

**humantech**

## **D5.3 – Mobile Demonstrator Platform**



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<b>Task Leader/Main Author</b>	Joseph Thomas Thekkekara (Baubot)
<b>Contributing Partners</b>	Printstones GmbH (Baubot)
<b>Reviewer(s)</b>	Dr. Gabor Sziebig (SINTEF), Dr. Jason Rambach (DFKI)

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## Acronyms and definitions

Acronym	Meaning
<b>BIM</b>	Building Information Modelling
<b>DSDT</b>	Dynamic Semantic Digital Twins
<b>HMI</b>	Human Machine Interface
<b>CAN</b>	Controller area network (CAN)
<b>I/O</b>	Input/Output



### **Abstract**

This deliverable describes the development of a modular mobile robotic system. The focal point of the robotic system is to serve as a platform for developing diverse applications suited for the construction sector. The intent is to create a foundational structure for future mobile robotic solutions that can serve as a testing ground for diverse applications. The system architecture of the mobile robotic system is first described including the individual elements of the system. Subsequently, the external application interface for developing new applications on top of the mobile robotic platform is described. Finally, the Human Machine Interface and the safety elements of the system are described.



## The HumanTech project

The European construction industry faces three major challenges: increase the safety and wellbeing of its workforce, improve its productivity, and become greener, making efficient use of resources.

To address these challenges, HumanTech proposes to develop **human-centred cutting-edge technologies** such as wearables for workers' safety and support and robots that can harmoniously coexist with human workers while contributing to the ecological transition of the sector.

**HumanTech aims to achieve major advances in cutting-edge technologies that will enable a safe, rewarding, and digital work environment for a new generation of highly skilled construction workers and engineers.**

These advances will include:

- **Robotic devices equipped with vision and intelligence** that allow them to navigate autonomously and safely in highly unstructured environments, collaborate with humans and dynamically update a semantic digital twin of the construction site in which they are.
- **Smart, unobtrusive workers protection and support equipment.** From exoskeletons activated by body sensors for posture and strain to wearable cameras and XR glasses that provide real-time workers' location and guidance for them to perform their tasks efficiently and accurately.
- An entirely new breed of **Dynamic Semantic Digital Twins (DSDTs) of construction sites** that simulate in detail the current state of a construction site at the geometric and semantic level, based on an extended Building Information Modelling (BIM) formulation that contains all relevant structural and semantic dimensions (BIMxD). BIMxDs will act as a common reference for all human workers, engineers, and autonomous machines.

The **HumanTech consortium** is formed by 22 organisations — leading research institutes and universities, innovative hi-tech SMEs, and large enterprises, construction groups and a construction SME representative — from 10 countries, bringing expertise in 11 different disciplines. The consortium is led by the German Research Centre for Artificial Intelligence's Augmented Vision department.



