preparations for the deployment	✓	Negotiations with external robotic integrator have been concluded. Contract signing in progress	N/A (deployed by the HORSE consortium)	N/A (deployed by the HORSE consortium)	Negotiation with external robotic integrator in progress
(Phase II) Assess readiness for deployment	Lab testing of solution in progress	To start after contract signing	✓	✓	Demo has been shown. Full lab testing to start after contract signing.
(Phase III) Deployment	Planned in October 2018	-	✓	✓	-
(Phases IV-V)	3 months after actual deployment in production				

3 Deployment plans

3.1 Robert Bosch España Fábrica de Castellet S.A.U. (BOS)

The demonstrator deployed in BOS is in line with the planned use case, as described in D2.1, paragraphs 3.2.1 and 3.3.1, and refined in D5.1, paragraph 3.1. The detailed description of the use case and the scenario are given in D5.1, paragraphs 3.2 and 3.3 respectively. A summary is given below.

The demonstrator is currently being tested at the Eurecat lab and is planned to be commissioned in the factory on October 2018.

3.1.1 Use case summary

The BOS facility has four production areas. The HORSE Project is primarily interested in the final assembly area of front wiper systems. This production area contains multiple parallel production lines, of which the semi-automated line is of primary concern.

The solution to be deployed is related to releasing the workers from the physical and mental strain. More specifically, an automated agent will be deployed, which will execute the following tasks:

- Pick up of WSAs,
- Place WSAs in designated visual control positioning,
- Place WSAs in packaging box or at the secondary platform boxes.

3.1.2 Deployment diagram

The deployment diagram is shown in Figure 1.

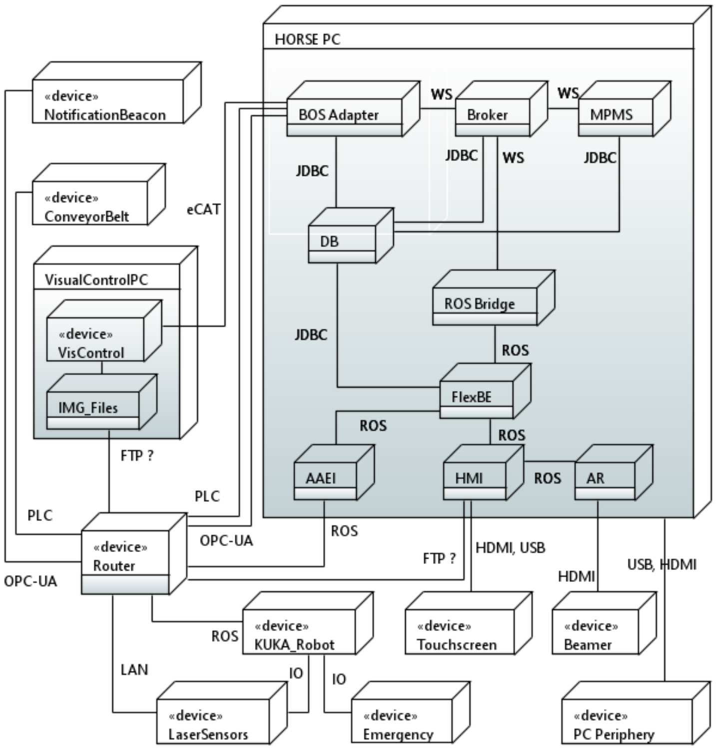

Figure 1: Deployment diagram for BOS pilot experiment

The deployment diagram elements are described in Table 3.

Table 3: Description of BOS deployment diagram elements

Element	Description
NotificationBeacon	Industrial light bulb, used to attract the attention. Connected with the local PLC and managed over OC-UA (over PLC) protocol.
ConveyorBelt	Sensor, registering the arrival of the WSA to the position for a pickup and inspection. Signals are sent as DDL files over PLC.
VisualControlPC	Industrial PC hosting the ATMO2 components for visual inspection. Accessible over etherCAT communication protocol.
VisControl	ATMO2 equipment for taking and analysing snapshots of the WSA.
IMG_Files	Temporary repository for the images produced by VisControl.
Router	A network router for connectivity between the different devices.
KUKA_Robot	The robot arm, KUKA iiwa
LaserSensors	Laser sensors to detect humans within their detection field.
Touchscreen	A touchscreen to be used during the quality inspection with AR assistance.
Emergency	An emergency button for halting all movable objects (the robot arm, conveyor belt)
Beamer	The beamer that projects beams onto points of the part under inspection.
PC Periphery	Keyboard and mouse needed for local administration of the system
BOS Adapter	The HORSE-Bosch adapter interface component
Broker	The HORSE broker (part of the HORSE middleware component)
MPMS	The HORSE MPMS component
DB	The HORSE database
ROS Bridge	The HORSE-ROS bridge interface component
FlexBe	The HORSE-FlexBe module
AAEI	Automated Agent Exec Interface. A set of libraries and scripts enabling the interaction with the robots (automated agents)
HMI	Human Machine Interface. A touchscreen for human inspection of faulty WSA, equipped with additional features for basic interaction with the HORSE system (browsing through the images of the faulty WSAs, resuming HORSE operation after emergency situation has been resolved)
AR	The HORSE Augmented Reality for quality inspection component

The state machine for the robot as designed in FlexBe is given in Figure 2.

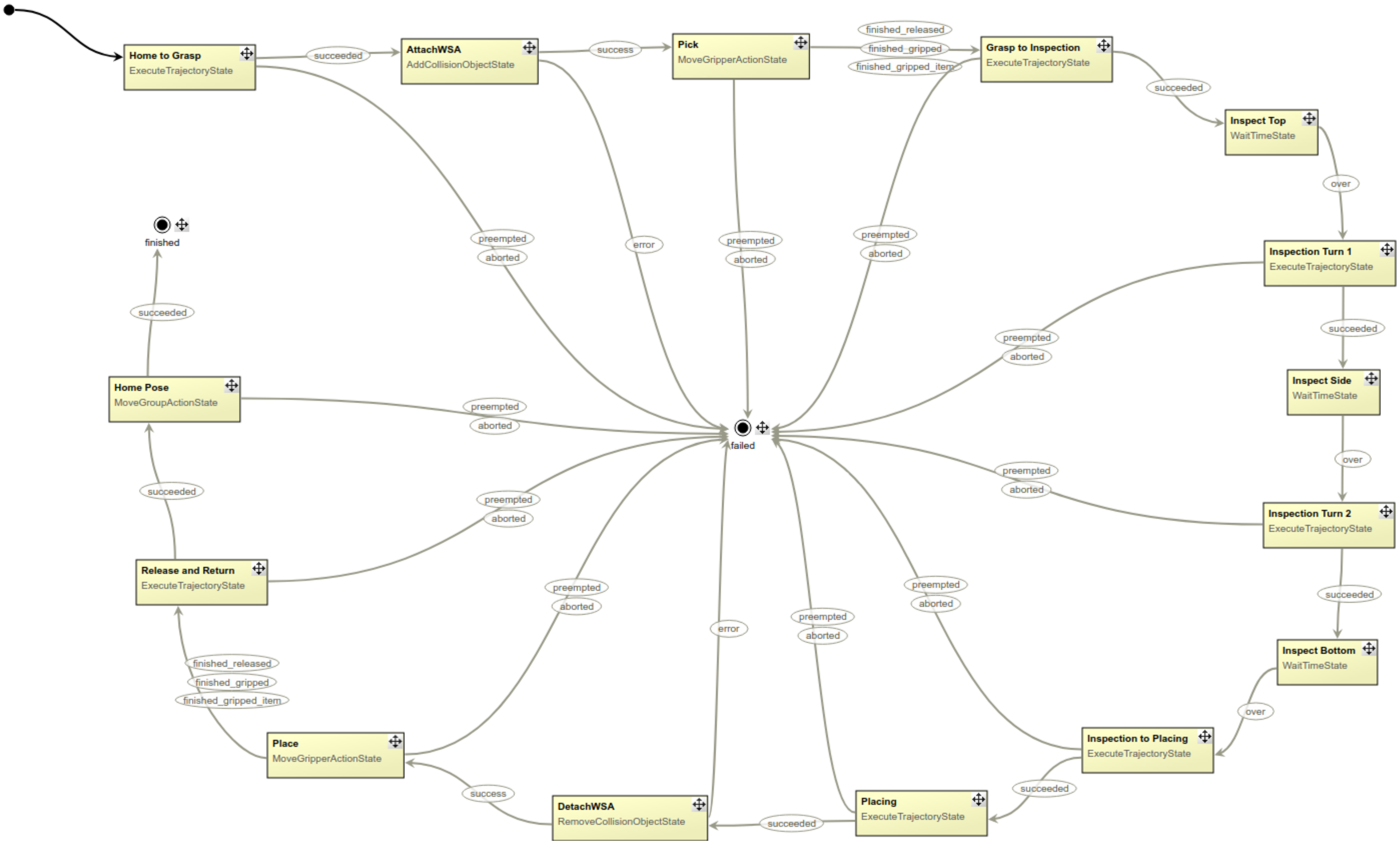

Figure 2: FlexBe state machine for BOS

3.1.3 Mechanical design

The mechanical design (initial and final) of the work cell is illustrated in Figure 3 and Figure 4.

