People Detection in Ports and Terminals

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Contents

1. Introduction

Document Purpose

This document intends to provide a high-level overview of the topic of people detection in ports and terminals. This document summarises the technologies available on the market and in which applications they can be used.

About This Document

This document is one of a series of Information Papers developed by the Safety Committee (SC) of the Port Equipment Manufacturers Association (PEMA). The series is designed to inform those involved in port and terminal operations about the design and application of software, hardware, systems and other advanced technologies to help increase operational efficiency, improve safety and security, and drive environmental conservancy. This document does not constitute professional advice, nor is it an exhaustive summary of the information available on the subject matter to which it refers. Every effort is made to ensure the accuracy of the information, but neither the author, PEMA, nor any member company is responsible for any loss, damage, costs or expenses incurred, whether or not in negligence, arising from reliance on or interpretation of the data. The comments set out in this publication are not necessarily the views of PEMA or any member company. Further Information Papers, Surveys and Recommendations from PEMA and partner organisations can be downloaded free of charge in PDF format at: www.pema.org/publication.

Background

Personnel detection is a key factor in human-machine interaction in the operation of a container terminal. People detection technology can be used to ensure that only authorised persons have access to certain areas or machines, preventing accidents. When humans must interact with port equipment (cranes and transport vehicles), they must be identified by technology as described in this document. Should an uncertain or unsafe situation arise, the machine operator must be warned, or the automation process must be stopped.

In general, personnel detection enables the automation of a working process by improving safety. With such technology, workers can also be tracked on the terminal and their position visualised.

Before deploying personnel detection technology in a terminal operation, a risk assessment must be carried out. The evaluation of the measures necessary to ensure a safe operation is the responsibility of the crane manufacturer, port operator and/or the local authorities who carry out the evaluation and give approval for the operation.