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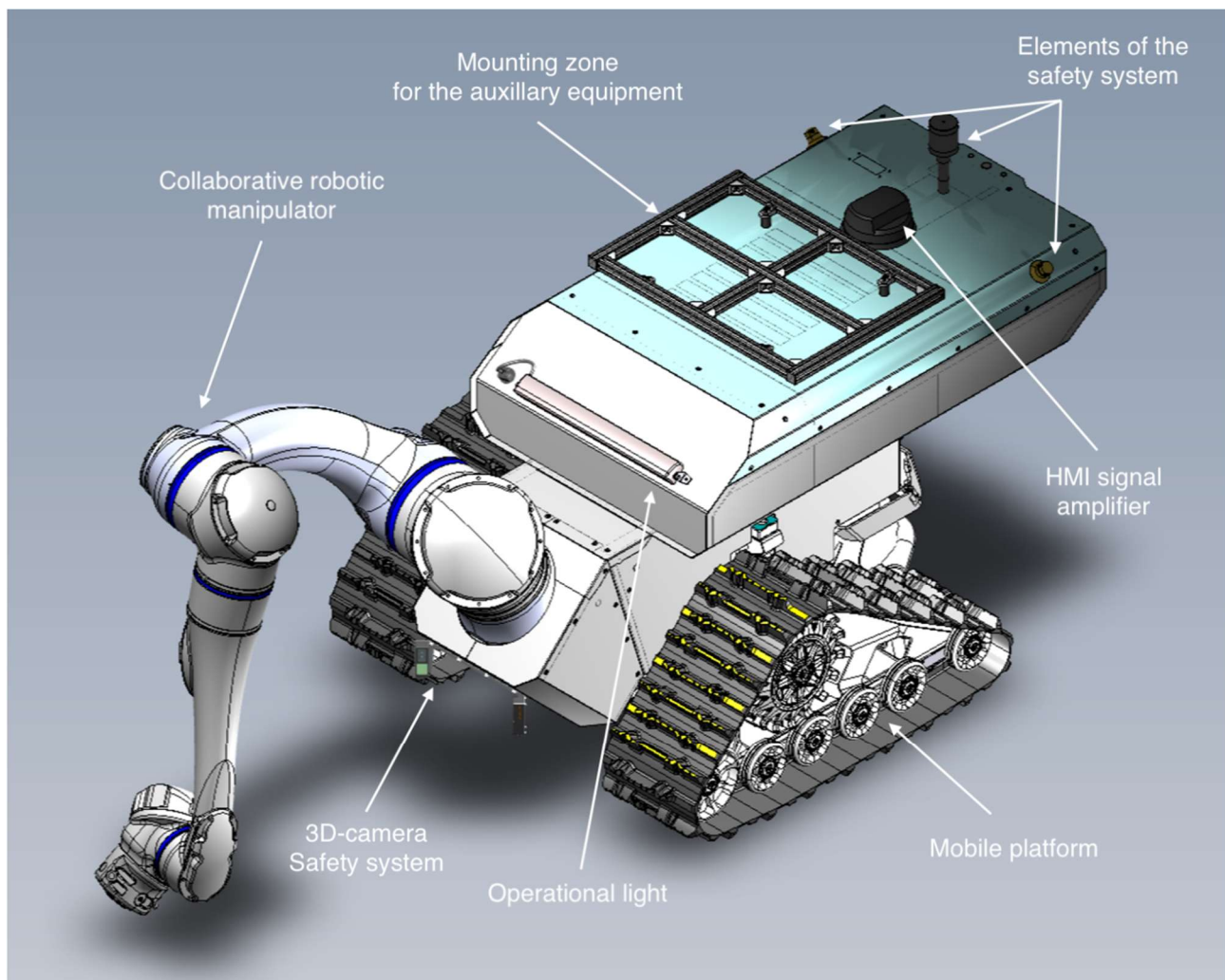


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## 1. Introduction

The European construction industry is currently faced with challenges that include a lack of highly skilled workers, concerns surrounding the safety of human workers and efficient use of resources. The HumanTech project addresses these issues to create a more greener and sustainable construction sector. The challenges are addressed by using robotic systems equipped with vision and intelligence sensors, smart wearable devices for worker protection and Dynamic Semantic Digital Twins (DSDTs) of construction sites.



*Figure 1 – Baubot mobile demonstrator platform*

Deliverable D5.3 deals with the mobile demonstrator platform. This deliverable is part of the WP5 and is connected to task T5.3.

The Baubot mobile demonstrator platform developed for the HumanTech project is a mobile robotic system equipped with a collaborative robot arm. **Error! Reference**

**source not found.**1 shows the Baubot mobile robotic platform with its basic elements. Applications involving human-robot collaboration can be additionally developed and integrated into the platform. The robotic system can take inputs from various external applications and perform actions based on the commands that are being passed to the robot. The general specifications of the mobile demonstrator platform are described below:

