H2020 – FOF – 09 – 2015

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

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 680734

HORSE Competence Centres Scenarios

Report Identifier:			
Work-package, Task:	WP7	**Status – Version:**	2.0
Distribution Security:	PU	**Deliverable Type:**	R
Editor:	CEA		
Contributors:	TNO, TCS, TUM		
Reviewers:	FZI, TCS		
Quality Reviewer:	ED		

Keywords:	Competence Centre, robot, SME, use cases, scenarios, equipment, services, Framework, OSGi
Project website: www.horse-project.eu	

Table of Contents

List of Tables

List of Figures

Abbreviations

CC	Competence Centre
CEA	French Atomic Energy Commission
EC	European Commission
HORSE	Project acronym
MPMS	Manufacturing Process Management System Part of the HORSE framework that takes care of assigning actors to tasks according to the current production demand
SME	Small and Medium Enterprise
TCS	Toolmakers Cluster Slovenia
TNO	The Netherlands Organisation for Applied Scientific Research TNO
TUM	Technical University of Munich

Executive Summary

This document provides a first description of the robotics Competence Centres elaborated in the HORSE project.

A Competence Centre is a facility or an entity that provides leadership, evangelization, best practices, research, support and/or training for a focus area. Competence Centres are instruments promoted by the I4MS[1] program to support the European leadership in manufacturing through the adoption of ICT technologies. HORSE project supports the creation and development of four Competence Centres dedicated to robotics in France (Paris-Saclay), Germany (Munich), the Netherlands (Delft) and Slovenia (Celje). The Competence Centres will provide robotics equipment and services to facilitate the appropriation of robotics by manufacturing industries. All Competence Centres will provide places to assess and enhance the capacities of the OSGi-based HORSE framework developed during the project.

Competence Centres have a regional focus and will target the local actors having an interest in the deployment of ICT and more particularly robotics in manufacturing industries.

The Paris-Saclay Competence Centre at CEA in France focuses on manipulation and human robot collaboration with no fences for application like painting, welding, trimming, assembly and scenarios involving accurate control of the position, of the torque applied and on the velocity control. The TUM Competence Centre in Munich concentrates on pick and place operations for various types of handling applications in a production line where human robot cooperation with no fences is needed (co-assembly, logistics). The Competence Centre in Delft at TNO focuses on human-robot & AR solutions for manufacturing industries. The TNO CC aims at facilitating feasibility studies, demonstration, and knowledge transfer of the HORSE results to its stakeholder and in particular SMEs. The ROBOFLEX Competence Centre in Celje is a one-stop-shop for robotics for Slovenia; it is related to human-robot co-manipulation. The Competence Centre in Slovenia is built from the experience gained during the HORSE project in the three other Competence Centres.

The document provides as examples the first descriptions of the scenarios that will be covered in each of the Competence Centre. At this stage, the entire functionality of the HORSE framework is not known yet and the connection with the functionalities for business process management (ERP, MES, PLM, and SCADA) is not totally identified. In addition, equipment and services provided have large chances to be improved throughout the HORSE project. Therefore, the description of the equipment, services and scenarios covered by each of the Competence Centre will be refined and updated all along the HORSE project and gathered in a document about best practices on Competence Centre in robotics.

[1] ICT innovation for Manufacturing SMEs

1 Overview of the document

HORSE project is aiming to foster advanced manufacturing technology deployment in industries and especially SMEs. The notion of **Competence Centres** of I4MS will be implemented in the HORSE project to constitute one of the instruments to facilitate the appropriation of new technologies in European industry. HORSE's model of Competence Centres (CCs) will be established in four locations across Europe, in order to simplify usage and facilitate access to robotics by European industry and especially first-time users from SMEs. The HORSE Competence Centres will take their strength from their connection to the regional initiatives in Slovenia, the Netherlands, Germany and France, and from the existing experience, infrastructure and capabilities of the partners. The Competence Centres will be enriched during the project with the new integrated technologies that result from the HORSE framework. These functionalities will be demonstrated in the CCs in a generic way to showcase the technological possibilities offered by HORSE in order to be further adopted by other or new manufacturing players. In line with the EC initiative to support the European leadership in manufacturing through the adoption of ICT technologies, HORSE is an **implementation of the second phase of I4MS**[2], focusing on **Advanced Robotics** for manufacturing.

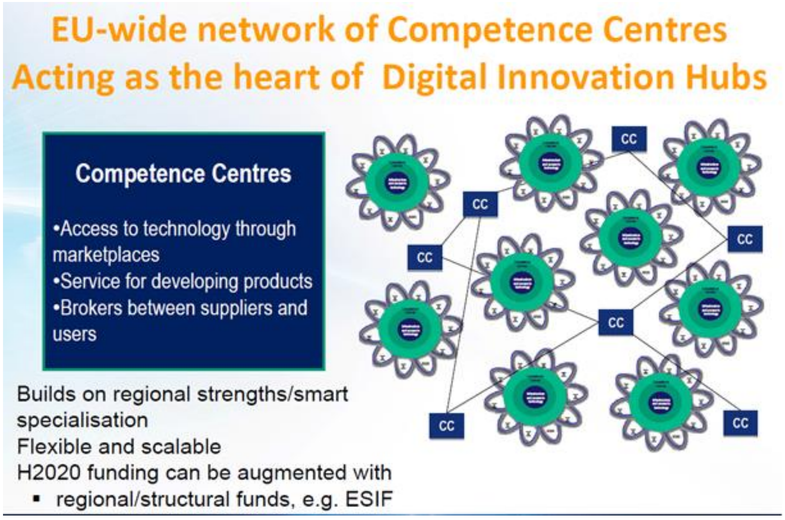


Figure 1-1: Competence Centres in European Union

This document (HORSE project Deliverable D7.1) describes scenarios that will be implemented in the Competence Centres to demonstrate possible uses of cooperation between humans and robots with no fences in manufacturing applications. These scenarios are meant to be representative of a large set of possible experiments in the industry. They are defined in agreement with the capacities offered by the CCs together with the equipment available, and according to the indications of industrial partners. The scenarios described in the current document do not make reference to the whole set of functionalities that will be available in the HORSE framework. This is due to the fact that the pilot scenarios are still under development and that the applications to be selected in the Open Call are not known yet. Therefore, this document will be maintained in the project as a living document, which will be updated with the possibilities that are created for demonstration, as the pilot scenarios are defined and the technological components become available. The three existing CCs have to be set up as well, starting from now, so that they can be used during the project as integration and validation infrastructure.

2 "The second phase of the I4MS initiative is dedicated to share best practices and lessons learnt in the fields of Advanced robotic solutions, Simulation, Laser based applications and sensors."

The document is organized as follows. In the first part, which includes Chapters 2, 3 and 4 the concept of Competence Centres and their role in the HORSE project is resituated and the organization of the activity within HORSE is described. Main HORSE concepts are being recalled as well as their connections with the concept of Competence Centres.

In Chapters 5, 6, 7 and 8 the Competence Centres that are being set up in HORSE in France, Germany, the Netherlands and Slovenia are described respectively, together with demonstration scenarios that they will cover. Equipment that is already in possession of the existing CCs, as well as the new equipment and services to be offered through the HORSE framework, are also described in the aforementioned sections. In Section 9, an insight for next steps and final perspective of the organization of the Competence Centres in HORSE is given.

2 Introduction to HORSE and the Competence Centres

2.1 What is HORSE

To stimulate interest in robotics by manufacturing SMEs, HORSE project sets up a set of different instruments

- The HORSE framework
- The HORSE pilot experiments
- The HORSE application experiments
- The HORSE Competence Centres

The HORSE framework contributes to the flexibility of the production, the improvement of quality, and the enhancement of safety. Based on the OSGi middleware, it is enabling management of collaborative robotics in a manufacturing environment and rapid reconfiguration of processes. It also allows end-to-end control of productivity and efficient use of resources. The reusable framework providing access to services for end-to-end production management and provides easy way to integrate with other existing legacy systems (ERP, MES, BPML, and PLC and existing robotic equipment) over existing standards and open interfaces. It enables the robots and other manufacturing equipment to be considered as centrally and remotely scheduled resources, dynamically allocated to new and varying production tasks in collaboration with humans in working cells without fences. A variety of services to support cooperation between human and robots in the same workspace and ensure safety are integrated including :

- Technologies for enabling autonomous and effective cooperation between humans and robots without barriers
- Multi-modal supervision and control modes for a variety of existing and novel robotic co-workers: cooperative robots (cobots) and "third hand" robots for diverse manufacturing applications.
- Innovative hybrid position/force control for intrinsically safe flexible robots
- Demonstration based robot programming techniques for an intuitive programming of robots tasks by non-robotics experts.
- Situation awareness software for manufacturing tasks where humans and robots are working at the same place with no fences will allow anticipating safety issues for the operators from observations of events and determination of actions to undertake according to the context. Situation awareness will apply to all agents in the work cell (humans, robots, cobots etc.)
- Immersive and innovative augmented reality technologies to provide assistance for manufacturing tasks in cooperation between humans and robots (tools assembly, quality checking and packaging).

The HORSE pilot experiments are used to gather initial requirements, identify demonstration use cases and validate the HORSE framework in real-life settings. The HORSE pilots are three partner industries in the Netherlands, Spain and Poland representing three different applications of robotics in manufacturing. Innovative collaborative applications are designed and developed for them adopting the HORSE framework and solving existing challenges,

The HORSE application experiments are selected after an open call which become beneficiaries of HORSE funding. Around ten experiments will be selected in order to assess the HORSE framework and to lead to:

1. development of new use cases and solving new industrial challenges.

2. further expansion of the HORSE framework to smoothen the integration of the technology by adopting machinery or other systems as much as possible.
3. collecting evidence of benefits to be promoted for further spreading the technology to new industrial challenges.
4. raising awareness of the results in various application domains, countries, and communities.

2.2 What are the Competence Centres?

2.2.1 Scope of the Competence Centres

Competence Centres are instruments implemented within the HORSE project. HORSE establishes them and provides feedback on the model, the best practices and the possibility to replicate the model in other regions in Europe.

Competence Centres in HORSE are physical locations providing expertise, equipment, service, advices and support in robotics technologies and applications in manufacturing. Competence Centres will offer expert advising support on deployment and fast assessment of robotics solutions in manufacturing.

Competence Centres become one-stop shops for manufacturing industries interested in robotics for their production line. They are places to support SMEs to overcome the difficulties they face in adopting robotics such as:

- low awareness of the technological improvements,
- low technical competence beyond their core business,
- hesitation to new long-term investment,
- concerns about advanced robotic solutions, especially Human-Robot-Interaction.

Competence Centres have a regional scope. They aim at capturing the industrial ecosystem in each region where they are implemented.

During the HORSE framework development they serve as laboratories where the pilot experiments are set up, integrated and tested before they are actually installed in the factories.

During the HORSE open call preparation and execution, Competence Centres will support the application experiments with knowledge and equipment, as they hold robotics equipment and supplies used in production lines. They will be available to support the adoption and customisation of HORSE framework for the Application Experiments selected by the Open Call.

After HORSE they will continue to operate as places for demonstrating the HORSE framework and implementing and assessing in settings representative of manufacturing installations use cases for SMEs. The lessons learnt from the Pilot Experiments, the operations in the Competence Centres and the Application Experiments, will be used to promote the experience in order to pave the way for further adoption by other manufacturers and SMEs in Europe. These will also be capitalised to further develop themselves to become examples for European Competence Centers in Robotics or other domains. The experience obtained during different phases of the project: setting up the CCs and deployment of the framework will be shared in a form of publicly available guides presenting the best practices established within the project. Thus, they will become regional market places and regional one-stop shops of robotics for manufacturing.

Since the beginning of the project and even after HORSE is completed, Competence Centers will be promoting HORSE framework and will be working on ensuring their own sustainability.

2.2.2 Location of the Competence Centres

Four Competence Centres are supported within the project. Three existing Competence Centres in France (Paris-Saclay, CEA), Germany (Munich, TUM), the Netherlands (Delft, TNO) will be further equipped and expanded, thus exploiting existing facilities, equipment, experience and network. The fourth one will be established by HORSE in Slovenia (Celje, TCS), and will be the seed for the future and a model for the deployment of Competence Centres in Europe.

Figure 2-1: Location of HORSE Competence Centres

CEA – CC Rue Noetzlin, 91190 Gif-sur-Yvette, France www.digiteo.fr	TNO – CC Bakemastraat 97K, 2628VK Delft, Netherlands
TUM – CC Schleißheimer Str. 90A, 85748 Garching bei München, Germany	ROBOFLEX SLOVENIA Kidričeva ulica 25, 3000 Celje, Slovenia

2.2.3 Services of Competence Centers

The goal of the Competence Centers is, on the other hand, to provide the necessary expertise to the manufacturing companies and to help them address some of the questions mentioned earlier. The scope of the expertise is not necessarily limited to the technical aspects. As the Competence Centers have a regional scope they are aiming at capturing the industrial ecosystem and the particular needs of the local companies. Depending on these characteristics, as well as the expertise and equipment available in the CC, the following services may be offered:

- General information (HORSE project objectives, description of tangible benefits for manufacturing SMEs, system integrators and other project stakeholders. *),
- Physical and/or virtual demonstration (HORSE scenarios),
- Access to related products and services (HORSE framework, *),

- Technical consulting (HORSE framework, *),
- Business consulting (*),
- The full scope of technical services (HORSE framework, *);
- Business engineering services (re-engineering of existing or introduction of new business models, and related business processes, organizational structure, information system and competencies change, *)
- Establishing contact with other stakeholders (*)
- Education, training, coaching (*)

The fields with (*) are specific to each CC. The services offered by each CC are the fruit of the relation established in the past by each CC with SMEs, integrators, industries, etc.

To summarize, the HORSE framework provides tools to introduce robotics in a manufacturing company, whereas the role of CCs is to provide the necessary knowledge, advice and support to adopt HORSE framework and customise it to their needs. Within the duration of the project the CCs will also be used to customize the HORSE framework for application in real settings and will help to define, implement, and assess it. After the end of the project they will provide continuous support to the companies using or planning to use the framework.