Figure 3: Initial mechanical design of BOS experiment

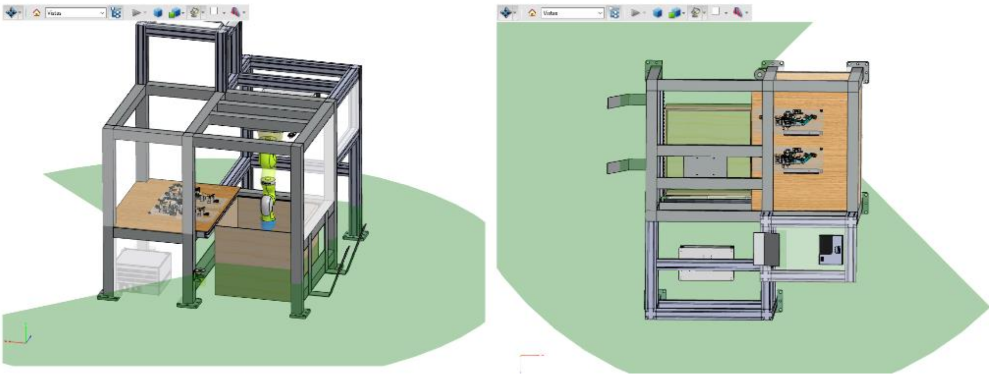

Figure 4: Final mechanical design of BOS experiment[2]

3.1.4 Equipment

The testing equipment needed for the execution of the experiment is summarized in Table 4.

Table 4: BOS equipment list

Item	Model/description
HORSE Desktop PC	Lenovo ThinkStation
etherCAT Master Card	Beckhoff F9002
19" LED monitor	AOC E975SWDA
Touchscreen	Planar PT194R 24"
Projector	Epson EB-1980WU
Safety laser scanner	Omron OS32C
Robot arm	KUKA robot LBR iiwa 14 R820 with Schunk gripper

[2] Green area indicates the cover area of the laser scanner used for detecting approaching humans

3.1.5 HORSE software components deployed

The HORSE software components deployed are:

- Middleware
- MPMS
- FlexBe
- ROS-Bridge
- Bosch adapter
- AR for quality inspection
- HMI
- AAEI
- Database server

3.1.6 Safety aspects

Safety analysis has been used to draw up the inventory of risks and dangerous situation. As for any machinery, preferred solutions are inherently safe-by-design.

- Safe geometry: use of a robot with collaborative vocation,
- Safe trajectory: avoid crushing zone,
- Safe layout plan: prevent access to hazardous area.

Risk assessment shows that these measures maybe not sufficient to bring risk to an acceptable level. It requires, implementation of complementary measures.

BOS pilot case is complex as the robot is switching between different collaborative modes, as in Table 5.

Table 5: Collaborative modes and safety functions in BOS pilot experiment

Actions	 Power and force limiting	 Hand guiding	 Safety-rated monitored stop	Safety functions
Robot transfers WSA (automated inspection position, waiting carrier, rejection carrier)	X			Collision detection Velocity monitoring Cartesian protected space #1 monitoring
Automated inspection	X			Collision detection Velocity monitoring Cartesian protected space #1 monitoring
Manual inspection		X		External enabling device Velocity monitoring Cartesian protected space #2 monitoring
Robot places the WSA into the packaging box	X		X	External safety stop 1 Collision detection Velocity monitoring Cartesian protected space #3 monitoring

Each of these modes requires different safety functions. KUKA iiwa, used in the pilot, has this advanced ability to switch between different safety functions, implemented inside a safety layer.

EMERGENCY STOP device and External EMERGENCY STOP device safety function are also required in any mode (obligatory according to directive on machinery).

Additional safety measures are also required. It is protective action (gloves) and information on residual risk (marking on floor, collaborative pictogram).

3.2 Odlewnie Polskie S.A. (OPSA)

The demonstrator to be deployed in OPSA is in line with the planned use case, as described in D2.1, paragraphs 3.2.2 and 3.3.2, and refined in D5.1, paragraph 4.1. The detailed description of the use case and the scenario are given in D5.1, paragraphs 4.2 and 4.3 respectively. A summary is given below.

Due to technical and supply constraints[3] the experiment has not yet been implemented. Lab testing on the HORSE components has been conducted at CEA Competence Centre. Specific implementation plan to transfer the technology to the industrial environment of OPSA is in place, with ETRA acting as the robotic integrator and cell designer, and CEA providing the additional learning-by-demonstration and force-control functionalities. From the technical perspective the HORSE components have been already integrated with the torque sensor that will be used, and with the KUKA industrial robot that will be used. The current implementation design for the deployment is given in this paragraph.

3.2.1 Use case summary

In OPSA, liquid metal is poured into the sand moulds through gates. A single mould typically contains four to eight casts. Once the casts have cooled, they are attached to each other by the metal that remained in the gating systems. A collection of such connected casts is called a grape. The production line under consideration here is charged with separating the casts from each other and from the pieces of gating metal. This includes learning by demonstration functionality to learn cutting new castings.

3.2.2 Deployment diagram

The current draft of the deployment diagram for the OPSA case is given in Figure 5.

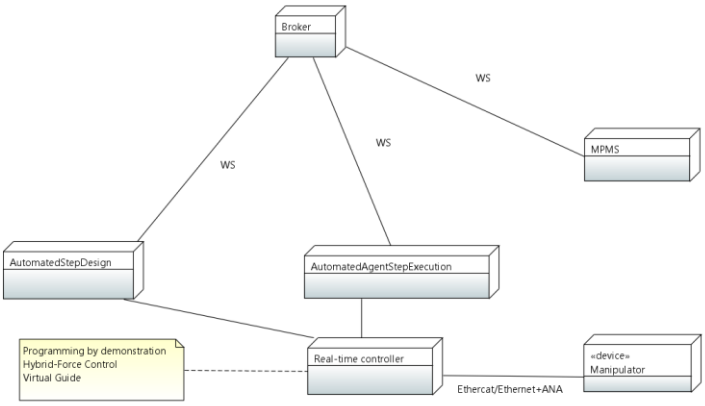

Figure 5: Deployment diagram for OPSA pilot experiment (current draft)

[3] More details in interim reports

The deployment diagram elements are described in Table 6.

Table 6: Description of OPSA deployment diagram elements

Element	Description
Broker	The HORSE broker (part of the HORSE middleware component)
AutomatedStepDesign	The HORSE Automated Step Design component
MPMS	The HORSE MPMS component
AutomatedAgentStepExecution	The HORSE Automated Step Execution component
Real-time controller	The real-time controller that manages programming by demonstration, virtual guides and the hybrid-force control
Manipulator	The robotic agent

3.2.3 Mechanical design

The initial mechanical design of the work cell is illustrated in Figure 6. Initially a two-drawer setup was designed. However, in order to stay within an acceptable cost, a one-drawer setting will be used.