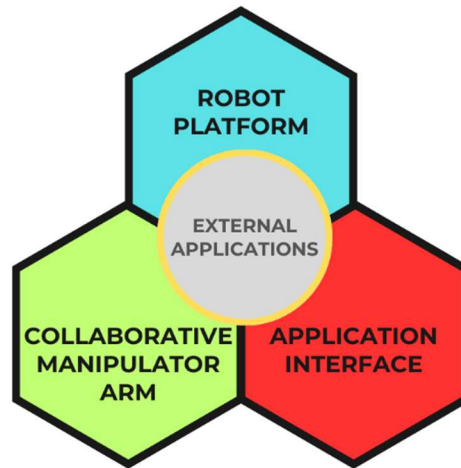
<b>DIMENSIONS</b>	<b>VALUES</b>
<b>Length</b>	1900 mm
<b>Width</b>	1300 mm
<b>Height</b>	1500 mm
<b>Weight</b>	approx. 700 kg

*Table 1 – Dimensions of Mobile Demonstrator Platform.*

The robotic system is equipped with various sensor systems that help it in its decision-making process. The robotic system is built in a modular way where new application use cases can be developed independently on top of the system and integrated into it. This aids in rapid research and development along with a parallel development cycle for various challenging use cases without having to be dependent on the platform. A universal interface is defined that can be used by external applications to access and read all system functions.

## 2. System Architecture

The system architecture of the mobile demonstrator platform consists of three core elements. The system architecture comprises of several hardware and software subsystems working together.



*Figure 2 – Baubot system architecture*

Figure 2 describes the structure of the system architecture of the mobile demonstrator platform and their relationship with each other. The three key elements of the system are described below:

- 2.1. Robot platform
- 2.2. Collaborative manipulator arm
- 2.3. Application interface

External applications, as shown in Figure 2 are applications that are independently developed and later integrated on top of the three key elements. The external applications can be either hardware-driven applications or purely software applications that perform various tasks with the demonstrator platform.

## 2.1 Mobile Robot Platform

The Mobile Robot Platform serves as the foundation for the entire mobile robotic system. It accommodates a range of vital components like electronics, sensors, energy management system and the robotic manipulator arm that collectively enable the robot to perform tasks and interact with its environment. Its fully electric track-mounted drive system is designed specifically for off-highway use. The agile chassis has a powerful drive and an in-house exchangeable battery. Figure 3 shows the mobile robot platform which uses a tracked vehicle as a base to provide mobility to the complete robotic system.

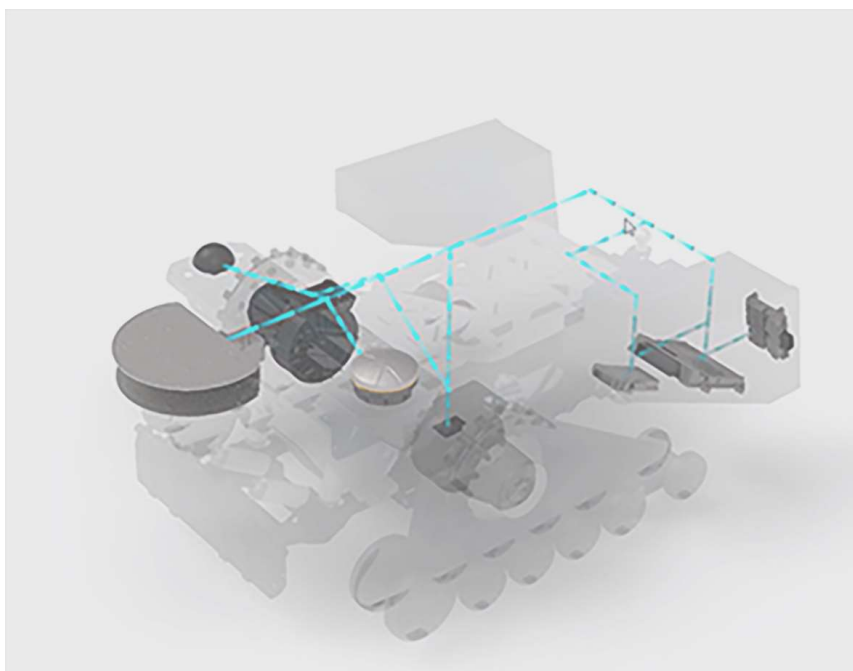


*Figure 3 – Mobile robot platform.*

With 1,000 Nm peak torque, up to 5km/h speed and a possible 30% incline, this Mobile Robot Platform is one of the top performers in its class. With the battery pack type EP088, it can be operated continuously for up to 8 hours and at the same time is highly resilient. The charging times are between 2.5 (fast) and 4 (standard) hours. The matching charger is also a part of the package. With its compact dimensions and low weight (incl. battery: 290 kg), the Mobile Robot Platform can be easily transported to the operation site on a trailer.