2.2.4 Sustainability of Competence Centres

The Competence Centres are interested to become self-sustainable after the end of the project. During HORSE they initiate their sustainability planning activities aiming to demonstrate the validity of the model and the EC vision for Competence Centres to rapidly assess and facilitate deployment of robotics solutions for manufacturing applications by providing a set of equipment and expertise at a regional scale in Europe. The sustainability of the Competence Centres work is ongoing and is adopting the approaches, experience and knowledge developed within the I4MS Digital Innovation Hubs in terms of business modelling, access to finance, ecosystem assessment, etc. These are adopted to support CCs in recognising their own competences and capabilities, in identifying the region needs and finally in defining their service offering.

3 Value of the HORSE framework and Competence Centres

The manufacturing industry and especially SMEs are in the process of assessing their needs with an eye on the improvement of their cost efficiency, safety and working conditions. Many of those needs can be fulfilled by adoption of robotic in their businesses. However, uptake of such solutions is limited by many challenges, which are addressed in literature [1] [2] [3] [4]. Some of the most important questions, raised by these needs assessment, are the following:

1. What are the tasks that can be automated in a factory and how to optimize the process?
2. What is the role (i.e. tasks) of the operator in the new (semi) automated factory?
3. How to eliminate occupational risk factors which may cause work-related diseases (e.g., musculoskeletal disorders, burn out or stress symptoms)?
4. How to ensure the operator safety?
5. How to guarantee a high productivity, product quality and process flexibility?
6. How to speed up solution adoption and reduce risk for failure?
7. How can Competence Centers survive to support innovation and provide continuous access to their services?
8. What is the best model for the IPR protection for technology transfer?
9. Where to find the relevant suppliers and the integrators?
10. How to start with identifying the appropriate solution?
11. What is return of investment of robotics?
12. What are the skills needed?
13. Who provides training?
14. How can the business model be improved?
15. How can new markets be addressed?

The HORSE project provides several tools aimed at facilitating access to and adoption of robotics solutions by the manufacturing industry including the development of the HORSE framework and establishment of the CCs. These structures are aiming to support SMEs to pursue and see answers and demonstrations to their questions.

4 HORSE CCs Demonstration Scenario

HORSE CCs scenarios are meant to demonstrate usage of cooperation between humans and robots with no fences in manufacturing applications. The scenarios will be defined with respect to the capacities offered by each CC, the equipment available, and according to the indications of industrial partners. In order to help SMEs to find solutions for their needs, a scenario template has been adopted in table 4.1 based on HORSE framework to show several functionalities according to each CC expertise.

In this template, the SMEs can identify the context of their challenges and find generic solutions from HORSE framework. This will be then further elaborated to fit the specific needs of the SME in order to select the relevant features that may answer to the identified problem. Finally, the HORSE framework perspective provides an indication on which modules from the framework that can be used to the specific solution.

In the next chapter, each CC exposes its context, organisation, equipment and services in addition to the demonstration scenarios within the HORSE framework.

<table>
<tr><td colspan="4">End-use perspective:
In the cells below, the end-user can describe his view on the problem at hand. This can be completed before going to the CC. The content is evaluated in the CC.</td></tr>
<tr><td>Context</td><td colspan="3"></td></tr>
<tr><td>Expected outcome/ Challenges</td><td colspan="3"></td></tr>
<tr><td>Expected benefits/ Impact
(From D2.1)</td><td colspan="2">☐ Safety
☐Production Monitoring
☐Comfortable working conditions
☐ Gain of productivity</td><td>☐Flexibility
☐ Cost Efficiency
☐Quality
☐ Cycle Time</td></tr>
<tr><td colspan="4">Technical mapping to HORSE framework:
In this section, the CC experts together with SME make the translation from a problem to a solution.</td></tr>
<tr><td>Task / User Story</td><td colspan="3">Work cell 1: ...</td></tr>
<tr><td>Benefit</td><td>HORSE component</td><td>Description</td><td>Hardware</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">HORSE framework perspective:
The section below illustrates the use of the HORSE framework.</td></tr>
<tr><td>Features from the HORSE Framework
(Aggregation level 2)</td><td colspan="2">☐Process Design
☐ Human Step Design
☐ Agent Design
☐Automated Step Design
☐Global Execution</td><td>☐ Work cell Design
☐ Global Awareness
☐Local Execution
☐Task Design
☐ Local Awareness</td></tr>
</table>

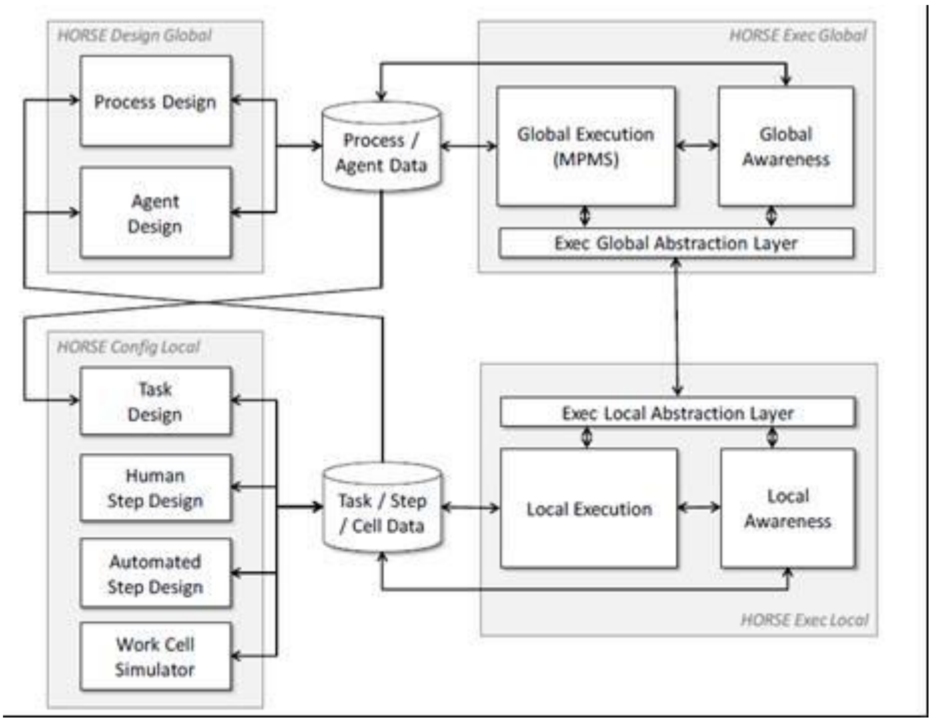
<table>
<tr>
<td>Architecture mapping
(explanation below)</td>
<td>
</td>
</tr>
</table>

Table 4-1 - Scenario Demonstration Template

Description of the features:

- **Process Design:** Design of the manufacturing process, i.e., what needs to happen in which order and with what requirements to the agents involved (role specifications).
- **Agent Design:** Design of manufacturing agents, i.e., the humans and machines (robots and other relevant automated machines) with their characteristics. In this scenario the module is used to define the roles and responsibilities to the human operator and to the robot.
- **Global Execution:** Supporting execution of manufacturing processes, i.e., making things happen; execution module developed within HORSE: MPMS.
- **Global Awareness:** supporting awareness about the global state of execution, i.e., observe things that happen and processing this into relevant signals for controlling execution.
- **Task Design:** Configuration of manufacturing tasks, i.e., the high-level activity spanning a work cell; note that this may require multiple agents of different kinds that each execute manufacturing steps. In this scenario the module is responsible for coordinating the actions of the robot and the human operator.
- **Human Step Design:** Configuration of manufacturing steps, i.e., the low-level procedures performed by the human. This module is responsible for defining the human operator actions: providing additional parts and rearranging the rack.
- **Automated Step Design:** Configuration of manufacturing steps, i.e., the low-level procedures performed by the robot. This module is responsible for defining the robot actions: picking up the part and putting it on the rack.
- **Local Execution:** Supporting execution of manufacturing tasks and steps.
- **Local Awareness:** Supporting awareness about the state of execution, i.e., observe things that happen and processing this into relevant signals for controlling execution

5 Paris-Saclay Competence Centre at CEA

5.1 Organization context of the Competence Centre

CEA (Atomic Energy Commission) is a French government-funded scientific and technological research organisation. CEA is active in three main fields: energy, information and health technologies, and defence and national security. CEA-LIST is a research institute inside CEA. Located at the heart of Saclay area (Paris region), the CEA LIST institute focuses its research activities on developing innovative technologies for smart and complex systems. Its R&D programmes, with potentially major economic and social implications, focuses on interactive systems (ambient intelligence), embedded systems (architecture, software and systems engineering), sensors and signal processing (industrial control systems, health, security and metrology). Dedicated to technological research, CEA LIST researchers and technicians strive to encourage innovation and technology transfer through long-term industrial partnerships. The dynamism of the institute's teams, their project-based culture and their consistently high standard of scientific excellence underpin this objective. CEA LIST is a partner for industry seeking breakthrough technology, from the initial concept down to working demonstrators.

The Paris-Saclay CC is strongly connected to the French program New Face of Industry in France[1] (Nouvelle France Industrielle) for industrial recovery (launched in 2013). This program aims at favouring growth in France through bringing products and services together and providing practical and coherent responses to the big challenges of the future. The PS-CC is also linked to national advanced manufacturing platforms such as Factory of the Future @Lorraine (FFLOR[2]) and FactoryLab[2]. Both of them are collaborative and multi-users platforms with many different technology providers, system integrators, SMEs which bring added-value solutions for end-users applications. The PS-CC will take advantage of the cooperation between CEA and CETIM to stimulate SMEs using robotics in the national projects CAPMEUP and Robot Start PME.

Paris-Saclay CC is constructed on top of the Paris-Saclay RIF[3]. The Paris-Saclay RIF has been set up during the FP7 ECHORD++ project and is dedicated to robotics. The RIF provides a set of robotics equipment usable for feasibility studies and demonstration in a large number of application domains including Healthcare (rehabilitation, surgery, assistive robotics), Manufacturing, Logistics, Security, Transport, Intervention in Hazardous environment, Agro industries (food processing), Field robotics.

The Paris-Saclay CC differentiates from the RIF in that it focuses on manufacturing application. It will include manufacturing equipment representative of a production line including robots. The Paris-Saclay CC is aiming at facilitating feasibility trials, demonstration, benchmarking and training. It is dedicated to the stimulation of new users or industries which do not have the capacities to purchase robotics equipment to make simple trials.

[1] New Face of Industry in France

[2] Factory of the Future @Lorraine ; FactoryLab

[3] Robotics Innovation Facility

5.2 Brief Description of the Paris-Saclay Competence Centre

The Paris-Saclay Centre of Competence is located within the premises of CEA Interactive Robotics Laboratory in Saclay, about 15km south west from Paris. It can be easily accessed from Paris and its two international airports using RATP and SNCF train services.

The laboratory includes 45 researchers and PhD students and covers an aggregate surface of 250 square meters. It is structured so as to provide technological innovation integrated into industrial prototypes. Core technologies are new robotic architectures, high performance actuation, force and supervised control, methods and software tools. Research activity carries on simplifying the interaction and ensuring safety of users in robotics.

Figure 5-1: Digiteo building location of Paris-Saclay Competence Centre

Figure 5-2: Paris-Saclay setting of the Competence Centre

5.3 Equipment and Services offered at Paris-Saclay

The Paris-Saclay Competence Centre offers capacities to make experiments in a realistic production line, owning robots, environmental sensors, and other typical equipment like conveyors and safety sensors. It is a place to speed up new applications in manufacturing by providing simplified access to industries into a realistic setting of a production line which involves human robot cooperation.

The Competence Centre will be relying on the HORSE framework and the services it relates (ERP, MES, BPM, PLC).

A set of robotics platforms with their controllers and supervisor for applications involving human robot cooperation with no fences is available: cobotics, co-working, co-manipulation, as well as equipment representative of manufacturing applications will be connected to it.

5.3.1 List of Equipment

- Two highly transparent robots SYBOT usable as collaborative robots or as a telerobotic slave robots
- One HAPTION haptic device usable as a master arm for teleoperation
- One A6.15 RB3D 7 DOFs collaborative robot
- One COBOMANIP from SARAZIN technology – collaborative robot for assistance to load handling
- STAUBLI RX90L and TX90XLTX90 6-axis industrial robot for tele-operation or hybrid command (force and position control)
- One KUKA arm IIWA
- One YUMI from ABB
- One UR10 from Universal Robotics
- One Artemis AGV (automated driverless vehicles) from BA system for intra logistics
- VR platform for virtual prototyping and training for industrial applications
- One 3D TV equipped with a real time simulation environment for physical interactions.
- One high performance 7 degrees of freedom upper limb exoskeleton ABLE from HAPTION
- One KINOVA 6 DOF JACO robot equipped with a 3 fingers gripper and mounted on a ROBOSOFT ROBULAB 10 mobile platform for feasibility tries

The listed equipment is presented on the pictures below. Other robots focused on cobotics and collaborative robotics could be added in the future.

Figure 5-3: SYBOT highly transparent robot arm

Figure 5-4: RB3D - A615

Figure 5-3: Intralogistics platform from BA system; Haption haptic device and STAUBLI TX90; TX90 from STAUBLI and COBOMANIP from SARAZIN

5.3.2 List of Software

- XDE interactive multi-physics simulation software runtime licences. XDE is a software suite developed at CEA since more than 12 years and featuring interactive multi-physics simulation of multibody systems, rigid and (simply) deformable objects and contacts as well as a biomechanical digital human able to interact with its environment. Composed of different modules (XDE Physics, X-Fitting, X-Robotics, X-Ergonomics), XDE has applications in Virtual Prototyping, ergonomic studies, maintenance in virtual and mixed reality, training to dexterous gestures, robotics and cobotics simulation
- TAO (Computer Assisted Telerobotics) runtime licences. TAO is a telerobotics controller developed at CEA since more than 20 years and featuring force feedback master/slave control, robotics trajectory control, Cartesian/joint position control, virtual Mechanisms, position/force homothetic setting, gripper pursuit with camera, 3D graphical supervisor.
- SCORE 3D supervisor runtime licences
- AVISO assistive robotics programming environment Entail
- **HORSE framework**

5.3.3 List of investments foreseen

- Sensors for safety
- Vision sensors (ROBOCEPTION)
- Conveyors
- Devices for quality control

5.3.4 List of Services

- Advices on the management of intellectual property rights
- Assistance to technology transfer
- Advices on how to deal with ethical, legal and societal issues in robotics
- Knowledge exchange workshops on robotics related issues
- Demonstration, feasibility tries of robotics for manufacturing
- Training on various types of robots
- Contacts with integrators

5.4 Paris-Saclay CC Scenarios

Three scenarios are proposed to highlight the usefulness of HORSE in Paris-Saclay CC. An overview is given by the Figure below.