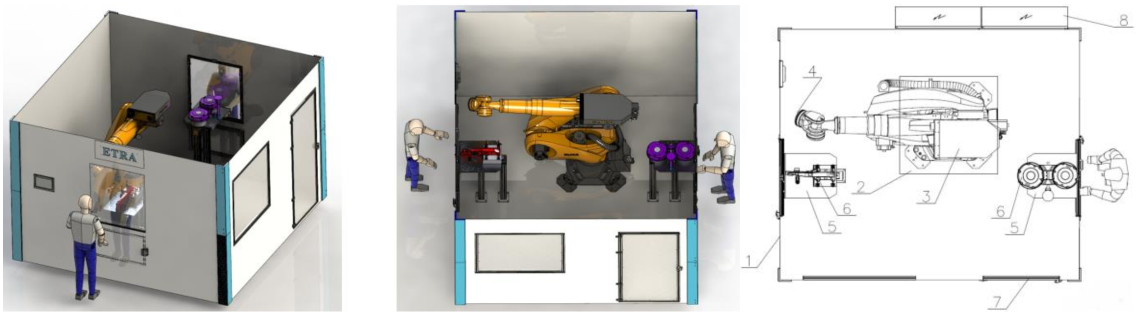

Figure 6: Initial mechanical design for OPSA

3.2.4 Equipment

The equipment needed for the execution of the experiment is summarized in Table 7.

Table 7: OPSA equipment list

Item	Model/description
Robot	KUKA KR120 with cable tensiometer
Motor with cutting plate	Giordano Colombo 5,9 kW
CEA controller	Real-time controller for programming by demonstration, virtual guides and hybrid-force control
Torque sensor	DELTA IP60 sensor

3.2.5 HORSE software components to be deployed

The HORSE software components (currently confirmed) deployed are:

- Middleware
- Automated Step Design
- AAEI
- MPMS
- Database

3.2.6 Safety aspects

Safety for this experiment will be re-evaluated during the implementation of the experiment.

3.3 Thomas Regout International (TRI)

The demonstrator deployed in TRI is in line with the planned use case, as described in D2.1, paragraphs 3.2.3 and 3.3.3, and refined in D5.1, paragraph 5.1. The detailed description of the use case and the scenario are given in D5.1, paragraphs 5.2 and 5.3 respectively. A summary of the use case is given below.

The first testing deployments for the P1 – Tool changeover and P1 – Unloading to trolley have been made at the TRI premises. One more deployment in P2, hanging profiles on hooks is under design.

3.3.1 Use case summary

In TRI, an Augmented Reality solution that gives instructions for assembling the tool, superimposed on real tool parts was tested in “P1” area. This includes an advanced planning system (MPMS) to help TRI with planning change overs with minimal reconfiguration of tooling, as well as a mobile platform to fetch tooling blocks.

Another solution tested in TRI is a fenceless robot solution at the end of the “P1” area, which unloads parts from the production line, and places them in an ordered way in transfer trolleys, making possible the use of robots in “P2” area.

Another solution that is also under design and lab testing, with the involvement of an external robotic integrator, is related to releasing the workers from the physical and mental strain, by executing the task of hanging parts on designated hooks.

3.3.2 Deployment diagram

The deployment diagram is shown in Figure 7.

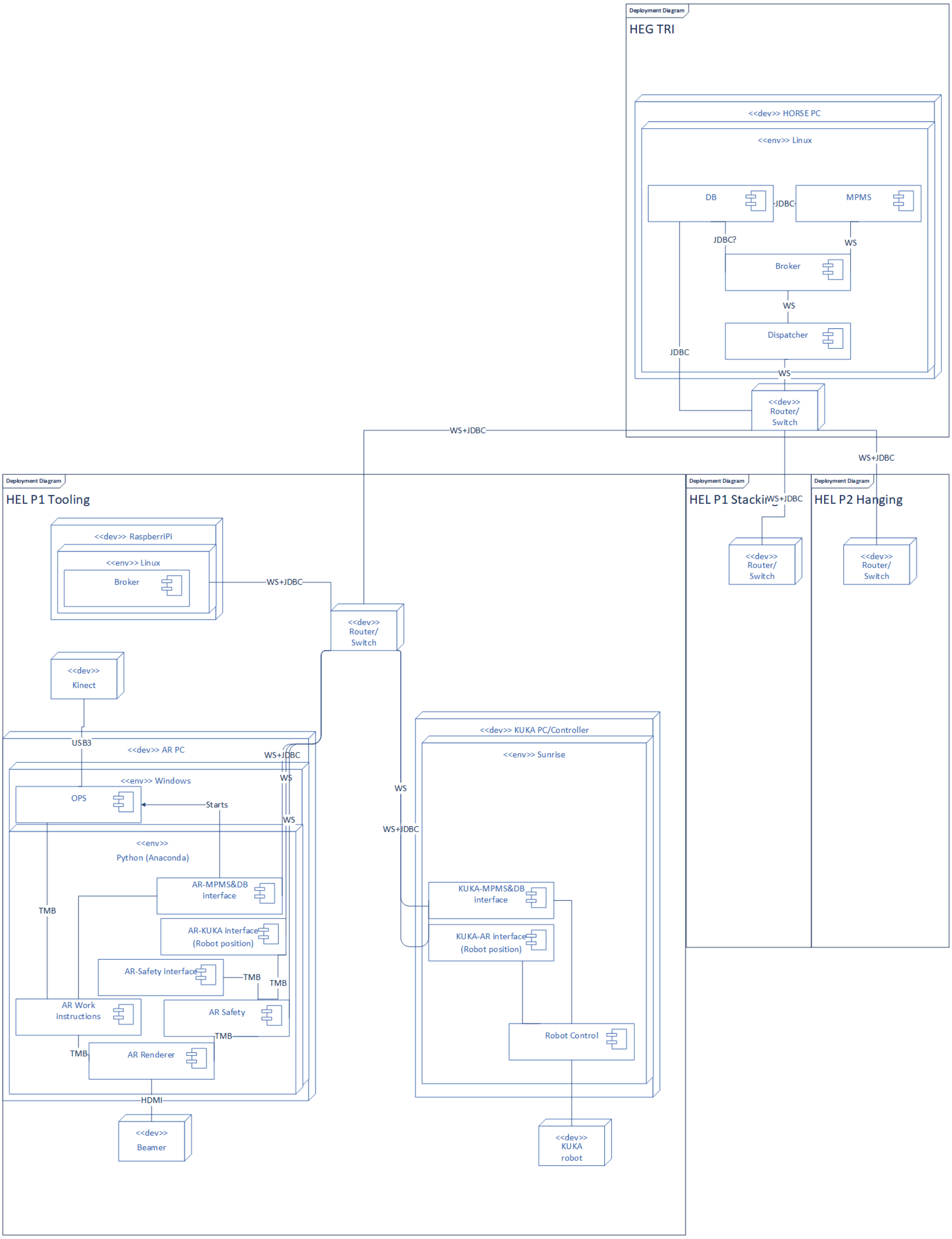

Figure 7: Deployment diagram for TRI pilot experiment

The deployment diagram elements are described in Table 8.

Table 8: Description of TRI deployment diagram elements

Element	Description
HORSE PC	The PC that runs the HORSE software.
DB	The HORSE database
MPMS	The HORSE MPMS component
Broker	The HORSE broker (part of the HORSE middleware component)
Dispatcher	The HORSE Messaging Dispatcher (part of the HORSE middleware component), mediating between the brokers
Router / Switch	A network router/switch for connectivity between the different devices.
Kinect	A Kinect camera
AR PC	The PC that runs the Augmented Reality for assembly module
OPS	Supplier of commercial AR system
AR-MPMS&DB interface	Interface between the AR and MPMS modules
AR-KUKA interface	Interface between the AR and the KUKA mobile platform
AR-Safety interface	Software module for visualizing preventive safety information
AR Work instructions	Software module for visualizing step-by-step guidance to the operator
AR Safety	Software module for calculating preventive safety information
AR Renderer	Software module for blending the safety and work instructions combining them into an immersive experience for the operator
Beamer	The beamer that projects the assembly instructions and other information.
KUKA PC / Controller	The controller PC of the KUKA mobile platform
KUKA-MPMS&DB interface	Interface between the MPMS and the KUKA mobile platform
Robot Control	The module within the KUKA controller that controls the KUKA mobile platform
KUKA robot	The KUKA mobile platform

3.3.3 Mechanical design

The mechanical design of the work cell is illustrated in Figure 8.