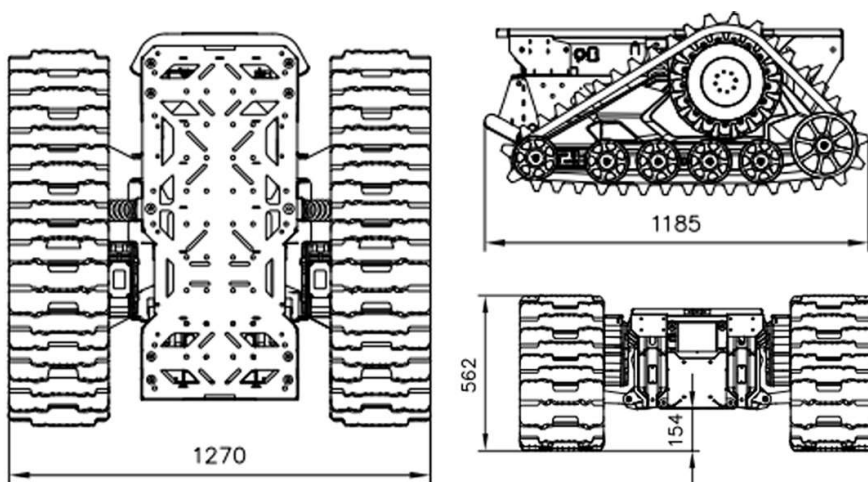
Both the hardware components and the software systems with high intrinsic safety have already proven themselves in extreme applications. The Mobile Robot Platform is fully operational at temperatures from +5°C to +40°C, has protection class

IP54 and a chassis made of high-strength steel. At the same time, the sprung chassis and precise manoeuvrability ensure a safe ride.



Its sophisticated design and numerous interfaces in hardware and software make the Mobile Robot Platform the ideal platform for rapid prototyping. For example, a CAN bus interface is implemented for external control.

The specifications of the mobile robot platform are described below:



DIMENSIONS	VALUES
<b>Maximum speed</b>	5 km/h
<b>Maximum inclination</b>	Up to 30% incline

<b>Driving over obstacles</b>	< 100 mm in height
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Table 2 – Dimensions of Mobile robot platform.

The robot platform is as shown above and uses a single-phase power source with 230V and 16A.

## 2.2 Collaborative Manipulator Arm

The collaborative manipulator arm is designed to support various hardware elements of the external applications and provides the robot platform with the capability to work seamlessly alongside human workers, promoting a cooperative and safe working environment. Various tools that are commonly used in the construction sector like gripping, drilling, marking, mastic applicators, etc can be easily mounted to the universal flange of the manipulator arm. Depending on the diversity of the application and the final payload of the application tool, a range of applications can be easily carried out.





Figure 4 – Collaborative manipulator arm.

Figure 4 shows the collaborative manipulator arm that is used on the mobile demonstrator platform. The collaborative arm can carry a payload of up to 20 kg and can be used with any standard tools that is below the weight threshold.

DIMENSIONS	VALUES
Maximum payload	20 kg
Maximum reach	up to 1900 mm
Effective reach	up to 1700 mm
Repeatability	0.05 mm
Number of axes	6

Table 3 – Dimensions of Collaborative Manipulator Arm

Table 3 gives the specifications of the mobile demonstrator platform along with the effective ranges of the collaborative manipulator arm.