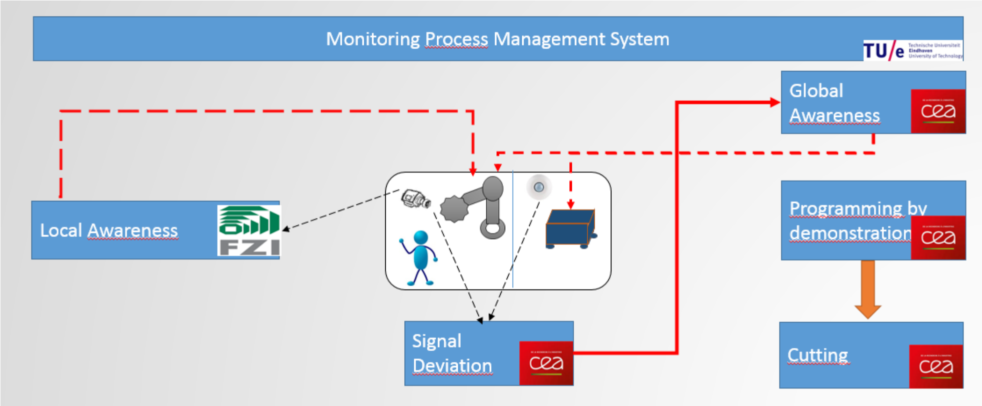


Figure 5-4 - Overview of the Paris-Saclay CC Scenario

The first scenario is focusing on working conditions and flexibility of the production line through programming by demonstration for the cutting task. The second scenario is focusing on operator safety through context analysis and behaviour adaptation. Information of the environment are gathered through a Kinect camera and a motion sensor. The third scenario is dedicated to local awareness through a Kinect camera where the geometric model of the robot is represented.

Table 5-1- Paris-Saclay CC Collaborative robotics Scenario

<table>
<tr><td colspan="2">End-use perspective:
In the cells below, the industry interested in adopting HORSE framework can see the generalized use case for a problem at hand. This can help them to recognize their needs. This template can be used for reaching the CC to start further elaboration and customization.</td></tr>
<tr><td>Context</td><td>The scenario demonstrates application of the HORSE framework for a foundry and focuses on the task of separation of parts from casting-grapes. The castings are usually grouped into assemblies that need to be separated from each other. Right now this task is predominantly realized through manual labor with heavy tools in often uncomfortable conditions. Such a situation leads to significant risk of injuries and development of musculoskeletal disorders. Moreover, the repetitive nature of the task, combined with tiresomeness affects the quality of the produced parts.

The foundry has a very diverse range of products consisting of over 1000 types of different castings. This makes it particularly difficult to robotize the production, as the cutting procedure needs to be programmed for each of the part types separately. Moreover, the dominance of manual labor makes it difficult to properly monitor and track the production status in the factory.</td></tr>
<tr><td>Expected outcome/ Challenges</td><td>The main outcome of the scenario is the increased quality of the working conditions. Using robots to perform the cutting removes the need for exhaustive manual labor and shifts the responsibilities of the human operator towards setting up the task and its monitoring. Moreover, the high repeatability of the robots positively affects the quality of the final products.

The main limitation for the robotization is overcome by using the programming by demonstration approach. The operator is able to intuitively program the robot to perform the cutting of a new part. The programming task is further augmented by using virtual guides restricting the movement of the end effector. Afterwards, the process can be repeated automatically, providing a very flexible solution.

All the elements are controlled by the Manufacturing Process Management System (MPMS), which is responsible for allocating tasks and tracking the production.</td></tr>
<tr><td>Expected benefits/ Impact (From D2.1)</td><td>☐ Safety ☒Flexibility
☒Production Monitoring ☐ Cost Efficiency
☒ Comfortable working conditions ☒ Quality
☒ Gain of productivity ☐ Cycle Time</td></tr>
<tr><td colspan="2">Technical mapping to HORSE framework:
In this section, the CC experts together with SME make the translation from a problem to a solution.</td></tr>
</table>

Task / User Story	Work cell 1: Castings separation station The tasks starts with the operator inputting the production parameters (type and number of parts etc.) into the MPMS, which then allocates the tasks and monitors their execution. Afterwards, the worker places parts in the fixture in the work station. Depending on the availability of the previously programmed trajectories either the autonomous cutting and separation or programming by demonstration are triggered. The hybrid force-position control system, embedded in the robot controller, reduces the vibrations during the cutting process, thus ensuring high quality of the produced parts. The results of the tasks are processed and stored by MPMS to provide traceability of the process.		
Benefit	HORSE component	Description	Hardware
Production monitoring	MPMS	The MPMS is responsible for monitoring the production process (number of parts, their types etc.), allocating and triggering tasks and dealing with the exceptions reported by components.	None – software component
Flexibility and re-configurability	Programming by demonstration Virtual guides HORSE Middleware	Programming by demonstration component allows defining the cutting trajectories for particular casting types in an easy and intuitive way. The programming is further augmented by the virtual guide mechanism, that restricts the movement of the robot tool to particular planes and/or lines. Thus, defining the cutting planes becomes even easier. The HORSE messaging middleware provides means to easily extend the system with additional components – e.g. safety measures, Augmented Reality assistance etc. thus increasing the flexibility of the solution.	The solution is hardware independent as long as a performant (cycle <1 ms) controller is available. The scenario is demonstrated using the ISYBOT robot arm.
Comfortable working conditions	Programming by demonstration Automatic cutting	Introduction of the programming by demonstration and automatic cutting removes the burden of manual separation of castings from the worker, and contributes to increased comfort. The worker's responsibilities are shifted from manual labour to setting up and monitoring the tasks.	
Quality	Automatic cutting	The high-accuracy of the automatic cutting contributes to the high quality of the end products. Moreover, the effects	

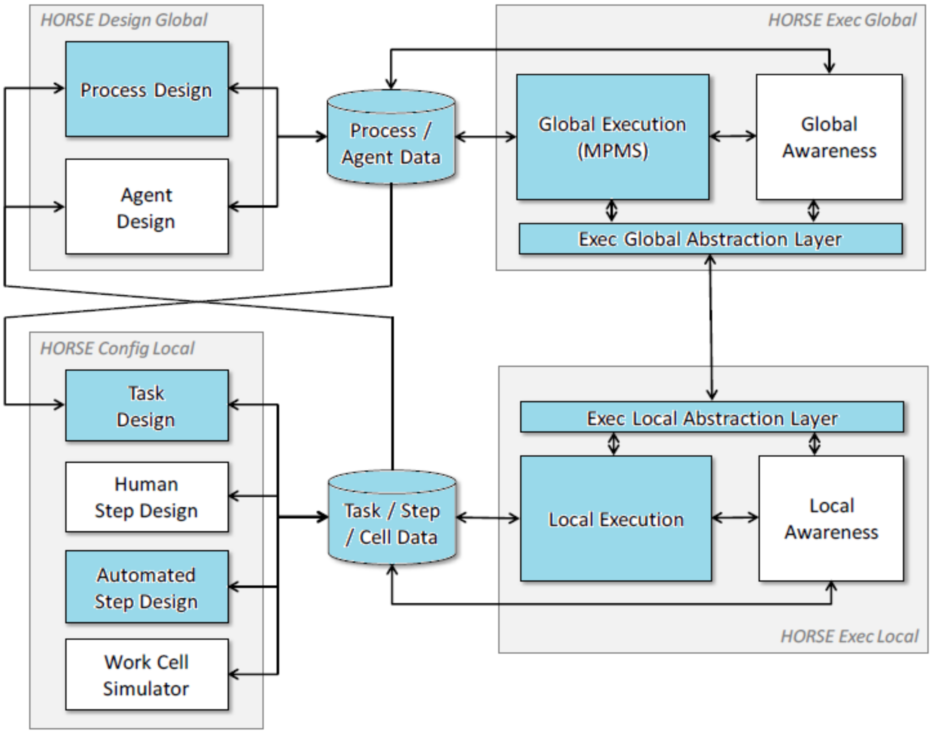
	Hybrid force-position control	of the cutting tool vibrations are reduces by the application of the hybrid force-position controller.	
HORSE framework perspective: The section below illustrates the use of the HORSE framework			
Features from the HORSE Framework	☒Process Design ☐ Human Step Design ☐ Agent Design ☒Automated Step Design ☒Global Execution	☐ Work cell Design ☐ Global Awareness ☒ Local Execution ☒ Task Design ☐ Local Awareness	
Architecture mapping			

Table 5-2- Paris-Saclay CC Global Awareness Scenario

<table>
<tr><td colspan="2">End-use perspective:
In the cells below, the industry interested in adopting HORSE framework can see the generalized use case for a problem at hand. This can help them to recognize their needs. This template can be used for reaching the CC to start further elaboration and customization.</td></tr>
<tr><td>Context</td><td>The scenario demonstrates application of the HORSE framework for a foundry and focuses on a collaborative robotic task. The task consists of parts separation from casting-grapes.

There are several risks related to the task itself and to the execution environment. Some situations may be dangerous for the human. For instance, during the cutting, the grinder blade can be broken. The human operator can also be hurt by the sparkles or by metal swarf. Several accidents may be caused only by the cutting task.

A foundry factory has reported that in the area of fettling division, they are mainly struggling with injures of the eyeballs. When metal swarf stuck in the eyeball of the operator, there is medical assistance needed to remove it. This happens once every 2 weeks.

On the other hand, in the case of several work cells where humans and robots work together, there could be a risk of collision when a mobile robot is moving from one work cell to another to carry objects.</td></tr>
<tr><td>Expected outcome/ Challenges</td><td>The main outcome of the scenario is to ensure human safety when robots and humans are working together. Using safety components to ensure humans safety and prevent them from critical situation will reduce risks of injuries.

A relevant representation of all the elements in the environment and distinguishing normal from abnormal events through an anomaly detection system will help to deduce the appropriate decisions to take in a given situation.

All the elements are controlled by the Manufacturing Process Management System (MPMS), which is responsible for allocating tasks and tracking the production.</td></tr>
<tr><td>Expected benefits/ Impact (From D2.1)</td><td>☒ Safety   ☐Flexibility
☒Production Monitoring   ☐ Cost Efficiency
☒Comfortable working conditions   ☐ Quality
☐ Gain of productivity   ☐ Cycle Time</td></tr>
<tr><td colspan="2">Technical mapping to HORSE framework:
In this section, the CC experts together with SME make the translation from a problem to a solution.</td></tr>
</table>

<table>
<tr><td>Task / User Story</td><td colspan="3">Work cell 1: Castings separation station with situation awareness

The task starts with the operator inputting the production parameters (type and number of parts etc.) into the MPMS, which then allocates the tasks and monitors their execution. Afterwards, the situation awareness component is launched and the robot executes its task.

A human operator moves towards the robot when the latter is performing the cutting. The anomaly detection system detects that the human operator is entering a non-safe zone and the situation awareness mechanism decides to stop the robot until the human moves away.

The human operator then leaves the work cell to go to another work cell. A mobile base is bringing an object but have no visibility that in 1 minute, the human operator will cross its way. The anomaly detection system reports a risk of collision and the mobile base adapts its trajectory to avoid colliding with the human operator.</td></tr>
<tr><td>Benefit</td><td>HORSE component</td><td>Description</td><td>Hardware</td></tr>
<tr><td>Production monitoring</td><td>MPMS</td><td>The MPMS is responsible for monitoring the production process, allocating and triggering tasks and dealing with the exceptions reported by components.</td><td>None – software component</td></tr>
<tr><td>Safety</td><td>Signal deviation

Global Safety Guard</td><td>The signal deviation/anomaly detection component detects anomalies in the system. It relies on data from the environment (the sensors, the data related to the robot, to the process, to the task, etc.). This system analyses the data and is able to interpret them to report whether an anomaly may occur.