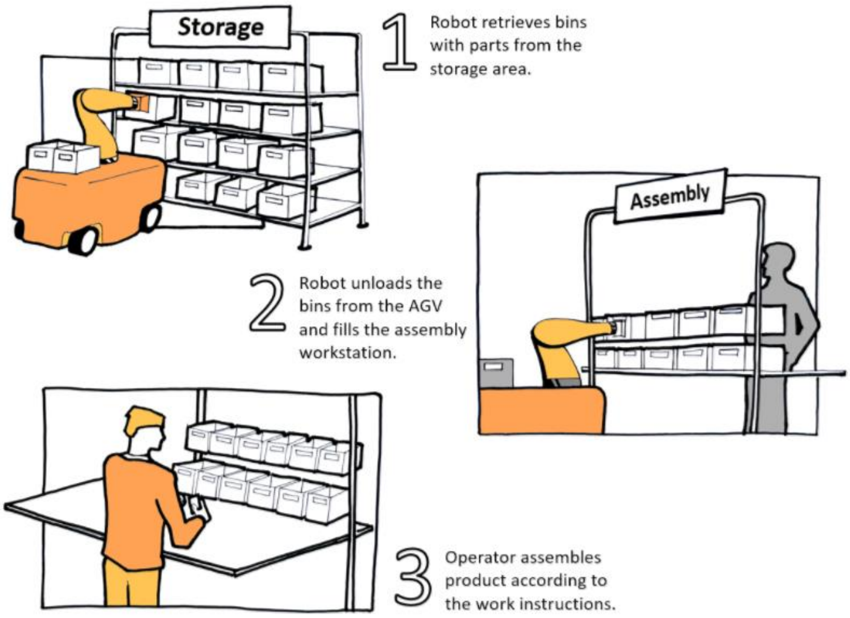

Figure 8: Mechanical design of TRI experiment (AR)

3.3.4 Equipment

The equipment needed for the execution of the experiment is summarized in Table 9.

Table 9: TRI equipment list

Item	Model/description
Robots for P1 and P2 material handling tasks	Universal Robots
Mobile robot for handling bins in the AR demonstrator	KUKA iiwa on KMR mobile platform
Workcell for the operator	AR workcell including depth camera and beamer
For running the AR software	PC-AR
For running the global part of the HORSE framework including MPMS	PC-Global
For operating the UR robot for the P1 and P2 scenario	PC-UR
TRI production equipment	Tooling bins, Material bins, racks, half-fabricates, tooling

3.3.5 HORSE software components deployed

The HORSE software components deployed are:

- Middleware
- MPMS
- FlexBe
- ROS-Bridge
- AR for assembly
- Database server

3.3.6 Safety aspects

The following aspects have been considered regarding safety:

- AR preventive safety: The AR safety gathers information from the depth camera and the robot coordinates to calculate if the human is in range of the robot. If so, the human is informed about the robots presence and instructed to move away. For more detail see D3.4
- On-Robot safety mechanisms of KUKA iiwa and KMR mobile platform
- Safety tests by CETIM on the UR robot, as installed by FZI

P1 unloading station is inserted in existing production area and Automated Guided Vehicle (AGV) clear access is required. It requires power and force limiting collaborative mode. UR10, as a so-called "collaborative robot", has this new advanced function. Maximum Force at Tool Center Point (TCP) is controlled from torque instantly measured at each axis.

Robot manufacturer is certifying a high level of performance of this safety function (PL=d, cat 2 according to 13849-1 (2016)). But as mentioned in the notice (and as for all existing robots), certain areas of the workspace should receive attention regarding pinching hazards. It is due to the physical properties of the robot arm.

Safe integration avoids hazards in non-collaborative area, as depicted in Figure 9 and Figure 10.

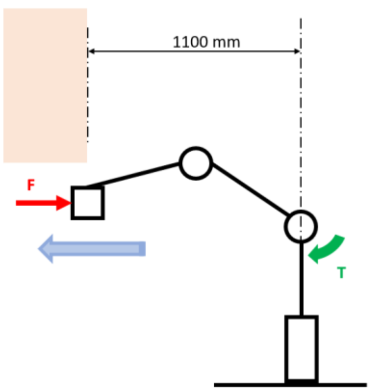

Figure 9: Radial motion wrist 1 joint at a distance of at least 1100 mm from the base of the robot

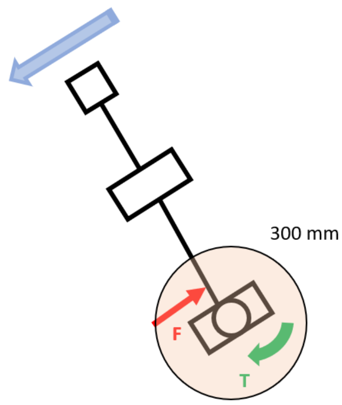

Figure 10: within 300 mm of the base of the robot, when moving in the tangential direction

But considering reasonably foreseeable misuse it is not possible to avoid possibility of chock at picking and deposit station.

Experience shows that robot trajectory programming (approach trajectory and speed) and general layout influences measured force. It can be understandable considering a great simplification in TCP force monitoring: we can consider that it is a torque monitoring equal to F x d. Therefore, we can reach non-acceptable force which will not be detected by torque monitoring (Figure 11 and Figure 12).

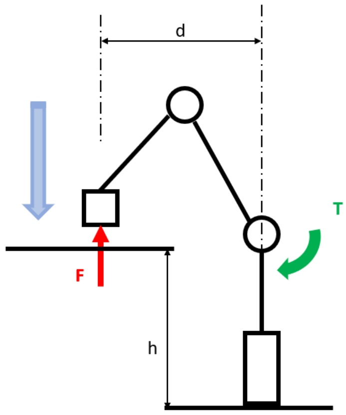

Figure 11: Not correct force monitoring at TCP -> d to be increased

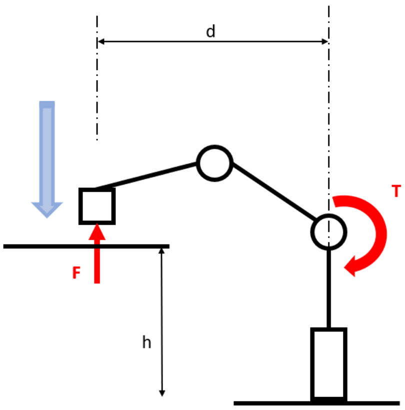

Figure 12: Correct force monitoring at TCP

There is no simulation tool available and it has been necessary to make shock measurement to have a general mapping of acceptable layout and speed.

In picking station position (d=1100 mm, h=130 mm): F transient =122 N for 280 N acceptable according to TS15066.

At deposit station (d>800 mm, -500 mm < h < 500 mm): F transient < 280 N acceptable according to TS15066.

Surface contact is more than .5 cm2 and it is also possible to validate maximal pressure available (560 N/cm2 according to TS15066.

Therefore, it is possible to justify in this specific application, that if a chock occurs considering reasonably foreseeable misuse, it is acceptable.

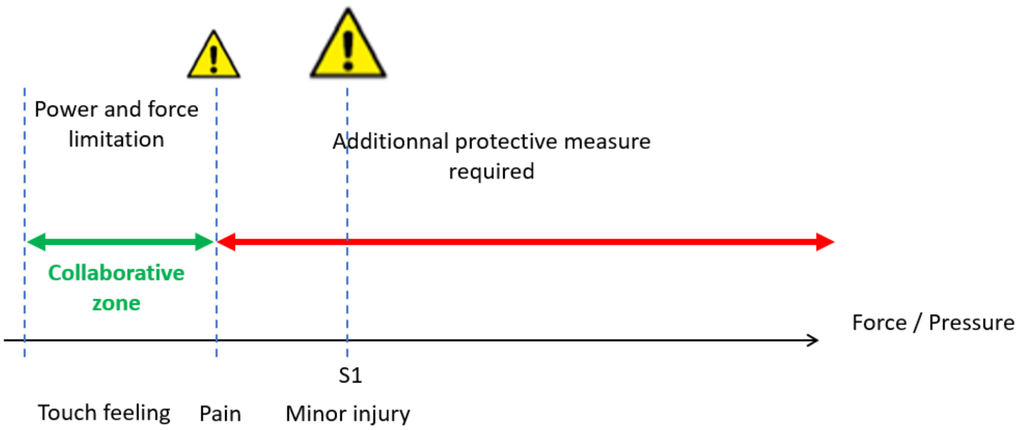

Figure 13: Illustration of consequences and protective measures with regard to applied force /pressure

4 Photo material

This section includes photos from the experiment labs and testing.