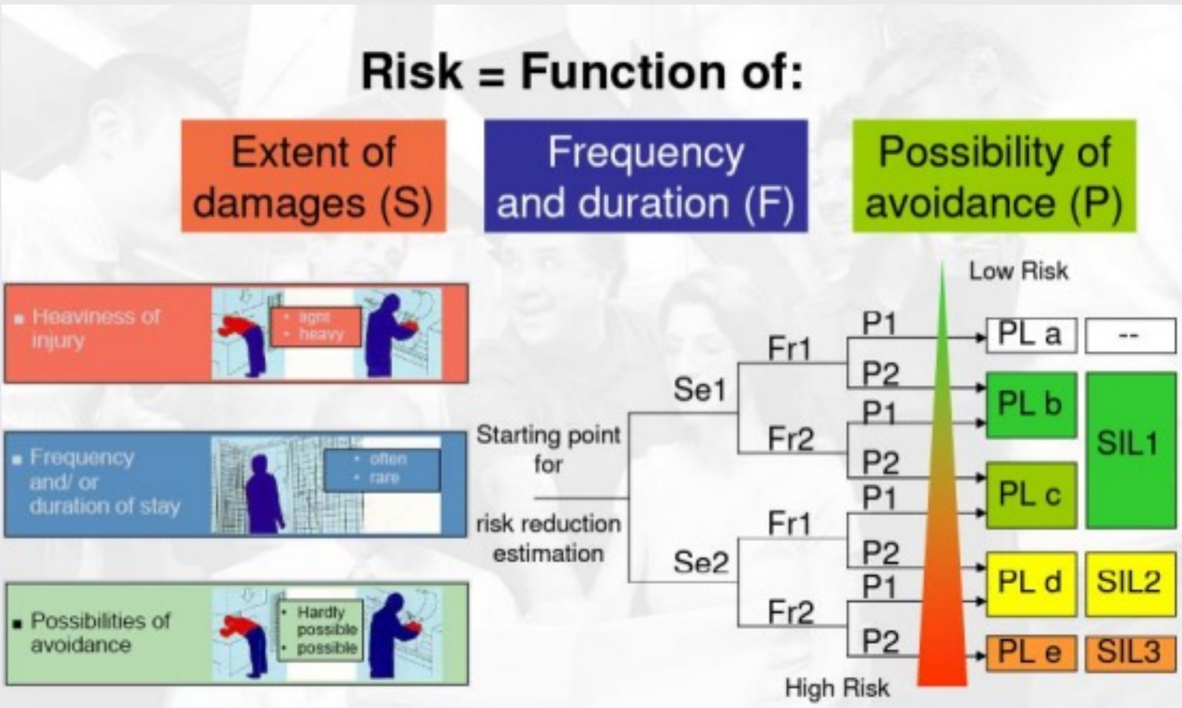
2. Safety Standards

The safety of machinery is crucial both for the protection of workers and the prevention of accidents. Risk assessment and risk evaluation, including determination of the limits, hazard identification, risk estimation and risk evaluation, play a central role in this. This process identifies and evaluates potential hazards and the requirements to take the appropriate safety measures. International standards such as EN ISO 12100 for risk assessment and risk reduction, EN ISO 13849 and IEC 62061 for functional safety, and the Machinery Directive 2006/42/EC (New Machinery Regulation 2023/1230 from January 2027) endorse this approach.

When the technology used is safety-certified, it simplifies the task. However, non-certified solutions are also capable of providing a safe work environment when used with a combination of technologies and processes.

In this context, the terms Safety Integrity Level (SIL) according to IEC and Performance Level (PL) according to ISO are frequently mentioned. These classifications, as defined by standardisation organisations, are used to assess the level of risk and, consequently, the required safety level of a specific product or solution. SIL is specified in the range between 1 and 4, and PL is in the range between a and e. Various methods, such as risk graphs and fault tree analyses, support the determination of SIL and PL levels.

Fig 1: Risk analyses according EN ISO 13849 PL (with its relation to the IEC 61508 SIL degree, simplified)



Risk analysis steps:

- Analyse the technology and identify potential risks.
- Assess the risks and define safety requirements.
- Development and implementation of safety measures.
- Validation of the safety measures through tests and simulations.
- Documentation of the entire process in compliance with standards.

In this context, practice-oriented and comprehensive staff training also plays a key role. Personnel should be familiar with the basic concepts of machine safety, including the relevant laws and standards. They should learn to identify, assess and minimise potential risks and understand and comply with safety regulations and procedures. Training should also cover the safe operation of machinery, maintenance processes and the importance of communicating safety concerns. Through such training, employees can be effectively educated in the safe use and maintenance of machinery.

International standards, regulations and certification play a leading role in machine safety. However, it should be noted that many terminals around the world already rely on technologies, designs and suppliers that are not safety certified. This approach can be a viable and sufficient option to meet the safety requirements if the selected technology is state-of-the-art and a thorough risk analysis and evaluation are undertaken.

3. Technologies

Various technologies are available for people detection, each with distinct advantages. Laser scanners and cameras can recognise both people and machines based on visual or motion data. RFID tags rely on radio signals to identify tagged individuals or equipment. Good planning, design and equipment selection are required before purchasing such a system. Redundancy and diversity for the chosen technology solution can also be considered as a means of reaching an enhanced safety level.

3.1 Laser-based People Detection Systems

The solution for laser-based people detection in the working area of machines (crane, AGV, straddle carrier, automatic truck) is provided by either multilayer or solid-state laser scanners. These laser scanners generate a 3-dimensional spatial image. If a person enters the monitored or working area of the machine, the laser measurement system detects the person, and the movement of the machine can be stopped.

Typical applications include personnel protection during machine movement by monitoring the travel path or during the transfer process of loading/ unloading a truck by monitoring the operations area.

3.1.1 Multi-layer Laser Scanner Technology

Multi-layer laser scanners and solid-state lasers generate multiple 2D scan planes. Lasers with 16, 24, 32, 64 and 128 scan planes are available on the market. The optical unit in the sensor can rotate up to 360°. Special mirror technology ensures high scanning field stability. Using multi-echo technology, the sensor can scan through rain, dust, and fog, while simultaneously multiplying the point density. These properties are particularly useful for creating a 3D point cloud without any gaps, which can be used to address a multiplicity of demanding applications.