The global safety guard component is responsible of reasoning and analyzing the current situation when an anomaly is detected and to trigger the appropriate decision associated to the reported anomaly.</td><td>The solution is hardware independent, it relies on raw data from all the sensors and agents in the environment</td></tr>
<tr><td>Comfortable working conditions</td><td>Programming by demonstration

Task automation</td><td>Introduction of the programming by demonstration and automatic cutting removes the burden of manual separation of castings from the worker, and contributes to increased comfort. The worker’s responsibilities are shifted from manual labour to setting up and monitoring the tasks.</td><td>The solution is hardware independent as long as a performant (cycle <1 ms) controller is available. The scenario is demonstrated using the ISYBOT robot arm.</td></tr>
<tr><td colspan="4">HORSE framework perspective:</td></tr>
</table>

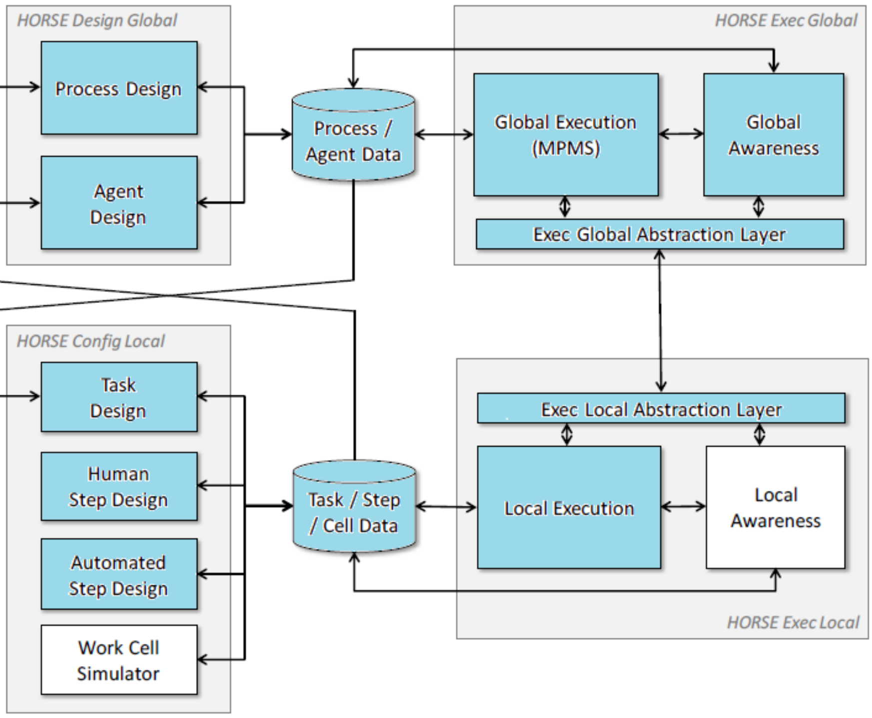
The section below illustrates the use of the HORSE framework.		
Features from the HORSE Framework	☒Process Design ☒Human Step Design ☒ Agent Design ☒Automated Step Design ☒Global Execution	☐ Work cell Design ☒ Global Awareness ☒ Local Execution ☒ Task Design ☐ Local Awareness
Architecture mapping		

Table 5-3- Paris Saclay CC Local Awareness Scenario

<table>
<tr><td colspan="4">End-use perspective:
In the cells below, the industry interested in adopting HORSE framework can see the generalized use case for a problem at hand. This can help them to recognize their needs. This template can be used for reaching the CC to start further elaboration and customization.</td></tr>
<tr><td>Context</td><td colspan="3">The scenario demonstrates application of the HORSE framework for a task execution where a robot arm is moving from one point to another automatically in close contact with a human. The robot needs to adapt its trajectory by an online manner. Otherwise the robot has to wait for the human to clear its workspace, which would lead to a robot waiting most of the time.</td></tr>
<tr><td>Expected outcome/ Challenges</td><td colspan="3">The robot must be able to adapt its speed and its trajectory to prevent from possible collisions with the operator.</td></tr>
<tr><td>Expected benefits/ Impact (From D2.1)</td><td colspan="3">☒ Safety
☐Flexibility
☒Production Monitoring
☐ Cost Efficiency
☐Comfortable working conditions
☐ Quality
☐ Gain of productivity
☐ Cycle Time</td></tr>
<tr><td colspan="4">Technical mapping to HORSE framework:
In this section, the CC experts together with SME make the translation from a problem to a solution.</td></tr>
<tr><td>Task / User Story</td><td colspan="3">Work cell 1: Castings separation station with local awareness
The tasks starts with the operator inputting the production parameters (type and number of parts etc.) into the MPMS, which then allocates the tasks and monitors their execution.
The local environment is captured with 3D perception systems and then transferred into a GPU-optimized environment model. The robot and its planned motions are also represented as GPU environment model. By taking advantage of the thousands of parallel threads on the GPU and the large memory it is possible to evaluate the current planned path (swept volumes) for collisions. The robot detects collisions in advance and can react and replan in a very fast and efficient manner, leading to less collisions and an increased productivity.</td></tr>
<tr><td>Benefit</td><td>HORSE component</td><td>Description</td><td>Hardware</td></tr>
<tr><td>Production monitoring</td><td>MPMS</td><td>The MPMS is responsible for monitoring the production process (number of parts, their types</td><td>None – software component</td></tr>
</table>

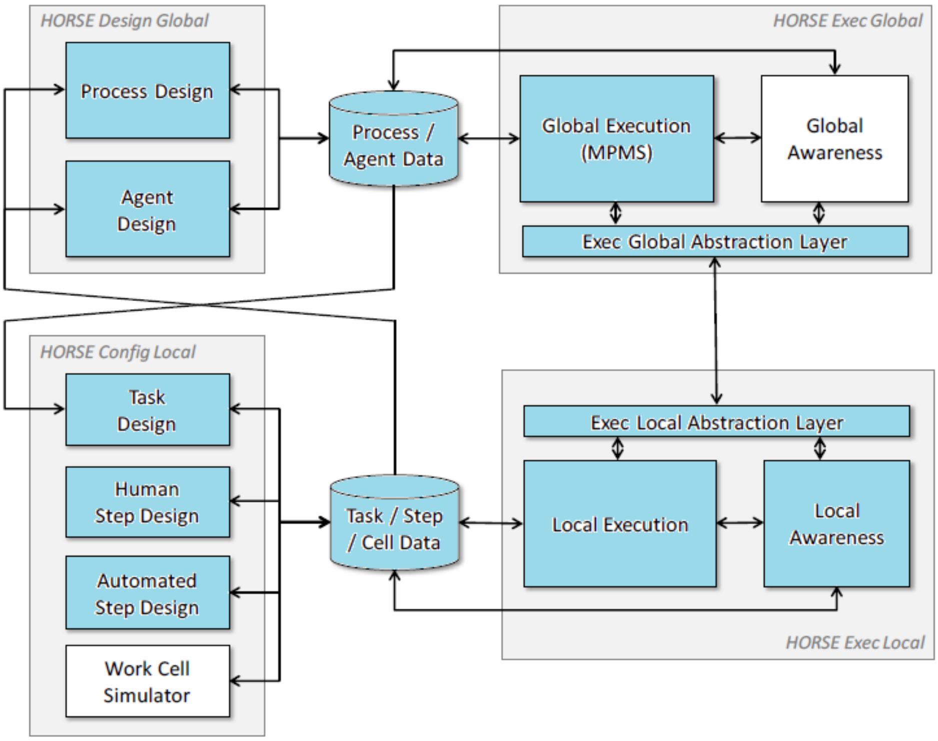
		etc.), allocating and triggering tasks and dealing with the exceptions reported by components.	
Safety	Collision prediction and prevention	This component is responsible of evaluating the the current planned path and is able to detect collisions in advance. A replanning is done online to adapt the trajectory of the robot depending on the current human position.	Any ROS-compatible 3D camera and CUDA-compatible GPU

HORSE framework perspective:

The section below illustrates the use of the HORSE framework.

Features from the HORSE Framework		
	☒Process Design	☐ Work cell Design
	☐ Human Step Design	☐ Global Awareness
	☐ Agent Design	☒ Local Execution
	☒Automated Step Design	☒ Task Design
	☒Global Execution	☒ Local Awareness

Architecture mapping



6 CC TNO

6.1 Organization context and brief description of the TNO Competence Centre

TNO is an independent organization for applied research in the Netherlands with 2,600 professionals. The mission of TNO is to connect people and knowledge to create innovations that boost the competitive strength of industry and the well-being of society in a sustainable way. TNO works in collaboration with partners and focus on innovations in five domains.

- Industry, for a strong, internationally competitive business community.
- Healthy Living, for a fit, healthy and productive population.
- Defence & Security, for decisive action in an uncertain world.
- Energy, for faster progress towards a low-carbon energy system.
- Urbanisation, to innovate for dynamic urban regions.

In the domain of Industry, TNO targets at strengthening the manufacturing industries by developing, transferring and implementing knowledge and technology for practical applications in industry.

Like in other countries in Europe, the Netherlands is developing programmes and Fieldlabs on Smart Industry in line with Industry 4.0 in Germany. In the Netherlands TNO is one of the key players within Smart Industry. There is a strong connection between the TNO Competence Centre and the national Dutch programme **Smart Industry**, http://www.smartindustry.nl/en/.

TNO Competence Centre, being established at TNO within the frame of HORSE, focuses on zero-defect manufacturing and flexible assembly including short changeover times for small quantities and high variety of products. Both require a high degree of flexible automation, optimized cooperation between humans and robots and (augmented reality) assistance of human operators.

The TNO Competence Centre aims at an environment where SMEs can get familiar with existing technology solutions for their challenges in flexible manufacturing. This familiarization aims to remove the barriers that restrict SMEs to actually adopt advanced robotics and AR technologies. The TNO CC focuses on facilitating feasibility studies, demonstration, and knowledge transfer of the HORSE results to its stakeholder and in particular SMEs. Core technologies are human-robot collaboration and interaction, inspection & vision technologies and operator support systems, using Augmented Reality. Regarding these core technologies, the TNO Competence Center is to provide expertise, support, and infrastructure to SMEs, facilitating research-based knowledge transfer to its SMEs ecosystem.

The vision for the TNO CC is to act as a one-stop shop for local industry, facilitating flexible robotization and digitization of manufacturing processes. Therefore, the CC and its partners will provide: access to technical expertise and research-based innovation in human robot collaborative systems and augmented reality, infrastructure to develop proofs of concept and perform initial tests, contacts to system integrators and hardware providers, advice and support in technical and social aspects of robotization.

The TNO Competence Centre is located in Delft. It can be easily accessed from Amsterdam Schiphol Airport and from Rotterdam/The Hague Airport. The layout of the Competence Centre is developed in the HORSE project in close collaboration with the Smart Industry network.

TNO is initiator of the Competence Centre. Relevant stakeholders of TNO CC are:

- OEM and suppliers (manufacturers) of parts

- End-users in manufacturing, and the agro food industry,
- System integrators
- Suppliers of robots (systems)
- Universities (Technical and Social Scientists)

There are strong connections too between the TNO Competence Centre and **Robovalley**, located in Delft (http://www.robovalley.com/), and **I-botics** (http://i-botics.com).

In RoboValley (in Delft) 170 robotics researchers (TU Delft Robotics) from a multitude of fields collaborate with other experts, entrepreneurs and decision makers in both public and private sectors. RoboValley plays a leading role in the development of the next generation robotics.

I-botics is a Joint Innovation Centre for Interaction Robotics which has been recently founded by TNO and University of Twente. I-botics is an open innovation centre and aims at developing knowledge and technology for value adding Robotic solutions. Two research lines have been carefully identified and selected: tele-robotics and exoskeletons

6.2 Equipment and services offered at TNO Competence Centre

6.2.1 List of equipment and software:

Current layout of the CC

- 2 Collaborative robot arms: KUKA LRB iiwa with a human-robot interaction safe R800 gripper (Figure 6-3)
- LRMate200iB
- HORSE framework
- Access to engineering software (Matlab, Python, CAD, etc.)
- Industrial (3D) cameras and Kinect camera's
- Computers for supervision and control
- Beamers
- OPS Light Guide systems
- AR Software
- Physical assembly work station (Figure 6-4)

Human Measurement systems available in TNO

- Human movement registration systems: XSENS MVN and KINECT (see Figure 6-1 and Figure 6-2)
- Muscle activity measurement system: EMG
- Eye tracking & emotional face reader
- Cognitive load registration system (e.g. VIG track)
- Force plate or alternatives to record forces for biomechanical analysis
- Heart rate registration devices

Future equipment:

- Cobot: UR 5 or Sawyer
- Digital Work Instruction Platform: Visual Factory or similar
- Vision sensors
- Franka

6.2.2 List of services to be offered:

- Development of proof of concepts and testing human robot collaboration and operator support systems
- Evaluation of new technologies for/ in human robot collaborative systems and operator support
- Demonstration of use cases on human robot collaboration and operator support systems
- Hands-on sessions on human robot collaboration and operator support
- SME Support in feasibility and pre-design: technical, human factors, (physical & mental load), task allocation, safety issues, business case
- Assistance to technology transfer
- Knowledge exchange in workshops
- Networking (e.g. with integrators, hardware providers etc.)

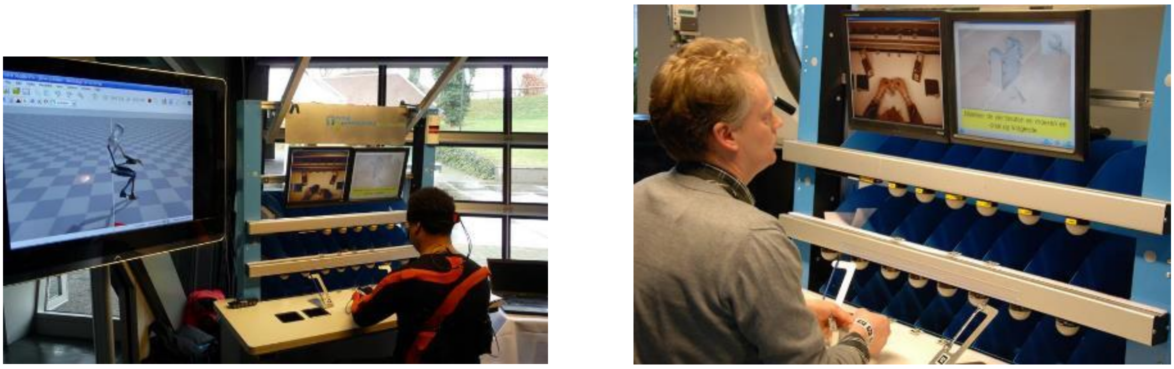


Figure 6-1: TNO assembly working cell: work instructions are presented making use of augmented reality. Working postures and movements can be measured and assessed by Xsens and Kinect.