4.1 Robert Bosch España Fábrica de Castellet S.A.U. (BOS)

Figure 14: Conveyor belt for testing

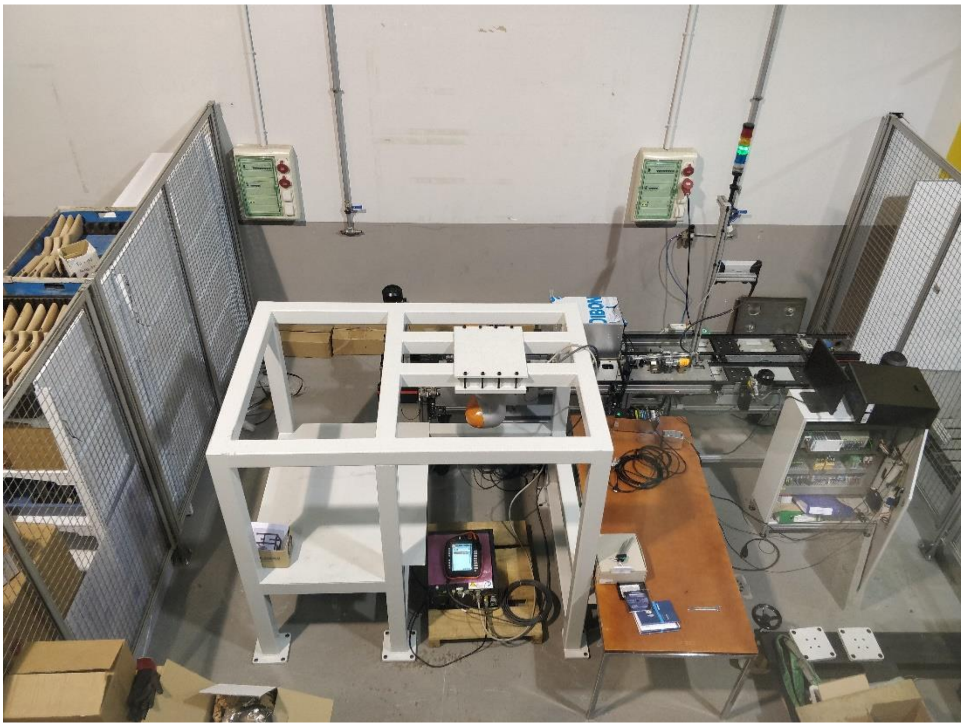

Figure 15: Testing lab for BOS pilot at Eurecat

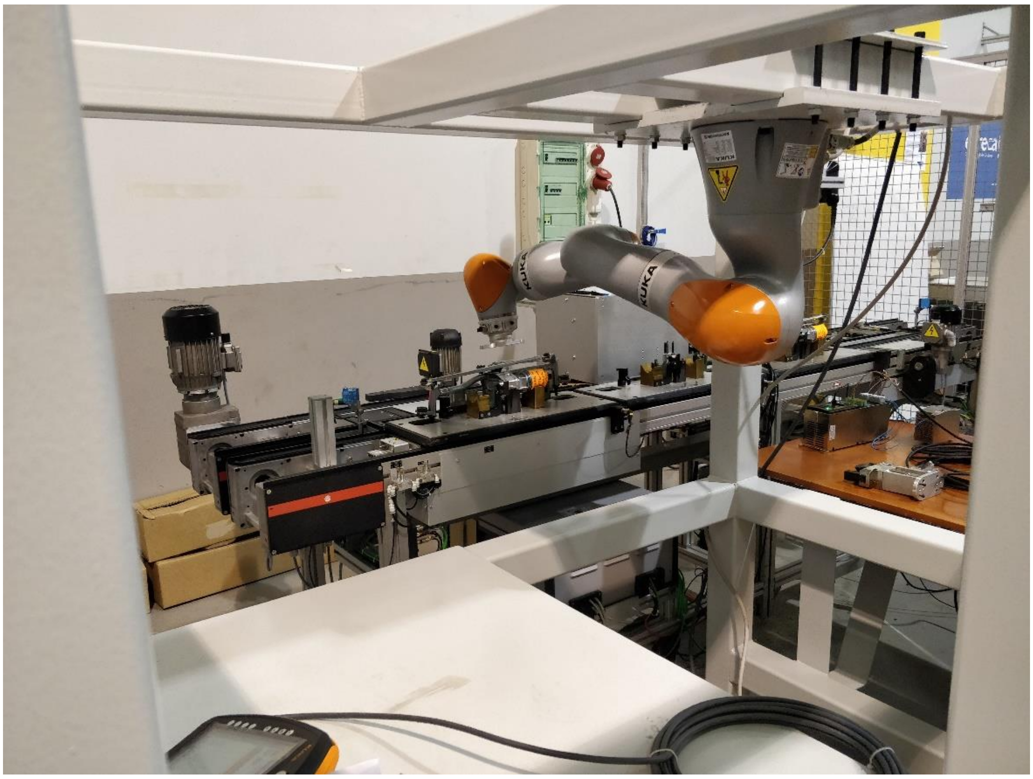

Figure 16: Testing lab for BOS pilot at Eurecat

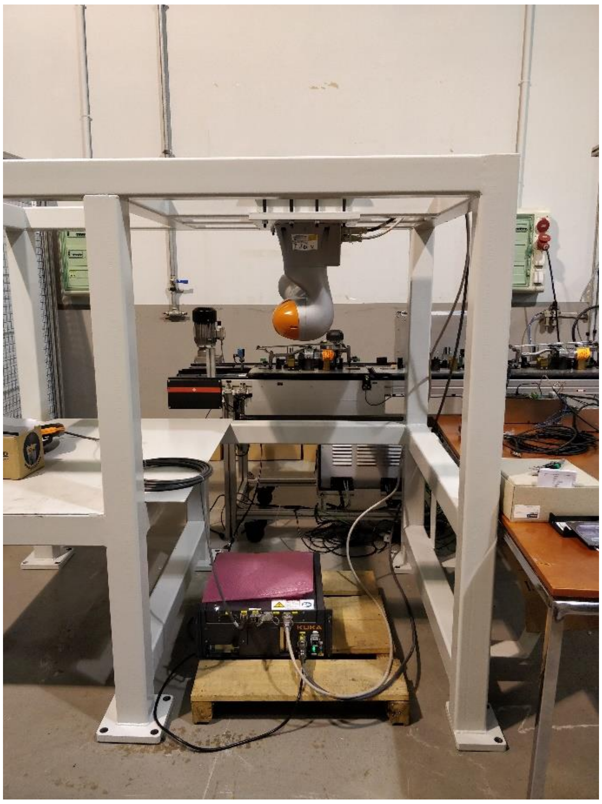

Figure 17: Testing lab for BOS pilot at Eurecat

Figure 18: Testing lab for BOS pilot at Eurecat

Figure 19: Testing augmented reality for BOS in TUM CC

4.2 Odlewnie Polskie S.A. (OPSA)

Figure 20: Learning by demonstration testing for OPSA in CEA CC