In addition to the number of scan planes, the following criteria are important when selecting the right sensor:

- Distance
- Accuracy
- Horizontal scanning field
- Vertical scanning field
- Number of laser points in the scan plane, i.e. distance between scan points in the scan plane
- Divergence of the laser spot (dot size)

The following is an example of a point cloud density calculation:

Within a 2D scan plane, the laser points are transmitted with angle steps of 0.175° (horizontal resolution). If a laser scanner is measuring an object at a distance of 20m, this means that the laser points are 61mm apart. The horizontal scan planes have a 360° range.

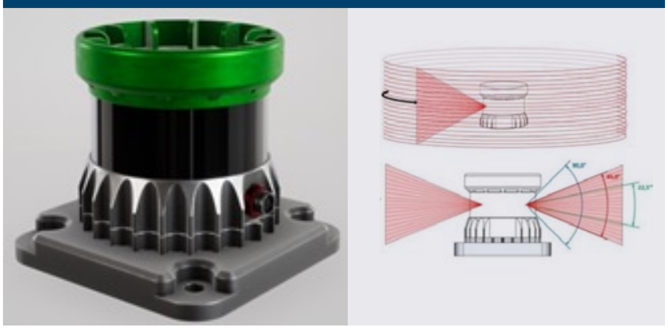
The scanner has a vertical scan angle of 22.5 degrees with 64 scan planes. The vertical resolution is 0.35°. This means that the scan planes have a 123 mm separation at a 20m distance.

3.1.2 Solid State Laser

The solid-state laser has no moving parts in the sensor. The 3D laser source is chip-based. As is the case for the Multilayer Laser Scanner, the same selection criteria apply when choosing the appropriate sensor for the application.

NOTE: Detailed technical information on laser-based technology is available in the PEMA publication IP08A

Fig 2: Laser scanner with the laser beam characteristic

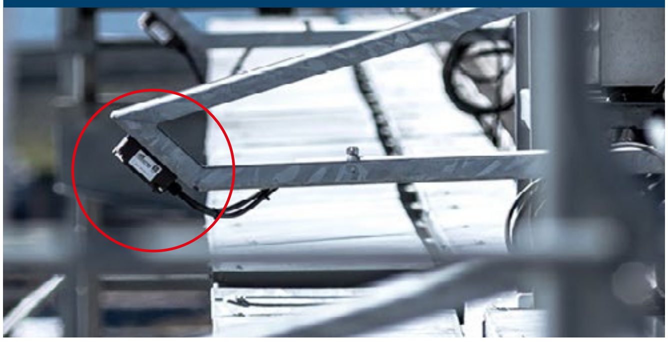


3.2 RFID / Radio-based People Detection Systems

The technology operates using radio waves, with Active RFID (Radio-Frequency Identification) often used simultaneously. Typically, ultra-wideband (UWB) frequencies serve as the primary radio waves, although frequency combinations are also employed to enhance performance and availability. Radio waves are used to localise, track, and identify various tags attached to objects or personnel, such as helmets (see ***Figure 3***). A secured area will be equipped with receivers or anchors (see ***Figure 4***). These anchors will receive the radio signal from the tags that belong to personnel or objects.

Fig 3: Tag mounted hard hat

Fig 4: Anchors / receivers mounted on a gantry crane



A minimum of three receivers is needed to calculate the position of a tag based on multilateration, "Time Difference of Arrival TDoA" technique (see ***Figure 5***). This tracking system works theoretically like a local GNSS. This technology also makes it possible to recognise people behind objects and does not necessarily require a line-of-sight situation.

RFID providers can use different technologies, frequencies and calculation models to utilise the various advantages and disadvantages of each (see ***Figure 6***). An optimised combination of these factors is the key to a robust and accurate solution in this challenging environment.

Fig 5: Personnel tracking based on RFID / RADIO

Fig 6: Radio based tracking with different calculation models

Precision, however, is not the primary focus, as the software is designed to manage inaccuracies.