Figure 6-2: TNO Human movement and posture registration systems: Xsens and Kinect

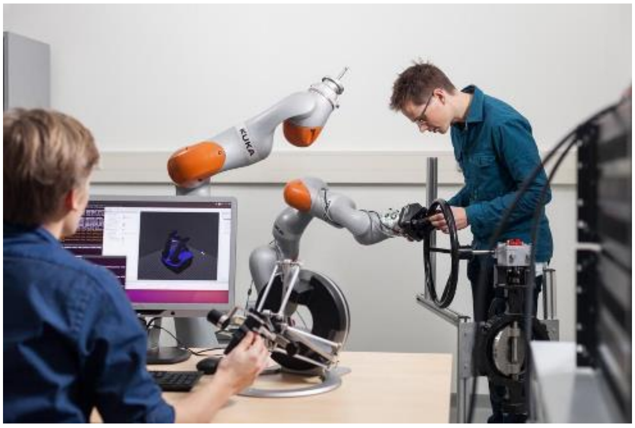


Figure 6-3: Robotic arms in TNO CC controlled by teleoperation device

Figure 6-4: Augmented reality setup in with beamer projecting work instructions on assembly table

6.3 TNO CC Scenarios

Table 6-1: Scenario 1 – Assembly use case

<table>
<tr><td colspan="4">End-use perspective:
In the cells below, the industry interested in adopting HORSE framework can see the generalized use case for a problem at hand. This can help them to recognize their needs. This template can be used for reaching the CC to start further elaboration and customization.</td></tr>
<tr><td>Context</td><td colspan="3">The scenario demonstrates the application of the HORSE framework to an assembly process done by a human. At TRI different stamping modules are configured for their products. In the order of 10000 configurations are possible with the current tooling. The operator currently has to interpret the end product drawings and search for the correct tooling parts in the warehouse. After the parts are gathered, they are integrated in a complex assembly without further instruction by experienced operators. To get sufficient experience to be able to do this work, operators need 3 years of on the job training. When the operator is interrupted from his work for other processes in the factory, it is difficult for the operator to continue his work when returning to the assembly task. The task is difficult to learn and prone to error.</td></tr>
<tr><td>Expected outcome/ Challenges</td><td colspan="3">The main outcome of this scenario is an easier and less error prone way to assemble the complex assembly without changing the current product.
The solution in mind is to use augmented reality to give step-by-step assembly instructions in such a way that unexperienced operators can do the job. This puts less stress on the few experienced operators and makes it easier to continue work after interruptions.</td></tr>
<tr><td>Expected benefits/ Impact (From D2.1)</td><td colspan="3">☐ Safety ☒ Flexibility
☐Production Monitoring ☐ Cost Efficiency
☒Comfortable working conditions ☒ Quality
☒ Gain of productivity ☐ Cycle Time</td></tr>
<tr><td colspan="4">Technical mapping to HORSE framework:
In this section, the CC experts together with SME make the translation from a problem to a solution.</td></tr>
<tr><td>Task / User Story</td><td colspan="3">The task starts when the operator gets instruction to assemble a tooling configuration. He enters the tooling-id into the user interface or this is already pushed by a MPMS/ERP system. The human receives step by step visual instructions by means of images and or video and or highlighting parts to assemble the tooling. The goal is that both experienced and un-experienced operators can use the solution.</td></tr>
<tr><td>Benefit</td><td>HORSE component</td><td>Description</td><td>Hardware</td></tr>
<tr><td>Comfortable working conditions</td><td>AR work instructions</td><td>Strain is relieved from the operator since he only has to follow instructions rather than figure out how to assemble</td><td>Beamer, 3D camera, camera, PC</td></tr>
</table>

Gain of productivity	AR work instructions	The operator finishes his task faster because the task is less demanding. There is less strain on the operator. He needs to follow instructions rather than figure out what to do.	Beamer, 3D camera, camera, PC
Flexibility	AR work instructions	The operator can easily be called away for another task and return to the assembly task. Alternatively the task can be completed by another operator.	Beamer, 3D camera, camera, PC
Quality	AR work instructions	By following well-prepared instructions, the system is more fault tolerant. Clear instructions on orientation of parts are provided if parts fit in more than 1 way.	Beamer, 3D camera, camera, PC

HORSE framework perspective:

The section below illustrates the use of the HORSE framework.

Features from the HORSE Framework		
	☐Process Design	☐ Work cell Design
	☒ Human Step Design	☐ Global Awareness
	☐ Agent Design	☒Local Execution
	☐Automated Step Design	☐Task Design
	☐Global Execution	☐ Local Awareness

Architecture mapping

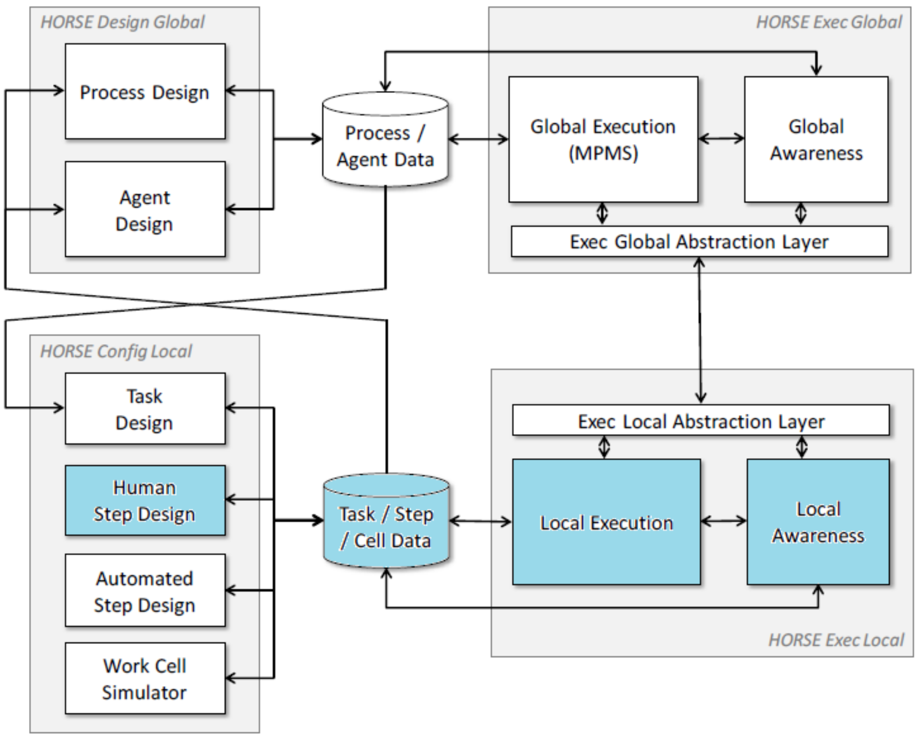


Table 1-2: Scenario 3 – The safety instructions

<table>
<tr><td colspan="4">End-use perspective:
In the cells below, the industry interested in adopting HORSE framework can see the generalized use case for a problem at hand. This can help them to recognize their needs. This template can be used for reaching the CC to start further elaboration and customization.</td></tr>
<tr><td>Context</td><td colspan="3">A worker needs to enter the robot operating space to do a reconfiguration. The robot is not surrounded by fences, such that the operator can enter easily. This creates the risk that the operator enters this area un-intended, causing a stop of the robot and therefore production. This un-intended action needs to be prevented.</td></tr>
<tr><td>Expected outcome/ Challenges</td><td colspan="3">The main outcome of this scenario is a non-intrusive way of informing the worker that a robot is near and that his actions possibly hinder the robot. (reducing its productivity)
The task is to support the operator by visual instructions to know where he/she can move without interfering with robot operations. This is known as preventive safety, a system that avoids the necessity of engaging the actual safety system.</td></tr>
<tr><td>Expected benefits/ Impact (From D2.1)</td><td colspan="3">☒ Safety
☐ Production Monitoring
☒ Comfortable working conditions
☐ Gain of productivity
☐ Flexibility
☐ Cost Efficiency
☐ Quality
☐ Cycle Time</td></tr>
<tr><td colspan="4">Technical mapping to HORSE framework:
In this section, the CC experts together with SME make the translation from a problem to a solution.</td></tr>
<tr><td>Task / User Story</td><td colspan="3">Work cell P2: Mounting steel profiles and reconfiguration of rods
The task is always active when the robot is putting the steel profiles on the rods. If a human enters this area unintended, he will be warned by visual instructions. Optionally additive signals can be added but are not preferred since they are less easily confined to the single worker.
When the robot is done with his task. The human can enter the robot area without hindering the robot. The human can now reconfigure the rods for the next batch.</td></tr>
<tr><td>Benefit</td><td>HORSE component</td><td>Description</td><td>Hardware</td></tr>
<tr><td>Safety</td><td>Local awareness and local execution</td><td>The human is detected</td><td>Sensor to detect human</td></tr>
<tr><td>Comfortable working conditions</td><td>AR preventive safety instructions</td><td>The operator is warned in a soft manner that he is entering an area where he should not be.</td><td>Beamer, camera, PC</td></tr>
</table>

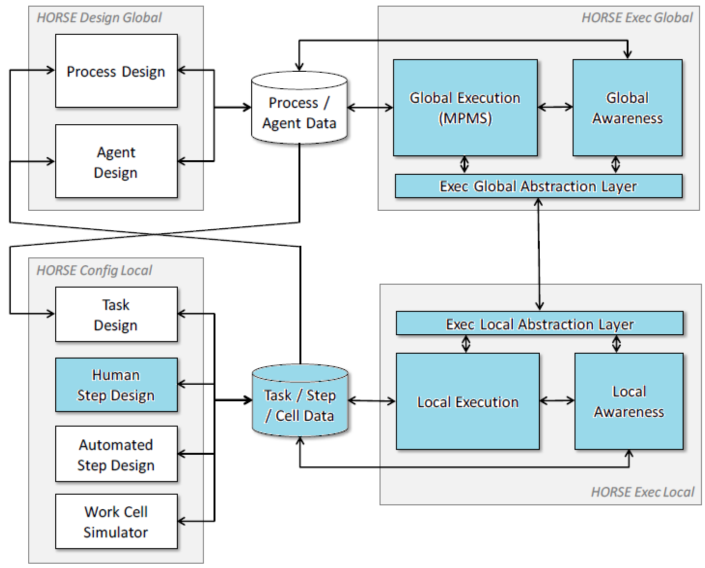
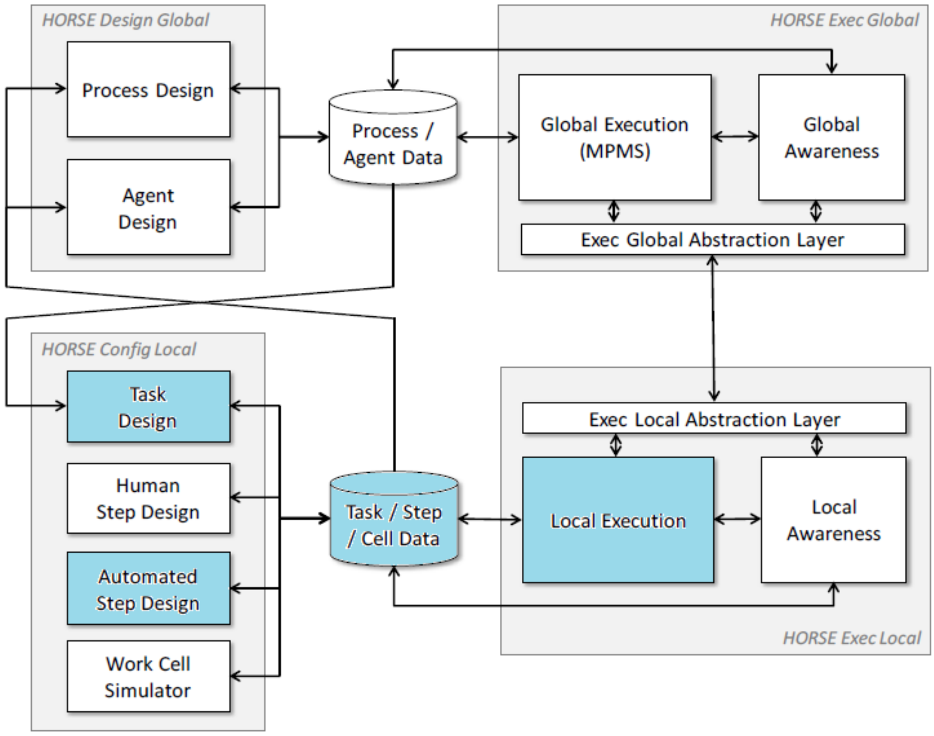
HORSE framework perspective: The section below illustrates the use of the HORSE framework.		
Features from the HORSE Framework	☐Process Design ☒ Human Step Design ☐ Agent Design ☐Automated Step Design ☒Global Execution	☐ Work cell Design ☒ Global Awareness ☒Local Execution ☐Task Design ☒ Local Awareness
Architecture mapping		

Table 1-2: Scenario 4 – Teach by demonstration

End-use perspective: In the cells below, the industry interested in adopting HORSE framework can see the generalized use case for a problem at hand. This can help them to recognize their needs. This template can be used for reaching the CC to start further elaboration and customization.	
Context	Some basic movements of a robot need to be re-programmed because of production differences in a new batch of products or relocation of parts in e.g. a warehouse. A worker needs to re-program (part of) a robot programming for a new type of product or changed location. The worker is not experienced in coding the robot itself.

<table>
<tr><td>Expected outcome/ Challenges</td><td colspan="3">A solution of easy re-programming the robot without having to write “complicated” code. The human should be able to touch the robot to guide it to its position or over its desired motion path. The robot records the movement and is able to reproduce it.</td></tr>
<tr><td>Expected benefits/ Impact (From D2.1)</td><td colspan="2">☐ Safety
☐Production Monitoring
☐Comfortable working conditions
☐ Gain of productivity</td><td>☒ Flexibility
☒ Cost Efficiency
☐ Quality
☒ Cycle Time</td></tr>
<tr><td colspan="4">Technical mapping to HORSE framework:
In this section, the CC experts together with SME make the translation from a problem to a solution.</td></tr>
<tr><td>Task / User Story</td><td colspan="3">As part of inventory reorganization, some storage locations have been changed for storage bins. The operator guides the robot by hand to record the new locations of these storage bins. When this task is done, the robot has stored the new positions and can continue the automated work.</td></tr>
<tr><td>Benefit</td><td>HORSE component</td><td>Description</td><td>Hardware</td></tr>
<tr><td>Flexibility</td><td>Automated step design</td><td>The robot can be reconfigured easily to new tasks.</td><td>Robot</td></tr>
<tr><td>Cost efficiency</td><td>Automated step design</td><td>Introduction of the programming by demonstration makes that normal workers can reconfigure robotic movements.</td><td>Robot</td></tr>
<tr><td>Cycle time</td><td>Automated step design</td><td>Introduction of the programming by demonstration makes that workers already present in the area can reconfigure robotic movements.</td><td>Robot</td></tr>
<tr><td colspan="4">HORSE framework perspective:
The section below illustrates the use of the HORSE framework.</td></tr>
<tr><td>Features from the HORSE Framework</td><td colspan="2">☐Process Design
☐ Human Step Design
☐ Agent Design
☒Automated Step Design
☐Global Execution</td><td>☐ Work cell Design
☐ Global Awareness
☒Local Execution
☒Task Design
☐ Local Awareness</td></tr>
</table>

Architecture mapping	

7 TUM Competence Centre

7.1 Organization context and brief description of the TUM Competence Centre

TUM is a research university based in the state of Bavaria, with locations in and around Munich, Germany. TUM, as an 'Entrepreneurial University', actively supports knowledge transfer – with over 300 start-ups created over the last years, numerous partnerships with industry (e.g. Audi, BMW, Siemens, etc.) and a comprehensive set of services aimed at technology transfer and successful commercialization of research. The robotics Competence Center (CC) being established at TUM within the frame of HORSE is directly in line with the university's continuous commitment to providing expertise, support, and infrastructure to SMEs, facilitating research-based knowledge transfer to its SMEs ecosystem.