Our selection of the 20kg Yaskawa collaborative robot was primarily influenced by its remarkable payload capacity and extended reach. It stands out as the leader in its class, allowing us to handle heavier objects and perform tasks that demand greater reach, all within the collaborative framework. This exceptional capability significantly expands the range of applications we can undertake.

One key advantage of the Yaskawa collaborative robot is its intrinsic safety features. Unlike some other options, it eliminates the need for additional safety elements such as safety scanners or pressure pads. This not only simplifies the system but also enhances safety by design, reducing the complexity of our setup and ensuring a secure working environment.

The robot's versatility is another compelling reason for our choice. It offers an extensive array of application interfaces and integration options, providing us with



ample opportunities for development and customization. This flexibility empowers us to tailor the robot to meet our specific requirements, adapt to evolving needs, and explore a wide range of applications.

The Yaskawa collaborative robot further distinguishes itself by offering direct control via the CAN bus system integrated into the robot itself. This feature streamlines our control and communication processes, enabling seamless coordination with other components and systems in our setup. The CAN bus support simplifies our control architecture and enhances efficiency.

Lastly, our decision to opt for the Yaskawa system is underpinned by its reputation as a reliable and proven solution from a well-known supplier. Yaskawa's track record of delivering high-quality robotics solutions instills confidence in the performance and longevity of our chosen robot. This reliability is essential for maintaining consistent productivity and minimizing downtime.

## 2.3 Application Interface

The application interface serves as a critical bridge between the mobile demonstrator platform and external applications. The application interface has been designed to enable independent development of new applications onto the demonstrator platform. Modularization of applications enables external applications to be conceptualized and integrated into the platform at a later point of time.

Figure 5 describes the main elements of the application interface and how they are interconnected to each other. The application interface connects the collaborative manipulator tool interface, the application interface plug, and the main robot controller.

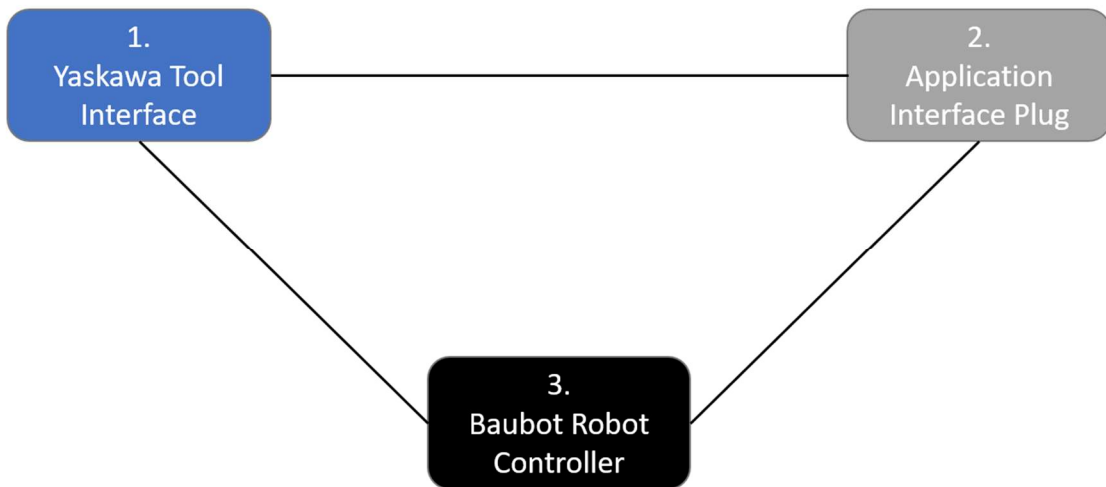


Figure 5 – Application Interface

The application interface is made up of two layers:

1. Hardware interface
2. Software interface

### 2.3.1 Hardware Interface

The hardware interface facilitates physical connections between the mobile demonstrator platform and external applications. It provides external application developers access to energy supply, network connectivity, Input/Output connections, and redundant safety functions. The I/O physical connections are provided with digital and analog signals that can cater to a diverse range of applications and requirements. A single physical hardware plug is provided to access all the above functions and multiple application integrators can use the plug to access the respective physical connections. The hardware plug also includes a physical CAN bus interface that provides the external applications with access to the robotics systems internal CAN network. Additionally, the hardware interface also provides compressed air for pneumatic systems and robot tools.