The development process can be summarised as follows:

- Define requirements for the solution during initial discussions with clients and/or during the project.
- Improve position accuracy and availability by using more sensors.
- Consider factors such as line of sight and reflections that affect accuracy.
- Ensure that a tag communication is never lost in a dangerous area to maintain availability and safety.
- Use the RFID approach to provide comprehensive monitoring of the entire hazardous area, ensuring continuous positioning rather than just tracking objects when they enter a specific sensor range.

3.3 Camera-based People Detection Systems

People detection using camera-based solutions refers to the detection of individuals. Such solutions are commonly used in security, surveillance, traffic control, and smart home applications as an assistance system. 2D cameras, which capture two-dimensional images, are typically used for applications such as image processing, machine automation, robotics, and quality control. When compared with regular 2D cameras, 3D cameras are used to capture the three-dimensional space by adding depth information to the image. This can be achieved with technologies such as stereovision.

Cameras can have different resolutions, frame rates and features, depending on the application requirements.

The overall quality of the camera-based people detection system depends heavily on the location, the environmental conditions and the functionality of the selected camera. The following should be considered when selecting a camera:

- **Resolution:** The camera should have a sufficient resolution to detect humans. Higher resolution allows for more precise recognition
- **Frame rate:** The camera should have a frame rate capable of capturing the movements of the objects within the application. A compromise between high resolution and data transmission rates must often be found.
- **Lighting:** The camera should have suitable lighting to effectively visualise the object. Illumination helps reduce shadows and reflections that can interfere with accurate detection.
- **Processing speed:** The camera should be capable of processing captured images quickly to enable real-time recognition. Slow processing speed can cause delays and reduce system efficiency. When choosing a camera and its associated algorithms, the maximum overall acceptable latency must be determined for the application.
- **Latency:** Depending on the maximum acceptable latency, the camera frame rate, the underlying network connection and the processing unit must be chosen. A compromise between high resolution and fast data transmission must be found. The higher the required resolution, the longer the transmission time of a frame. The selection of the detection algorithm to be used also has a critical influence on the total latency of the system.
- **Robustness**: The camera should be robust and resistant to shocks, vibrations, dust, and moisture. Not all industrial cameras are suitable for outdoor environment applications, particularly in a marine environment. In applications where there is heavy mechanical stress, lens adjustments can change over time (camera intrinsic and extrinsic change).
- **Field of view:** The camera's field of view should be selected such that the entire area to be monitored is covered and that the people in it can be identified with the required resolution. A lens with a larger focal length has greater zoom capability.
- **Environmental factors:** Consideration should be given to environmental factors such as background interference or other objects that may affect recognition. The camera should be positioned to minimise these factors.

3.3.1 2D Camera Technology

There are several different technologies used in 2D cameras, including:

- CCD (Charge-Coupled Device): CCD sensors are found in many 2D cameras. These devices consist of an array of light-sensitive elements that convert incoming light into electrical signals.
- CMOS (Complementary Metal-Oxide-Semiconductor): CMOS sensors are known for their low power consumption, fast readout speed, and cost-effectiveness.

These cameras can be connected directly to a computer or an image processing system to process and analyse the captured images.