The core mission of the TUM CC consists in supporting and facilitating digitization of the Bavarian manufacturing industry, in particular driving adoption of automation and robotics solution to enhance manufacturing capacities, with the ambition of placing Bavaria the forefront of the digitalized and robotized European industry. Accordingly, the activities of the TUM CC are in line with the following relevant digitalization initiatives: The European Digital Single market and Digitization of European Industry initiative (at the European level), the Industrie4.0 platform and Mittelstand4.0 initiative (at the national level), the Masterplan Bayern Digital II and the Smart Specialization Strategy for Bavaria (at the regional level). To provide comprehensive support to local industry, the TUM CC actively cooperates with a number of regional institutes providing services complementary to those of the CC, in particular the Zentrum Digitalizierung Bayern, the Bayerische Forschunsgallianz, the Projektträger Bayern and Bayerische Patentallianz.

The vision is for the TUM CC to act as a one-stop shop for local industry, facilitating robotization of manufacturing processes. Therefore, the CC and its partners will provide: access to technical expertise and research-based innovation in robotics, infrastructure to develop proofs of concept and perform initial tests, contacts to system integrators and hardware providers, advice and support in ethical, legal, and financial aspects of robotization.

The TUM CC is hosted within the Computer Science Department of the Technical University of Munich, in Garching Hochbrück. The CC is located 20Km from the center of Munich, and is well connected to the transport networks: via public transport with Munich airport and central railway station, by car via the A9 motorway, making it easily accessible. It spans over 400 sqm of indoor space, which are used for experimental testing of human-robot interaction, safe cooperative manufacturing (main area of focus of the Centre), operation of mobile (including aerial) robots, and test of automotive systems.

The CC will be operated by the Chair of Robotics and Embedded Systems, part of the Department of Computer Science (currently ranked at the 9th position in the world in computer science, according to the THE World University Ranking). At the moment, the Chair has 20 full-time employees and 55 PhD students, while the Department employs over 500 people in total. Benefiting from the long and rich history of successful industrial cooperations of the Chair, the CC enjoys direct connections with a number of significant industrial partners, in Bavaria and beyond, including BMW, Audi, KUKA, COMAU, and SIEMENS.

7.2 Equipment and services offered at TUM (1,5 page)

List of equipment and software:

- Collaborative robot arm : KUKA LRB iiwa with a human-robot interaction safe R800 gripper
- Industrial robots : 4x ABB IRB 120, Staubli TX80 and TX90
- SAPARO tactile floor
- Hokuyo UTM-30LX laser scanner
- RGB-D sensors (Kinect, RealSense)
- Logistic robot (FESTO Robotino)
- Mock-up of catory manufacturing cell with overhead, projector-based AR setup
- HORSE framework
- Access to engineering software (Matlab, ANSYS etc.)

Future equipment:

- Fully automated car testbed – Roding Roadster Electric car with its axes attached to external motors
- AGV (e.g. COMAU Agile platform)
- High-payload industrial robot

List of services to be offered:

- Development of proof of concepts and testing of robotic solution
- Consulting on robotic technology for manufacturing
- Assistance in technology transfer
- Hands-on sessions on robotics
- Networking (e.g. with integrators, hardware providers etc.)
- Financial, legal, ethical consulting (via regional partners)

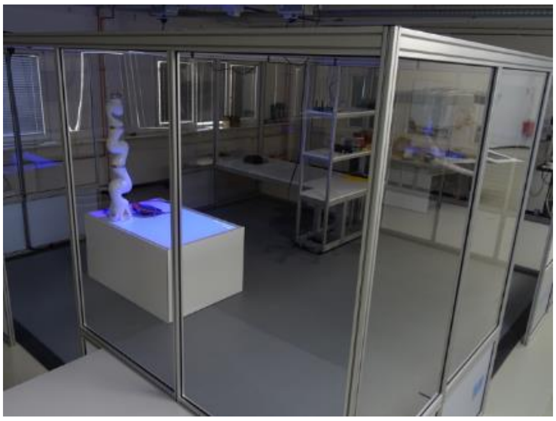


Figure 7-1: Manufacturing work cell

Figure 7-3: Staubli arm

Figure 7-2: Automated car testbed

Figure 7-4: ABB arm

7.3 TUM CC Scenarios

Table 7-1: Scenario 1 – Augmented reality in collaborative quality control

End-use perspective: In the cells below, the industry interested in adopting HORSE framework can see the generalized use case for a problem at hand. This can help them to recognize their needs. This template can be used for reaching the CC to start further elaboration and customization.	
Context	The scenario demonstrates application of the HORSE framework for a manufacturing company and focuses on the application of Augmented Reality (AR) for visual quality control and automated parcelling. Right now, the last stage of the production involves a human worker visually checking the quality of each product and then placing the part it in a box (if it is defect free), reworking and packing (if the defects are minor) or rejecting it all together. Such a routine is exhausting physically as lifting, manipulating and packaging the parts is tiring and can lead to serious musculoskeletal disorders. At the same time, the repetitive nature of the task makes it difficult to focus throughout the whole shift and the quality of the visual inspection deteriorates over time. Finally, purely human operated station at the end of the production line becomes a bottle-neck limiting the overall throughput of the line and hinders proper tracking and monitoring of the production status.
Expected outcome/ Challenges	The main outcome of the scenario is the increased quality of the working conditions. Using robots to lift and manipulate the part during the visual inspection and to put the part into a box will reduce the strain and physical effort of the human operators. The quality of the visual inspection will be increased as the AR system combined with the robot manipulating the part will highlight the exact elements of the part that need to be assessed. Finally, the productivity will be increased as the human operator needs to be called to the station only if the automatic quality control is doubtful. Thus he or she can share their time between several production lines and tasks. Using the MPMS will improve the monitoring of the whole production.
Expected benefits/ Impact (From D2.1)	☐ Safety ☒Production Monitoring ☒ Comfortable working conditions ☒ Gain of productivity ☐Flexibility ☐ Cost Efficiency ☒ Quality ☐ Cycle Time
Technical mapping to HORSE framework: In this section, the CC experts together with SME make the translation from a problem to a solution.	

<table>
<tr><td>Task / User Story</td><td colspan="3">Work cell 1: Visual inspection and parcelling station

The task starts with the operator inputting the production parameters (type and number of parts, size of the box etc.) into the MPMS (Manufacturing Process Management System), which then allocates the tasks and monitors their execution.

Afterwards, the robot picks up a part from the supply area and moves it towards the automated visual inspection station. In this particular setup, the automatic inspection will be simulated and will report faulty parts with a given probability.

If a part is considered to be faulty and alert will be sent to the human operator and the part will be moved to the visual inspection area. In this area the robot will manipulate the part in a way that makes the elements that are considered to be potentially faulty easily accessible and visible. The overhead, project-based AR system will additionally highlight the elements to be checked. Depending on the decision of the operator the part will be accepted or rejected.

If the part is accepted, it will be put into the box. The MPMS monitors the number of elements put into the box so far and, depending on the production parameters, will alert the human operator if a new box is required. The MPMS will also store the number of rejected parts and other relevant data.</td></tr>
<tr><td>Benefit</td><td>HORSE component</td><td>Description</td><td>Hardware</td></tr>
<tr><td>Production monitoring</td><td>MPMS</td><td>The MPMS is responsible for monitoring the inspection and packing process (number of parts, number of faulty parts, and number of faulty detections), allocating and triggering tasks (human check or replacing the box needed) and dealing with the exceptions reported by components.</td><td>None – software component</td></tr>
<tr><td>Comfortable working conditions</td><td>Part manipulation

Automatic packing

Augmented reality</td><td>Automated manipulation of the part during the visual inspection followed by the automated packing of the parts in boxes will reduced the amount of physical effort of the human operators.

Using AR to highlight the part elements to be evaluated will simplify the task and reduce its repetitiveness.</td><td rowspan="2">Human safe robot arm – KUKA iiwa

Workcell with AR setup</td></tr>
<tr><td>Gain of productivity</td><td>MPMS

Automatic visual inspection

Automatic packing

Augmented reality</td><td>With most of the repetitive tasks automated, AR facilitating quick visual inspection if needed the human operator is no longer limited to working on a single production line.

The MPMS dynamically allocates and monitors execution of tasks increasing the overall productivity.</td></tr>
</table>

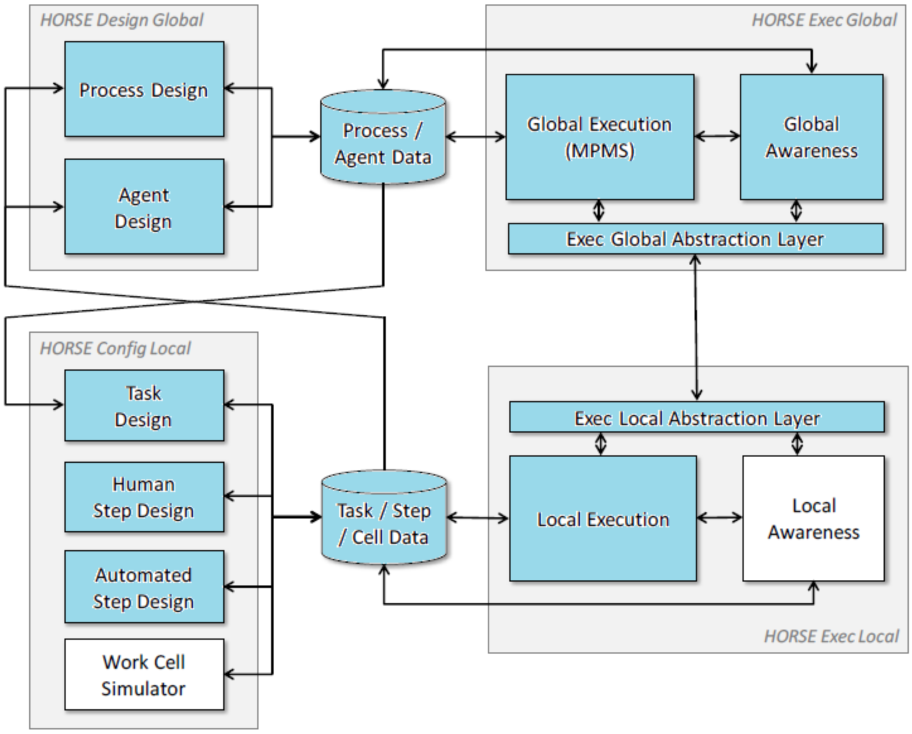
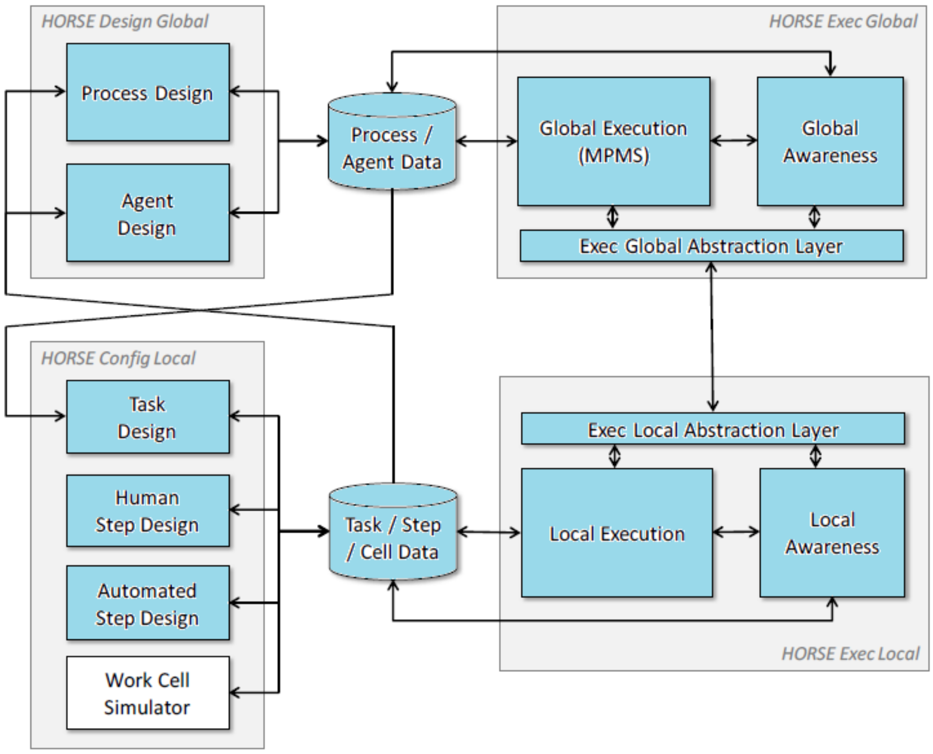
<table>
<tr><td>Quality</td><td>MPMS
Automatic visual inspection
Augmented reality</td><td>Bulk of the visual inspection is carried out by an automated system (simulated in this scenario). The human operator is alerted only in case of doubtful parts, which reduces the repetitiveness of the task and helps to fight the routine.
The human operator decisions can be used to fine-tune the classification system and reduce the frequency of alerts over time.
MPMS facilitates proper monitoring of the production and contributes to ensuring the overall quality of the manufacturing process.</td><td></td></tr>
<tr><td colspan="4">HORSE framework perspective:
The section below illustrates the use of the HORSE framework.</td></tr>
<tr><td>Features from the HORSE Framework</td><td colspan="2">☒Process Design
☒Human Step Design
☒ Agent Design
☒Automated Step Design
☒Global Execution</td><td>☐ Work cell Design
☒ Global Awareness
☒ Local Execution
☒ Task Design
☐ Local Awareness</td></tr>
<tr><td>Architecture mapping</td><td colspan="3">
</td></tr>
</table>