Figure 21: Cutting casting after learning by demonstration for OPSA in CEA CC

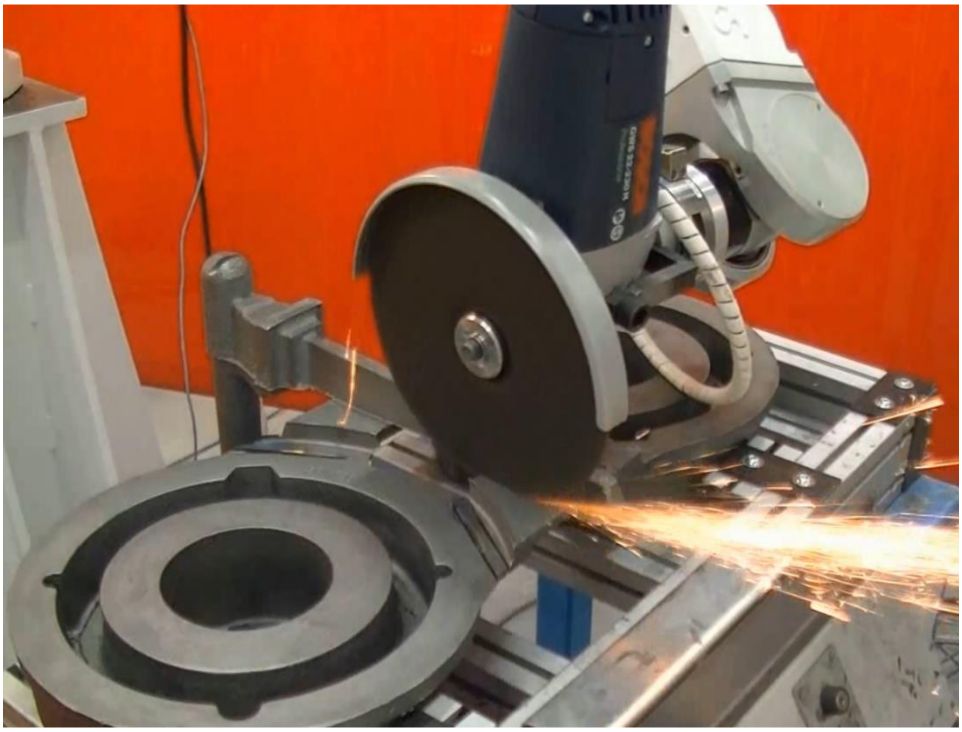

Figure 22: Cutting casting after learning by demonstration for OPSA in CEA CC (2)

4.3 Thomas Regout International (TRI)

On-site testing for the P1 – Tool Assembly, with the use of AR and mobile robot.

Figure 23: On site testing setup for TRI P1

Figure 24: On site testing setup for TRI P1 (2)

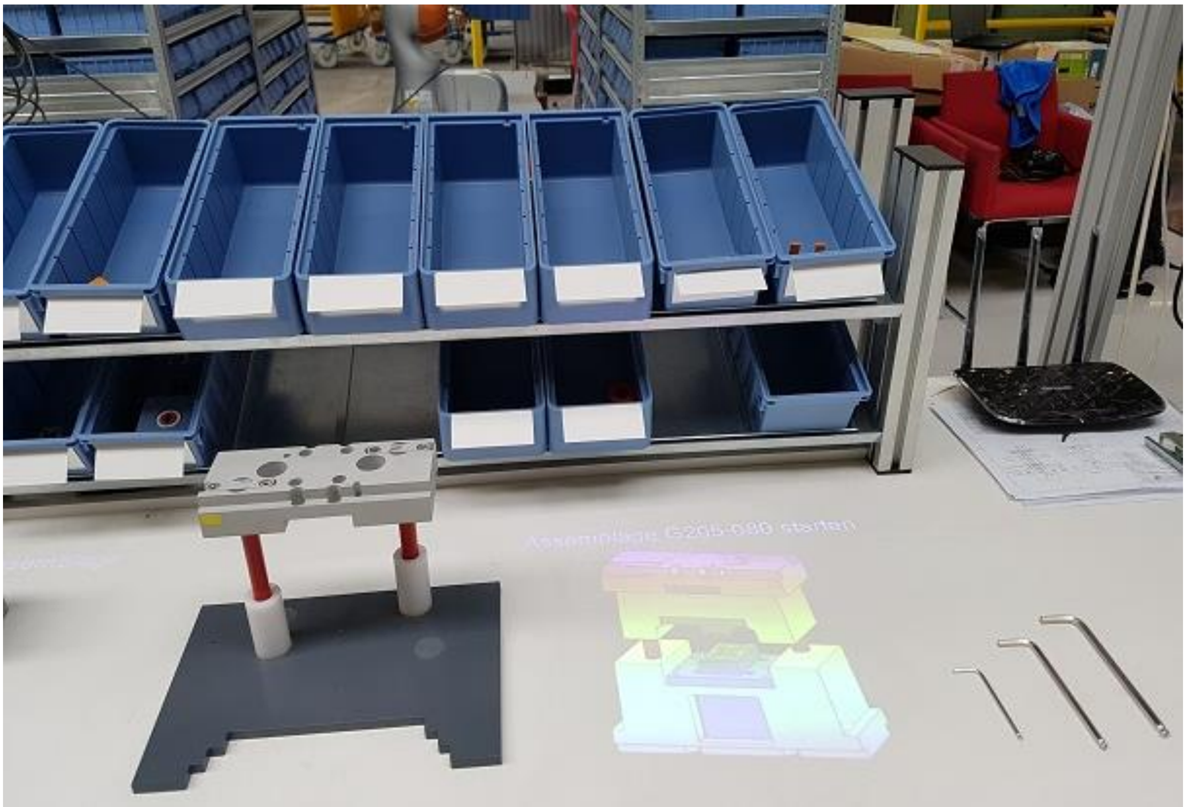

Figure 25: Work desk with AR for TRI P1

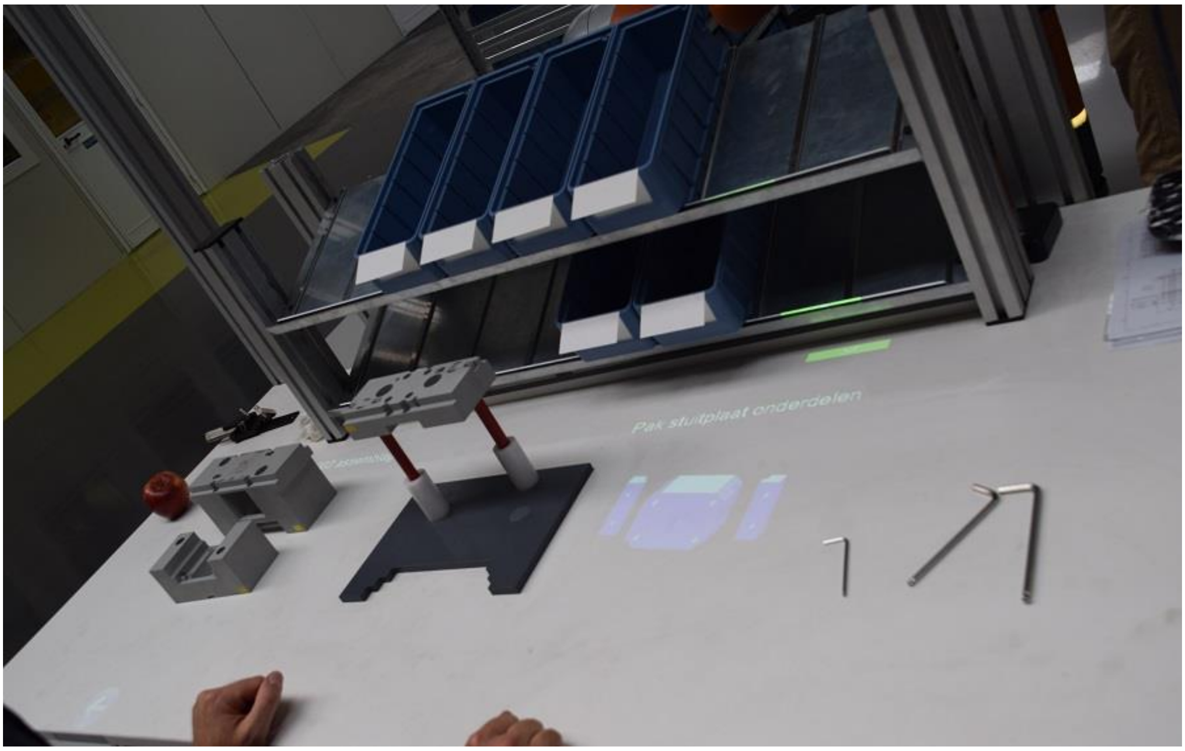

Figure 26: Work desk with AR for TRI P1 (2)