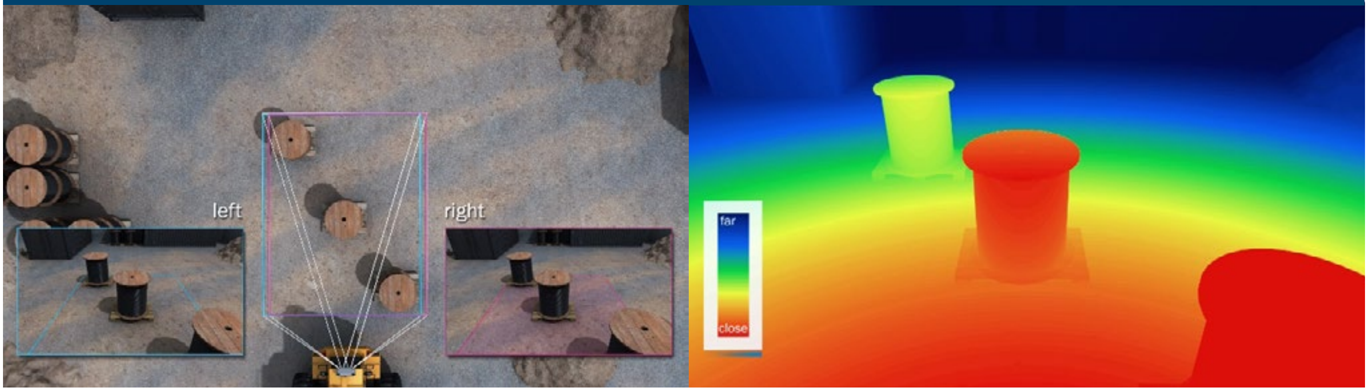
3.3.2 3D Stereo Camera Technology

Stereovision is a widely used 3D camera technology that makes the determination of the spatial depth of the image possible. The principle of this technology is similar to the human eye in that:

- A stereo camera consists of two separate cameras, and thus two sensors and lenses.
- Both cameras are separated by a fixed distance.
- The field of view of the two cameras overlaps and captures the same scene at a slightly different angle
- Objects in the two images appear in different positions. The closer an object is, the more it is shifted in the two images. This shift is known as “disparity”.
- Calibration of the two cameras makes it possible to calculate depth information based on these disparity values.

Fig 7: Spatial perception of 3D stereo camera in the port environment

Fig 8: Two images taken from different perspectives and depth calculation based on disparity



The result is a depth map where each pixel represents the distance of the corresponding point in the scene. Along with the 2D colour image from the camera, this depth map is used for further image processing.

Despite the same functional principle, 3D stereo cameras can differ significantly in their system architecture and, therefore, in the way they process and provide the data.

- Some 3D stereo cameras are calibrated directly in production to ensure the specified depth accuracy immediately on installation. Other cameras, which are not factory-calibrated, require and allow for calibration by carrying out a manual calibration routine of the complete system after it has been installed.
- The depth calculations can be performed either on or off the sensor. An embedded depth calculator reduces the amount of data post-processing on the receiver side and ensures a specified performance (e.g. frame rate, latency). This approach requires additional computing power on the camera itself (e.g. FPGA-based, i.e. Field Programmable Gate Array).
- In addition to streaming the data to a computer or an image processing system, smart 3D stereo cameras can offer additional embedded computing power (e.g. CPUs, GPUs, AI-accelerators) to run customised applications directly on the device, i.e. edge processing. Such cameras reduce the need for additional hardware while lowering the cost and complexity of the overall solution. Distributed systems, on the other hand, are more easily scaled to provide greater computing power if required.

4. Solutions

4.1 Laser-based Solutions

4.1.1 Example 1: Area Surveillance Truck Operation Under an RTG

In this solution, it is necessary to detect people in the crane's working area. In particular, the transfer from a manually driven truck to an automated RTG, RMG or STS crane must be performed safely and without injury. The design of the measurement system for this example of a truck lane under an RTG is based on two multi-layer lasers, each with a 22.5° horizontal field of view and 64 scanning planes.

The laser scanners are mounted under the main beams of the RTG and face downwards (*Figure 10*). The sensors are mounted at 90° such that the scan planes are vertical (*Figure 11*). One laser scanner (S1) is mounted on the main beam near the container stack and monitors the area from the container stack towards the truck/RTG wheels. The second scanner (S2) mounted on the main beam near the crane leg structure monitors the area from the RTG wheels towards the truck/container stack.