Table 7-2: Scenario 2 – Human-safe collaborative shelving station

<table>
<tr><td colspan="3">End-use perspective:
In the cells below, the industry interested in adopting HORSE framework can see the generalized use case for a problem at hand. This can help them to recognize their needs. This template can be used for reaching the CC to start further elaboration and customization..</td></tr>
<tr><td>Context</td><td colspan="2">The scenario demonstrates application of the HORSE framework for a manufacturing company and focuses on the task of arranging elements on a rack/shelf. Despite relatively small effort required to place a single element on the rack the overall task is physically exhausting.
The company uses many different types of elements, which in turn require rearrangement of the rack or shelf. This makes it particularly difficult to fully robotize the production: the pick-and-place operation can be automated; however, the rearrangement of the rack is not cost-efficient.
Partial robotization of the process, utilizing a collaborative station is considered. This introduces additional problems related to ensuring safety of human operators in a fenceless collaborative workcell.</td></tr>
<tr><td>Expected outcome/ Challenges</td><td colspan="2">The main outcome of the scenario is ensuring safety of the human operator sharing the workspace with a collaborative robot. By using several sensor types to detect and track humans in the workcell it will be possible to adjust the working speed of the robot. Moreover, the low-level collision detection and avoidance mechanisms will even further increase the safety of the cooperation. The AR system will be used to signalize the safety level to the operator and to dynamically provide information about potentially dangerous actions.
Another expected benefit of the scenario is improvement of the working conditions. The workers will no longer be required to arrange the elements, thus the physical effort will be reduced.
The system also facilitates monitoring of the production, as the MPMS tracks the number of elements, current status of the process, completion of tasks etc.</td></tr>
<tr><td>Expected benefits/ Impact (From D2.1)</td><td>☒Safety
☒Production Monitoring
☒ Comfortable working conditions
☐ Gain of productivity</td><td>☐Flexibility
☐ Cost Efficiency
☐ Quality
☐ Cycle Time</td></tr>
<tr><td colspan="3">Technical mapping to HORSE framework:
In this section, the CC experts together with SME make the translation from a problem to a solution.</td></tr>
</table>

Task / User Story	**Work cell 1: Collaborative pick-and-place station** The task starts with the operator inputting the production parameters (type and number of elements, the layout of the rack/shelf etc.) into the MPMS (Manufacturing Process Management System), which then allocates the tasks and monitors their execution. Afterwards the human worker verifies that a proper layout is arranged in the workcell. During the operation of the system the robot picks elements from the storing area and puts them on the rack / shelf. If the robot runs out of the elements or the rack needs to be rearranged the human operator is alerted. During the operation of the robot the workspace is monitored using several sensors: a 2D laser scanner and tactile floor detecting human presence and RGB-D sensors monitoring the area around the robot. The first ones are used to reduce the speed of the robot to human safe if anyone approaches the immediate vicinity of the robot. The latter is used for the collision detection and avoidance mechanism. When a human is present in the workcell the AR is used to highlight the areas that are potentially dangerous (e.g. the foreseen trajectory of the robot arm) and to provide additional information (e.g. information that a new batch of elements needs to be provided soon).		
Benefit	**HORSE component**	**Description**	**Hardware**
Production monitoring	MPMS	The MPMS is responsible for monitoring the production process (number of parts, their types etc.), allocating and triggering tasks and dealing with the exceptions reported by components.	None – software component
Comfortable working conditions	Pick-and-place Augmented reality	Introduction of the automated pick-and-place procedures to deal with arranging the elements on the racks / shelves removes the physical effort and strain from the worker. The amount of manual labor is reduced, thus allowing the operator to focus on monitoring the production process and intervening when needed (e.g. rearranging the rack layout). The AR system provides additional information and hints making the work more efficient and comfortable.	Collaborative robot arm – KUKA iiwa
Safety	Local awareness Collision detection and avoidance	Continuous detection and tracking of humans in the workcell allows prediction of potentially dangerous situation before they occur and adjusting the robot operating mode accordingly to ensure humans safety. The collision avoidance and trajectory replanning system developed by FZI provide	Sensors: SAPARO tactile floor, 2D laser scanner, RGB-D sensors Human safe robot arm – KUKA iiwa

	Augmented reality	means to anticipate potentially dangerous situation and to adjust the velocity and trajectory of the robot to avoid hitting the operator. The safety instructions provided through AR provide additional way to avoid collisions by dynamically alerting the operator.	Workcell with AR setup
HORSE framework perspective: The section below illustrates the use of the HORSE framework.			
Features from the HORSE Framework	☒Process Design ☒ Human Step Design ☒ Agent Design ☒Automated Step Design ☒Global Execution	☐ Work cell Design ☒ Global Awareness ☒ Local Execution ☒ Task Design ☒ Local Awareness	
Architecture mapping			

8 Competence Centre on Robotics - ROBOFLEX Slovenia

8.1 Organization and breef description of the CC ROBOFLEX Slovenia

The Competence Center ROBOFLEX (CC ROBOFLEX) is a long-term industry development consortium, established by TCS – Toolmakers Cluster of Slovenia and industry partners (system integrators and ICT partners) in March 2017 in Celje, Slovenia. CC ROBOFLEX is the HORSE Project 4th Competence Center and part of the initial network of a European network of competence centres on robotics. CC ROBOFLEX will operate as the regional digital innovation hub (DIH) on robotics for the flexible, cognitive robotics for manufacturing SMEs.

CC ROBOFLEX partners are industrial partners operating as automation and robotics systems integrators, providers of cloud computing and cyber physical systems, as well as industrial engineering service providers for the needs of manufacturing SMEs and their innovation ecosystems.

CC ROBOFLEX is a networked organization embedded in the regional and EU innovation ecosystem to support robotization and digitalization innovation processes and related markets in the region (Figure 8-1).

8.1.1 CC ROBOFLEX Mission:

- Organizer of the "***regional value space***" for promotion, demonstration and implementation of advanced robotics systems for the needs of manufacturing SMEs and their business ecosystems,
- Demonstrate, promote and support the introduction of advanced robotics systems and solutions in the manufacturing SMEs value chains and their business ecosystems,
- Promote, enable and support regional and international collaboration with industry-academy research and development of new robotic systems and applications and
- Development and utilization of new business models of sustainable partnering and collaboration in the areas of recognized interests.

8.1.2 CC ROBOFLEX Vision:

To be recognized as regional "**one-stop shop**" service and digital innovation hub for advanced cognitive robotic technologies and support services for the needs of manufacturing SMEs and their stakeholders – as an integral part of the pan-European network of competence centers from this area.

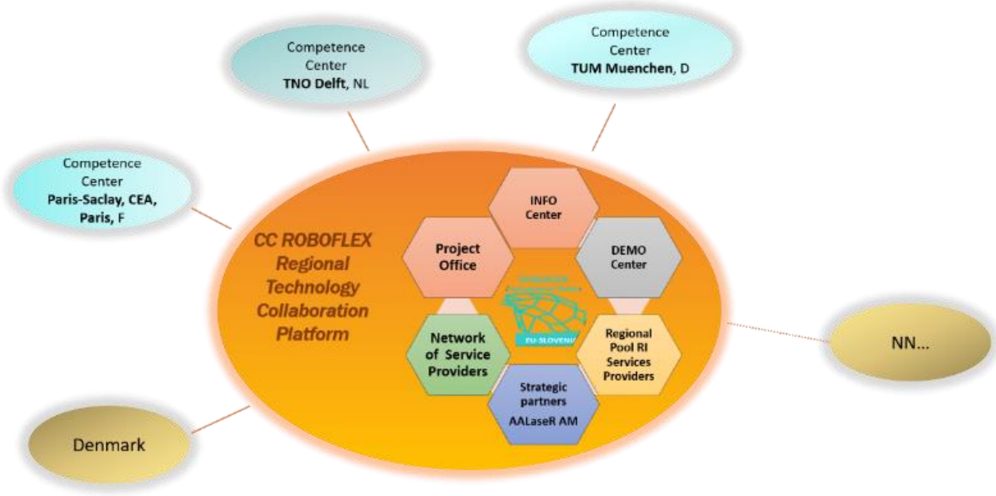


Figure 8-1: ***CC ROBOFLEX organization architecture***

The CC ROBOFLEX business functions are:

1. Regional INFO Center,
2. Demonstration Center,
3. Access point to the industry service providers
4. Pool of research and innovation services
5. Qualification and project office services
6. Access to the regional industry development partnering networks

The CC ROBOFLEX business service portfolio will be introduced by utilization of the phased development approach.

8.1.3 CC ROBOFLEX Demonstration Center

The available CC ROBOFLEX equipment, at this stage of the CC ROBOFLEX development:

- KUKA Robots LBR iiwa 14 R820,
- KUKA Sunrise Cabinet X11 X65 X69 X650
- KUKA Sunrise, Workbench 1.11
- KUKA SmartPAD holder RAL 7016
- KUKA Workstation toolbox
- Griper (in progress)

In development strategy of CC ROBOFLEX acquisition of robots from different vendors (FANUC, UNIVERSAL ROBOTICS, etc.) is planned.

Address

Competence Centre ROBOFLEX

Zavod C-TCS

Kidričeva 25

3000 Celje

Slovenia

8.2 Scenario 1: Flexible Cognitive Robot (FCR) Applications as Integral Part of Industry Flexible Progressive Assembly Line (IFPAL)

ETRA Ltd is Slovenian company specialized as developer and system integrator of different custom designed industry automation and robotic applications for the needs of different industries (manufacturing, logistics, energy, electronics, service industries). The ETRA's selected business case is addressing development and implementation of the various customized applications of the Industry Flexible Progressive Assembly Lines (IFPAL) for clients coming from different manufacturing sectors.

8.3 Scenario 1: Flexible Cognitive Robot (FCR) Applications as Integral Part of Industry Flexible Progressive Assembly Line (IFPAL)

ETRA Ltd is Slovenian company specialized as developer and system integrator of different custom designed industry automation and robotic applications for the needs of different industries (manufacturing, logistics, energy, electronics, service industries). The ETRA's selected business case is addressing development and implementation of the various customized applications of the Industry Flexible Progressive Assembly Lines (IFPAL) for clients coming from different manufacturing sectors.

End-use perspective

In the cells below, the industry interested in adopting HORSE framework can see the generalized use case for a problem at hand. This can help them to recognize their needs. This template can be used for reaching the CC to start further elaboration and customization.

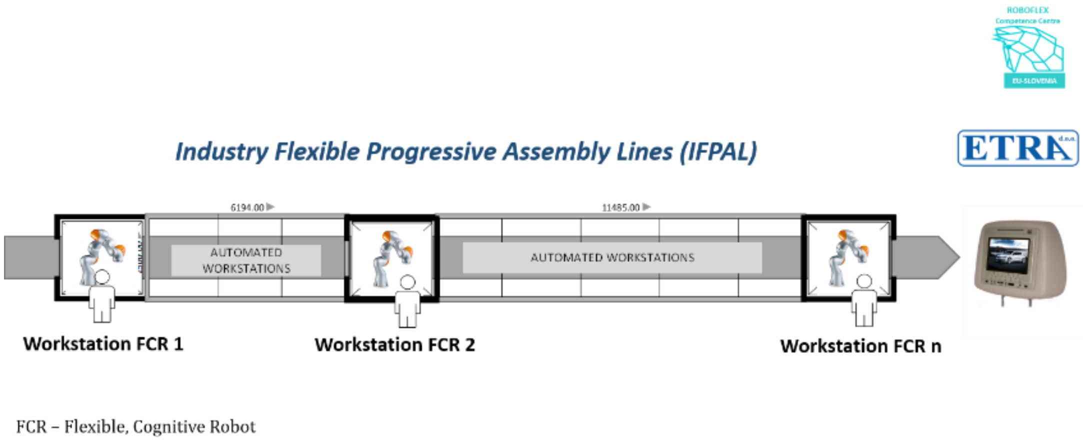
<table>
<tr>
<td rowspan="2">Context</td>
<td colspan="2">In IFPAL's manufacturing process parts are added as the semi-finished assembly moves from workstation to workstation according to the pre-defined technology sequence as long as the assembly process is not finished. Some processes and workstations are completely automated, some of them still need manual assistance. Workstations needing manual assistance are in the focus of ETRA's business case scenario. Such manually assisted workstation are usually related to quality control, IFPAL process changes, flexible IFPAL logistics activities, etc. fig. 8-2 is an illustration of typical industrial products in the focus of ETRA's business case scenario. Fig. 8-3 is an example of ETRA's IFPAL applications. The focus of this demonstrator is the quality check which is performed by a human, and automated packaging.</td>
</tr>
<tr>
<td>
Figure 8-2: Assembling lines for the car lights and parts of the passengers' seats</td>
<td>
Figure 8-3: Example of the ETRA's IFPAL application</td>
</tr>
<tr>
<td>Expected outcome/ Challenges</td>
<td colspan="2">Expected outcomes are related to the ETRA's IFPAL technology design and implementation projects, with the focus to replace critical manual workstations in the existing IFPAL solutions with the FCR- Flexible, Cognitive Robot applications (Figure 8-4). Such applications are commercial engineering projects performed for an external industrial client.


Figure 8-4: Illustration of the Industry Flexible Progressive Assembly Line (IFPAL)</td>
</tr>
<tr>
<td>Expected benefits/ Impact (From D2.1)</td>
<td>☐ Safety
☒ Production Monitoring
☒ Comfortable working conditions
☒ Gain of productivity</td>
<td>☒ Flexibility
☐ Cost Efficiency
☒ Quality
☐ Cycle Time</td>
</tr>
<tr>
<td colspan="3">Technical mapping to HORSE framework:</td>
</tr>
</table>

<table>
<tr><td colspan="4">In this section, the CC experts together with SME make the translation from a problem to a solution.</td></tr>
<tr><td>Task / User Story</td><td colspan="3">The robot graps the product from the assembly line and moves it to the human for quality checking (this is the same scenario as in BOS, however, the automated visual check is replaced by human check. When the human gives the ok the robot moves it for packaging in the customer box and when the human gives «not ok » it rejects it.