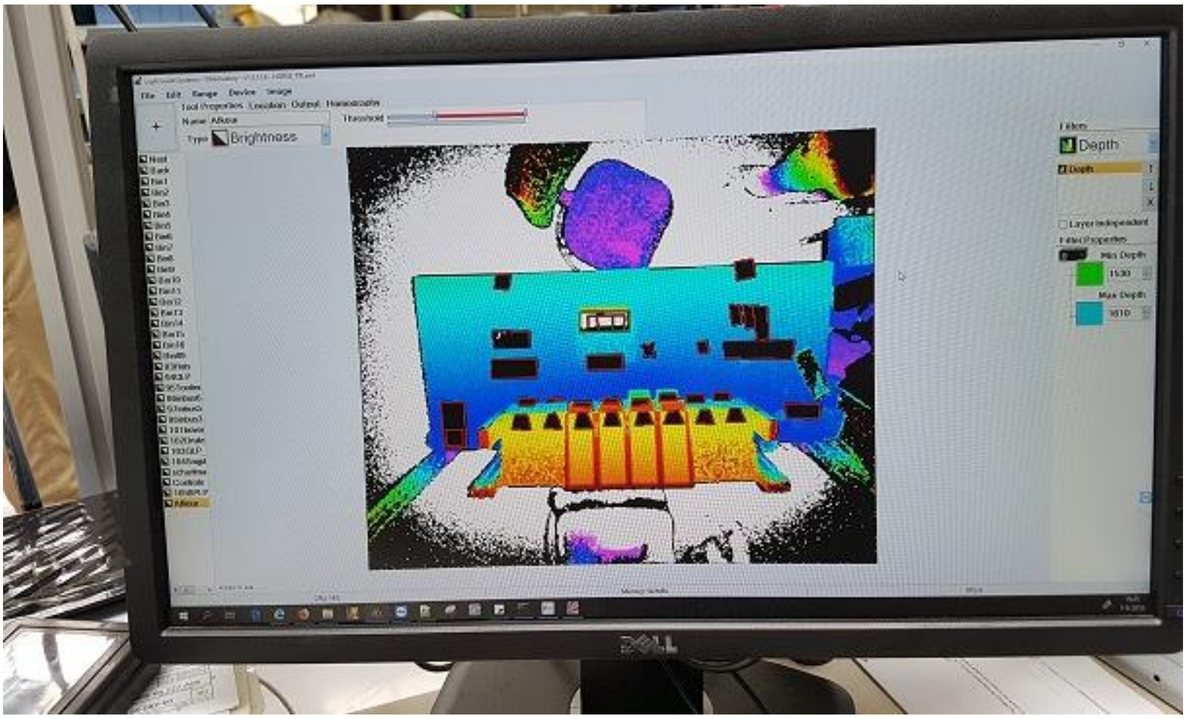

Figure 27: Monitoring of the work desk at TRI P1

Figure 28: Mobile robot picks up tooling box for TRI P1
(at the background: UR robot of P1 loading)

Figure 29: Placing tooling box in confined space for TRI P1

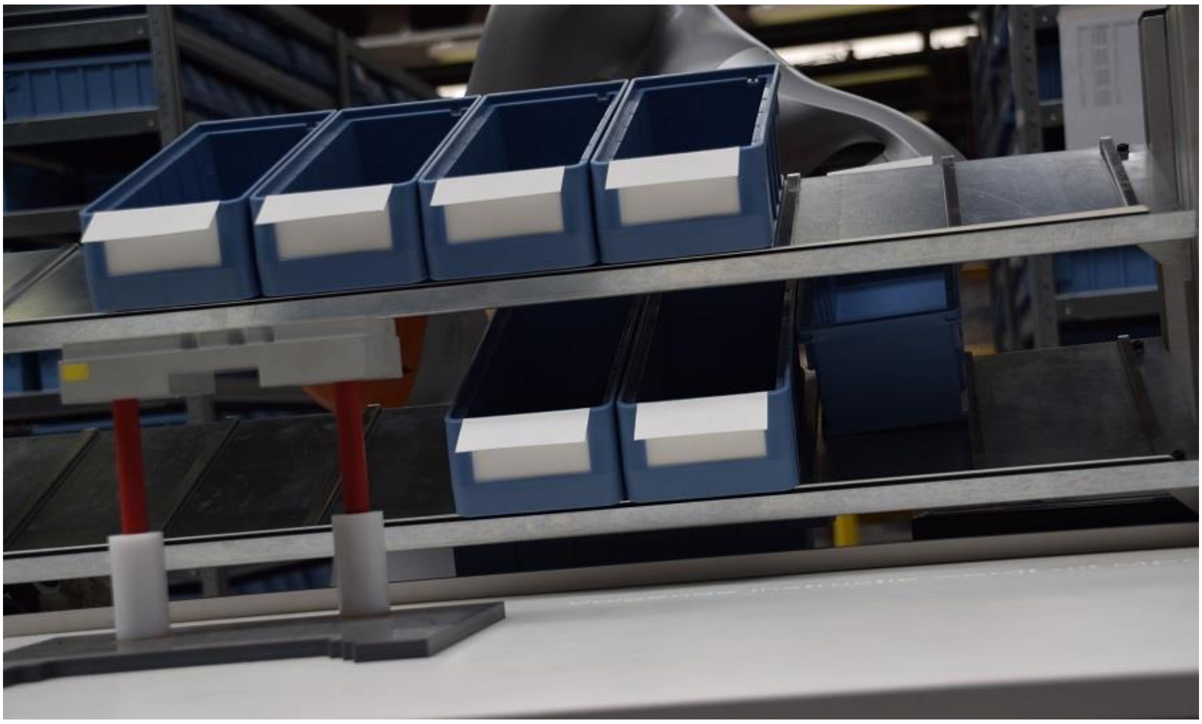

Figure 30: Placing tooling box in confined space for TRI P1 (2)

Figure 31: Mobile robot and worker in the same workspace (TRI P1)

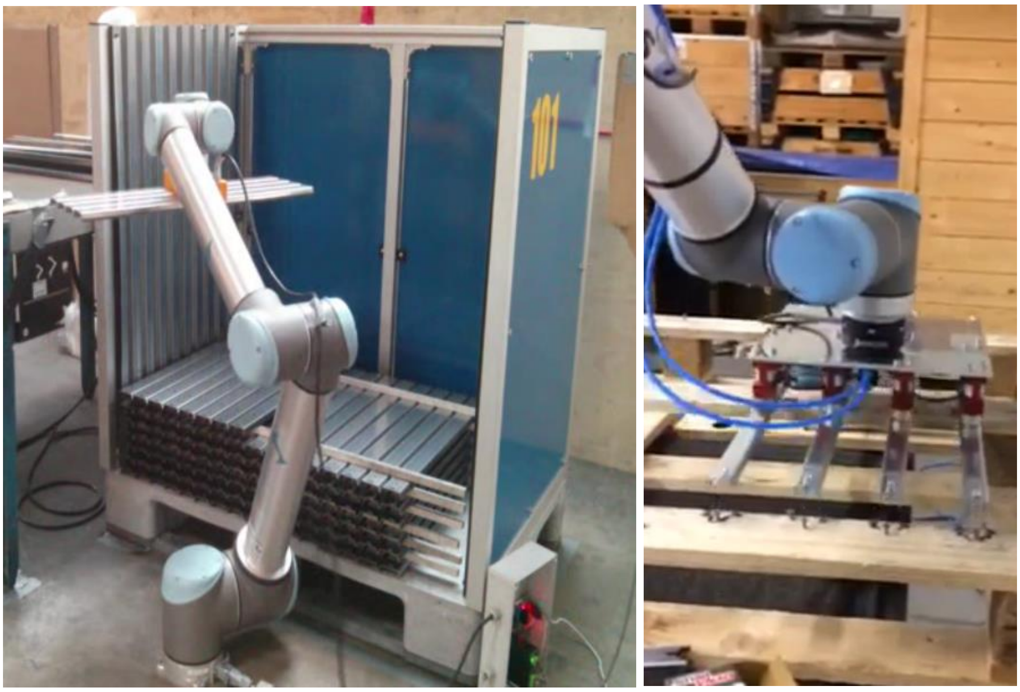

Figure 32: UR robots testing at TRI (left-P1, right-P2)