### 2.3.2 Software Interface

The software interface facilitates real time access between the mobile demonstrator platform and external applications. The external applications can have read access to any value in the robotic system controller. The software interface also allows reading of several set of functions and values via the CAN-Bus. It ensures that commands, sensor data, and feedback information can be exchanged in real-time enabling precise control and monitoring of the mobile robotic system and its associated applications.

## 3. Human Machine Interface

The Human Machine Interface provides the user with essential operation control and monitoring capabilities. The HMI displays relevant information pertaining to the mobile robotic system including system configuration, power management, safety status and application monitoring.

Figure 6 describes the Human-machine interface used in the mobile demonstrator platform. The HMI contains a haptic display that provides with various states of the machine and helps the user communicate directly with the mobile robotic system. The robot platform can be controlled, and various manual manoeuvres can be performed using the HMI.



Figure 6 – Human-machine interface

## 4. Safety Systems

The mobile robotic demonstrator platform developed for the HumanTech project, incorporates several safety aspects to ensure the protection of both human workers and the efficient operation of the robot. These safety features are essential for creating a secure working environment for human workers in the operational space of the robotic system. The key safety aspects are described below:



*Figure 7 – Safety elements of the mobile demonstrator platform*

Figure 7 describes the two main safety elements of the mobile demonstrator platform.



### 1. Safety controller

Independent safety controllers are provided on the mobile demonstrator platform that is designed to ensure the safe operation of the robot in the collaborative construction environment. These controllers play a vital role in safeguarding human workers, preventing accidents, and complying with safety regulations. The safety controller can also define and monitor the safe states of the robot, such as idle or safe hold positions. If the robot deviates from these states unexpectedly, protective actions can be triggered.

### 2. E-stops: Vehicle and HMI

In addition to the safety controller, emergency stops are provided that can quickly halt all robot motion in case of an emergency or when a hazardous situation is detected. The E-Stop button is typically easily accessible to human operators either through the demonstrator platform or through the Human Machine Interface. The user can engage any of the provided E-Stop that is relevant to the emergency scenario.

### 3. Three-stage enabling switch: HMI

A three-stage enabling switch is provided on the HMI to prevent accidental or unauthorized start-up of machines. The enabling switch provides a reliable means for the user to enable or disable certain robot or platform functions. This safety mechanism helps prevent accidental or unauthorized activation of the demonstrator platform, reducing the risk of accidents and damage to the system and its surroundings.

### 4. Safe speed monitoring for the robot manipulator arm

Safe speed monitoring for robot manipulator arms is implemented to ensure the safety of human operators and the efficient operation of the robot. These systems minimize the risk of accidents and collisions in various applications by consistently monitoring and controlling the speed of the robot manipulator arm.



### 5. Axis monitoring for the mobile manipulator arm

Axis monitoring for a mobile manipulator arm helps to ensure a safe and effective operation of the robot arm. It involves real-time tracking, feedback sensors, safety limits, collision detection, speed control, and emergency stop mechanisms to prevent and account for safety in case of an unpredicted behaviour of the robotic arm.

### 6. Predefined safety zones

Predefined safety zones are specific areas within the robot manipulator's workspace or environment that are established in advance to enhance safety measures. These zones are typically designated based on the specific needs of the task or operation to be performed. These zones are important so that they prevent collisions between the platform and the robotic arm.

### 7. Camera-based safety system

The mobile robotic system is also fitted with a camera-based system for enhanced safety. The robot is equipped with 3 cameras that can look into the surroundings of the robot and assess the changing environmental conditions.



A video showing the visualisation of the mobile demonstrator platform is provided under the following link: <https://youtu.be/NUr9IZ7UjZE>



## 5. Next steps

The next step involves integrating the external elements into the mobile demonstrator platform. This is done during an integration workshop conducted along with all the partners that are building the external applications into the system.