The visual inspection performed by the human operator can by optionally facilitated with the AR module. The module projects additional information (e.g. to highlight the points that need to be checked) onto the part held by the robot thus speeding up and improving the quality of the visual checks.</td></tr>
<tr><td>Benefit</td><td>HORSE component</td><td>Description</td><td>Hardware</td></tr>
<tr><td>Production monitoring</td><td>MPMS</td><td>The MPMS for monitoring the production quality inspection processes by allocating and triggering tasks</td><td>NA</td></tr>
<tr><td>Flexibility and reconfigurability</td><td>HORSE Middleware</td><td>Programming by the use of expected HORSE middleware components for communicating the messages between human (ok, not ok), and robot, MPMS</td><td rowspan="3">KUKA Robots LBR iiwa 14 R820,

KUKA Workstation toolbox

Griper,

Sensors,

Control unit Siemens S7 plus SW

Workcell with AR setup (overhead projector)</td></tr>
<tr><td>Comfortable working conditions</td><td>Automatic handling

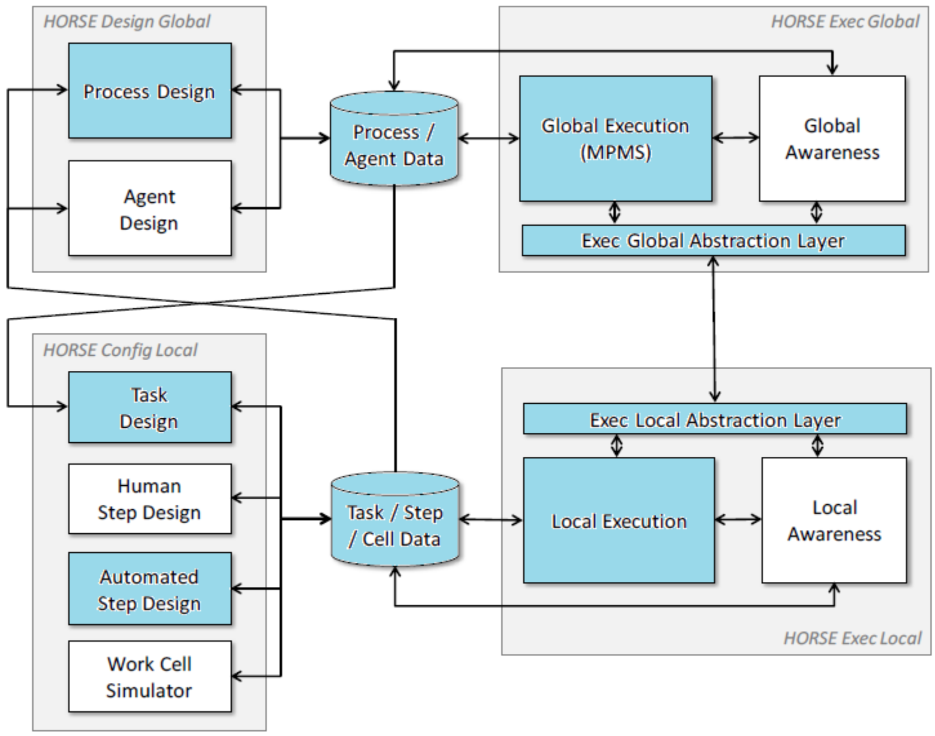
Augmented reality</td><td>Programming the robot for the path. Integrating the human UI for human feedback.

Assisting the human operator with AR during the visual quality control improves the quality of the workplace and reduces stress and anxiety.</td></tr>
<tr><td>Quality</td><td>Automatic handling

Human-robot collaboration for quality controlling

Augmented reality</td><td>Integrating the human UI for human feedback.ETRA's scenario business case.

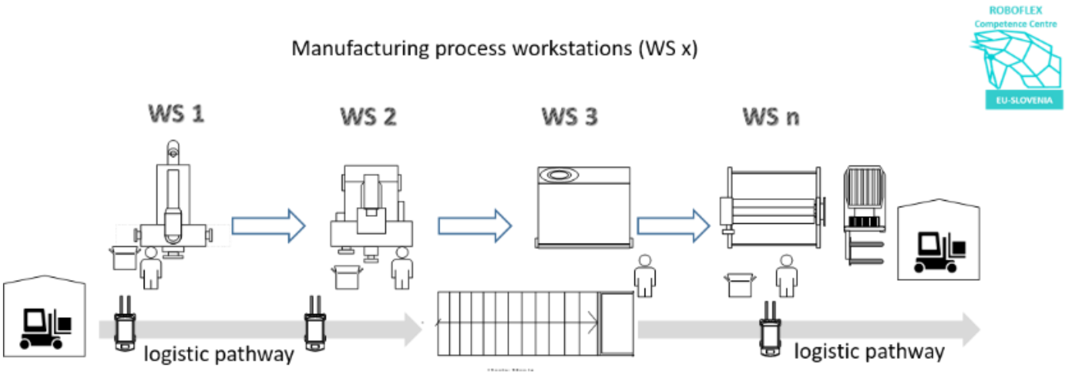
Supporting the worker with AR instructions during the visual checks improves the quality of the checks.</td></tr>
<tr><td colspan="4">HORSE framework perspective:</td></tr>
</table>

<table>
<tr><td colspan="3">The section below illustrates the use of the HORSE framework. If more than 1 tick box is ticked, the framework is to be used. If a single tick box is ticked, a solution without framework can be provided</td></tr>
<tr><td>Features from the HORSE Framework</td><td>☒Process Design
☒Human Step Design
☒ Agent Design
☒Automated Step Design
☒Global Execution</td><td>☐ Work cell Design
☐ Global Awareness
☒ Local Execution
☒ Task Design
☐ Local Awareness</td></tr>
<tr><td>Architecture mapping</td><td colspan="2">
</td></tr>
</table>

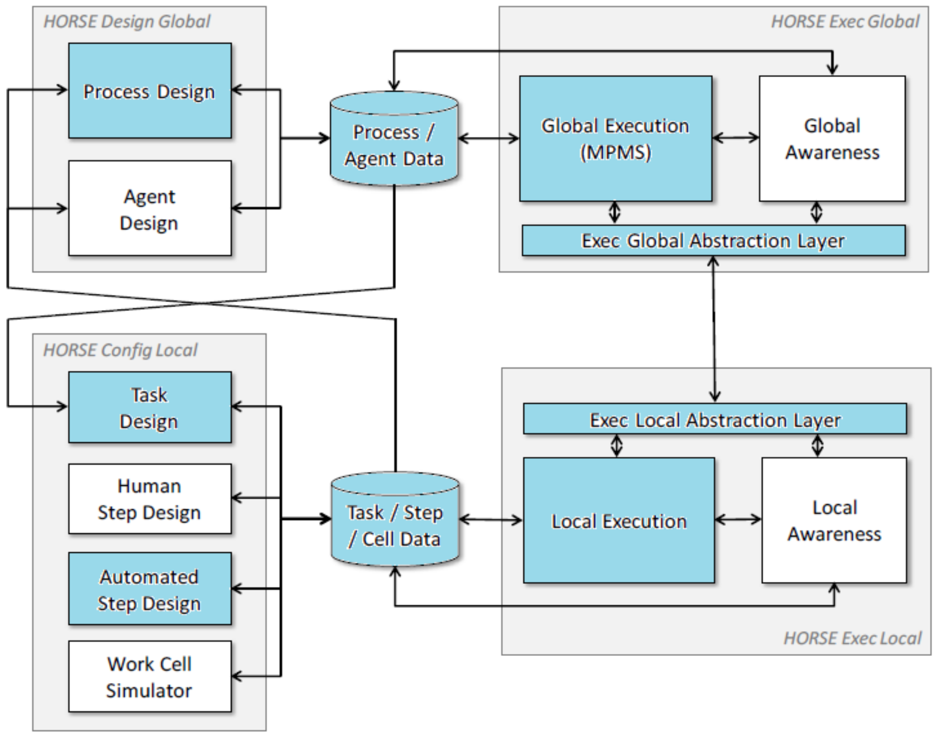
8.4 Scenario 2: CC ROBOFLEX demonstration FCR workstation

The primary intention of this scenario is to demonstrate benefits, and FCR value for manufacturing SMEs – target users of this technology. It is noted that this scenario is illustrative of the future vision of ROBOFLEX which will not be able to be demonstrated during the project. A demonstration workstation is the focus in the existing Competence Center ROBOFLEX which will illustrate FCR capabilities and replacement potential of existing typical manual or classical mechanical technology operations in manufacturing SMEs.

End-use perspective: In the cells below, the industry interested in adopting HORSE framework can see the generalized use case for a problem at hand. This can help them to recognize their needs. This scenario will be used for open

demonstration purposes in the demonstration center for the potential new industry clients. It will simulate and practically demonstrate the use of this technology within the framework of the manufacturing workstation, which is typical in many manufacturing SMEs. This is the critical scenario for the needs of our DEMO center. Remember, our task in this project is to set-up grassroots application of a new competence center.	
Context	Manufacturing SMEs face the problem of dosing input material in the production process workstation, especially when such technology operation needs components (parts) of various shapes and dimensions in such technology process. These components are typically transferred from other locations (storages or another production lines) to the observed production line or machine tool (Figure 8-5). The most common form of such internal logistic transfer is done by the use of different transportation containers in which such product components are laying distributed randomly. Components are usually sorting through a variety of products manually by the use of customized vibrators or other classical technology applications. Another technological solution is when product parts are shovelled into the hopper from which with the help of conveyor belts dosed in a dedicated vibrator. At the output of the vibrator, product's components are oriented and positioned and aligned according to the needs of observed technology process.  **Figure 8-5:** ***Typical manufacturing layout of a manufacturing SME*** Described classical technology solutions should be replaced by the proposed flexible, collaborative robot workstation (FCR) applications,
Expected outcome/ Challenges	The flexible, collaborative robot workstation (FCR) set-up, for the needs of technology demonstration and motivation of the regional manufacturing SMEs for its use. The introduction of the HORSE project based FCR workstations as replacement proposal for the industry's existing solutions of manual quality control and other manual workstations in the existing manufacturing processes.
Expected benefits/ Impact (From D2.1)	☒ Safety ☒ Flexibility ☒ Production Monitoring ☐ Cost Efficiency ☒ Comfortable working conditions ☒ Quality ☒ Gain of productivity ☐ Cycle Time

<table>
<tr><td colspan="4">Technical mapping to HORSE framework:
In this section, the CC experts together with SME make the translation from a problem to a solution.</td></tr>
<tr><td rowspan="3">Task / User Story</td><td colspan="3">A new FCR workstation would capture the current status of randomly distributed components in the container using a 3D camera. The output of the software package to process the captured image would give the robot the point of receiving the following component product in the container. The robot program then manages and performs collection from the received data.</td></tr>
<tr><td colspan="2">Since the positions of these containers are usually on internal logistic work paths, it is beneficial to introduce a flexible, collaborative robot that increases productivity and safety, as we do not need any safety fences anymore or other security equipment (fig. 8-6).</td><td>
Figure 8-6: FCR Workstation</td></tr>
<tr><td colspan="3">With the help of a 3D camera, the area of 1200 mm in length, 800 mm in width and 1000 mm in height could be detected, which corresponds to the size of the euro pallet. The size of individual component products can be typically up to 150mm in length, 100mm in width and 50mm in height, of course, each product needs to be reviewed and analysed beforehand.</td></tr>
<tr><td>Benefit</td><td>HORSE component</td><td>Description</td><td>Hardware</td></tr>
<tr><td>Production monitoring</td><td>MPMS</td><td>The MPMS for monitoring the production quality inspection processes by allocating and triggering tasks</td><td>NA</td></tr>
<tr><td>Flexibility and reconfigurability</td><td>HORSE Middleware</td><td>Programming by the use of expected HORSE middleware components.</td><td rowspan="3">KUKA Robots LBR iiwa 14 R820,
KUKA Workstation toolbox
Griper,
Sensors,
Control unit Siemens S7 plus SW
3D camera Sick PLB plus SW
Computer with SW</td></tr>
<tr><td>Comfortable working conditions</td><td>Automatic handling
Automatic controlling</td><td>The know-how outputs from the BOSCH and TNO pilots – scenarios will be used as an input for the development of this ETRA's scenario business case.</td></tr>
<tr><td>Quality</td><td>Automatic handling
Automatic controlling</td><td>The know-how outputs from the BOSCH and TNO pilots – scenarios will be used as an input for the development of this ETRA's scenario business case.</td></tr>
<tr><td colspan="4">HORSE framework perspective:</td></tr>
</table>

<table>
<tr><td colspan="3">The section below illustrates the use of the HORSE framework. If more than 1 tick box is ticked, the framework is to be used. If a single tick box is ticked, a solution without framework can be provided</td></tr>
<tr><td>Features from the HORSE Framework</td><td>☒Process Design
☐ Human Step Design
☐ Agent Design
☒Automated Step Design
☒Global Execution</td><td>☐ Work cell Design
☐ Global Awareness
☒ Local Execution
☒ Task Design
☐ Local Awareness</td></tr>
<tr><td>Architecture mapping</td><td colspan="2">
</td></tr>
</table>

9 Conclusions

This document presents the contours of the four robotics Competence Centres that are being set up in HORSE project. Competence Centres are one of the key elements of the I4MS program. They are central to the Digitizing Europe Initiative under discussion currently in the European Union. The Competence Centres are aiming at stimulating the industrial activity in robotics. We described the equipment and services provided as well as the regional ecosystem, the connection of the Competence Centres to their environments.

The Competence Centres will evolve during the HORSE project and according to the evolution of the HORSE framework and the experience gained in the interaction between Competence Centres and the actions with pilots and experiments. The evolutions and updates will be presented in another deliverable by the end of the project gathering the lessons learnt from the actual practice of the Competence Centres.

10 Bibliography

[1] European Commission, “Factories of the future PPP strategic multi-annual roadmap,” 2010. [Online]. Available: https://ec.europa.eu/research/industrial_technologies/pdf/ppp-factories-of-the-future-strategic-multiannual-roadmap-info-day_en.pdf.

[2] PricewaterhouseCoopers, D.L.L,P., “The new hire: How a new generation of robots is transforming manufacturing.,” 2014. [Online]. Available: https://www.pwc.com/us/en/industrial-products/next-manufacturing/robotic-trends-changing-manufacturing.html.

[3] HORSE Consortium, “D2.1 System Requirements Specification,” Prosyst, Cologne, 2016.

[4] HORSE Consortium, “D2.2 Complete System Design,” TU/e, Eindhoven, 2016.

[5] HORSE Consortium, “Smart integrated Robotics system for SMEs controlled by Internet of Things based on dynamic manufacturing processes,” Engineering Dynamics, Athens, 2015.