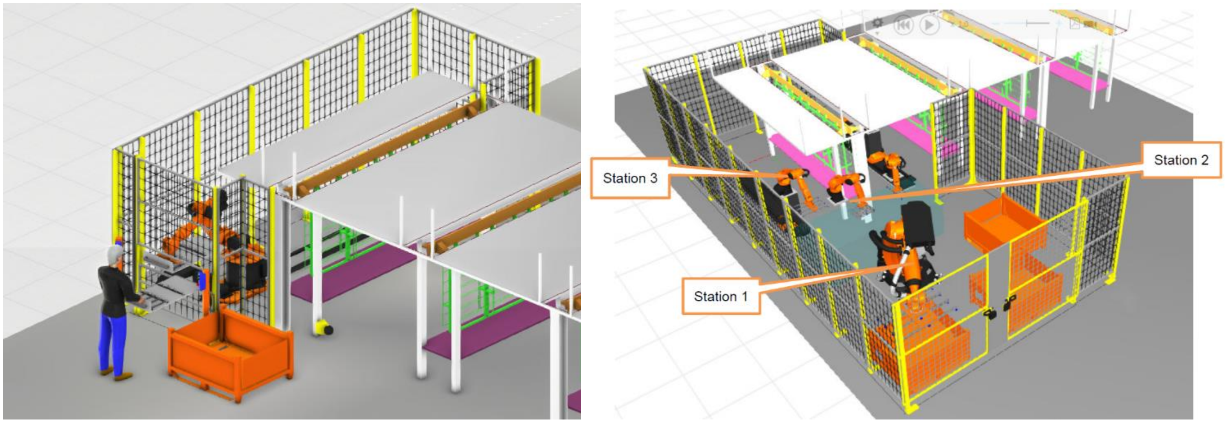

Figure 33: Trying alternative with simulation for TRI P2

5 Next steps

The first setups of the pilot experiments have been introduced in this report. The final deployment of HORSE at the pilot experiments will be presented in the follow-up deliverable of WP5, D5.3. The next steps for each pilot are:

- **BOS**: Verify the lab setup of the experiment and deploy in production.
- **TRI**: Deploy P1 solutions (Tool assembly and Loading) in production. Sign contract with external robotic integrator, verify P2 solution and deploy in production.
- **OPSA**: Sign contract with external robotic integrator, verify experimental setup in lab and deploy solution in production.

Annex A. Example interface messages

Some example interface messages used with the HORSE middleware are provided in this Annex.

A.1 BOS

Some example interface messages used in the BOS experiment are included below.

Task assignment message from HEG (MPMS) to HEL


```
  {'Topic': 'task_assigned',
  'Priority': '2',
  'SenderID':     'heg/global_execution/production_execution_control/91051701-fb73-11e7-be4e-
00059a3c7a00',
  'Receivers': 'rosbridge',
  'Type': '2',
  'Subtype': 'notification',
  'Timestamp': '20180117103317',
  'MessageID': '20180117103317',
  'ResponseMessageID': '',
  'Internal': 'true',
  'ExternalBrokers': '*',
  'SenderBroker': '',
  'Body': {'op': 'call_service',
  'service': '/task_request',
  'args': {'agent_ids': '1',
  'task_id': '3',
  'task_instance_id': '504b5bbb-55a5-11e7-81c4-2ae820524153',
  'process_instance_id': '81d29cf3-fb6d-11e7-8d69-5cab20524153'
}
}
}
```


Returning the check result from BOS Adapter (VisualControl over EtherCAT INF) to HEL/HTS


```
   {”Topic”:”org/horse/boschadapter/visual”,
    “Recipients”:” rosbridge”,
    “Priority”:”4”,
   ”Type”:”2”,
   ”Subtype”:”none”,
   ”Internal”:”true”,
   ”ExternalBrokers”:””,
    “SenderID”:”hel/local_execution/autagent_step_execution/bosch”,
    “Timestamp”:”12345678910”,
    “MessageID”:”3579249000”,
    “ResponseMessageID”:” 13579246810”,
    “ProtocolVersion”:”0.9”,
    “Body”:{ “op”:”call_service”,
    “service”:”/hel/local_execution/ht_supervisor/task_processor/visual”,
    “args”:{
    “ProductNumber”:”765234323299”,
    “PositionNumber:”25”,
    “ResultCode”:”1”,
    “ImageLink”:"/image/link/765234323299-25.bmp"
}
}
}
```


Activation/deactivation of the notification beacon - Instructions from HEL/HTS to BOS Adapter (Notification beacon over OPC-UA)


```
   {”Topic”:”org/horse/boschadapter/beacon”,
```

```
    “Recipients”:” hel/local_execution/autagent_step_execution/bosch”
    “Priority”:”4”,
   ”Type”:”2”,
   ”Subtype”:”none”,
   ”Internal”:”true”,
   ”ExternalBrokers”:”” ,
    “SenderID”:” rosbridge”,
    “Timestamp”:”12345678910”,
    “MessageID”:”3579249123”,
    “ResponseMessageID”:”0”,
    “ProtocolVersion”:”0.9”,
    “Body”:{
    “Operation”:”activate”/”deactivate”
}
}
```


A.2 TRI

AR-Work to MPMS


```
___CONTROL___{"ID": "hel/local_execution/humagent_step_execution", "Operation": "connect"}

___CONTROL___{"ID": "hel/local_execution/humagent_step_execution", "Operation": "disconnect"}

{'Topic': 'task_completed',
'Priority': '2',
'ResponseMessageID': '20170620115843',
'Receivers':      'heg/global_execution/production_execution_control/04c980ba-d1c0-11e7-8d1e-dc3e20524153',
'SenderID': 'hel/local_execution/humagent_step_execution',
'MessageID': '',
'Subtype': 'notification',
'Type': '2',
'Timestamp': ' '20170620120343 ',
'ExternalBrokers': '*',
'Internal': 'true',
'SenderBroker': '',
'Body':  {'EventID':  'EV108',  'Details':  {'process_instance_id':  'b6276ad0-5033-11e7-be1e-f65820524153', 'task_instance_id': '504b5bbb-55a5-11e7-81c4-2ae820524153', 'task_id': '19'},
'Variables':  {'aStringVariable':  {'value':'aStringValue'},  'aBooleanVariable':  {'value': true}}}
}
```


Robot to MPMS


```
 {'Topic': 'task_completed',
'Priority': '2',
'ResponseMessageID': '20180227115843',
'Receivers':      'heg/global_execution/production_execution_control/04c980ba-d1c0-11e7-8d1e-dc3e20524153',
'SenderID': 'hel/local_execution/autagent_step_execution',
'MessageID': '',
'Subtype': 'notification',
'Type': '2',
'Timestamp': '20180227120343',
'ExternalBrokers': '*',
'Internal': 'true',
'SenderBroker': '',
```

'Body': {'EventID': '', 'Details': {'process_instance_id': 'b6276ad0-5033-11e7-be1e-f65820524153', 'task_instance_id': '504b5bbb-55a5-11e7-81c4-2ae820524153', 'task_id': '21'}, 'Variables':{'aStringVariable': {'value':'aStringValue'}, 'aBooleanVariable': {'value': true}}}
}

AR-Safety to HMB

{"Topic":"safety_notification",
"Priority":"2",
"ResponseMessageID":"20180226130719",
"Receivers":"horse.localawareness.localsafetyguard",
"SenderID":"hel/local_execution/humagent_safety",
"MessageID":"",
"SubType":"safety_notification",
"Type":"2",
"Timestamp":"20180226130719",
"ExternalBrokers":"*",
"Internal":"true",
"SenderBroker":"",
"Body":{"EventID":"","Variables":{},"Details":{"process_instance_id":"b2d7cf98-1ae9-11e8-828f-00059a3c7a00","task_instance_id":"b2d86c10-1ae9-11e8-828f-00059a3c7a00","task_id":"19"}}
}