The system functions as follows (*Figure 9*):

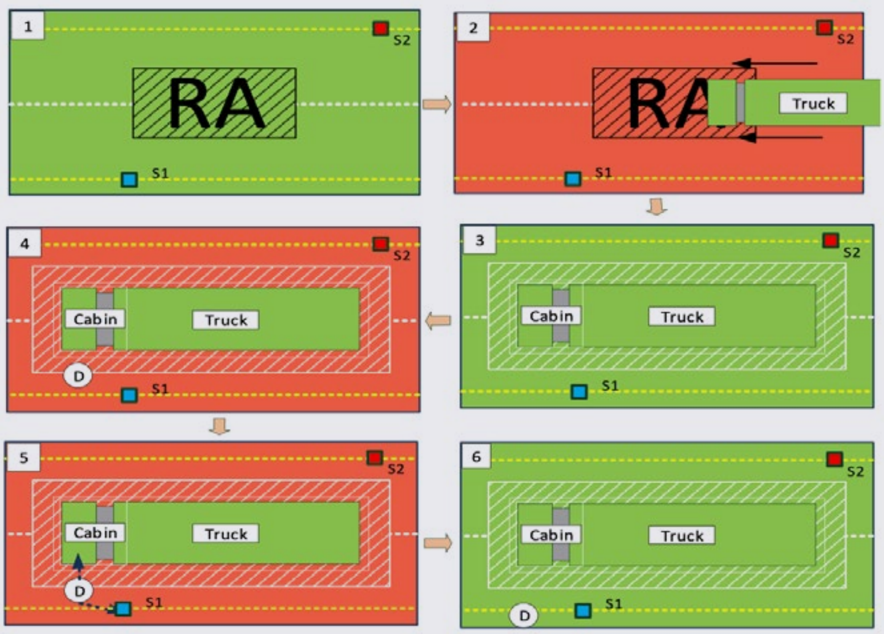
1. A 3D monitoring area is defined that is the width of the lane between the container stack and the gantry and extends approximately 10 meters beyond the RTG gantry footprint in both directions.

2. A truck with trailer (with or without a container) enters the transfer area under the RTG.

3. The truck and trailer are permitted objects that do not trigger an alarm.

If the truck driver leaves the cabin or any person enters the monitored area, this is detected, and a stop signal is sent to the crane control system. This signal disables the Hoist drive, preventing the load from being raised or lowered in the monitored area.

Fig 9: Zones in different stages



PROCESS FLOW:

Red means: RTG Operation in the area is not permitted

Green means: RTG Operation in the area is permitted

1. Area is empty (status: green)
2. Truck arriving (status: red)
3. Truck at delivery position (status: green)
4. Driver leaving cab (status: red)
5. Driver re-enters the area from outside (status: red)
6. Driver is outside the area (status: green)

Fig 10: 3D-scan with Surveillance Area

Fig 11: Scanner mounting positions on an RTG

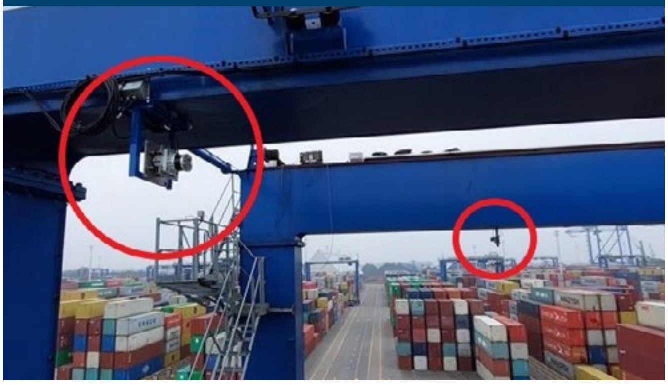


Fig 12: Mounting positions on an RTG

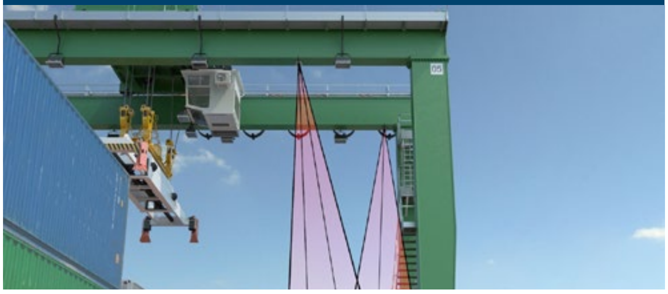
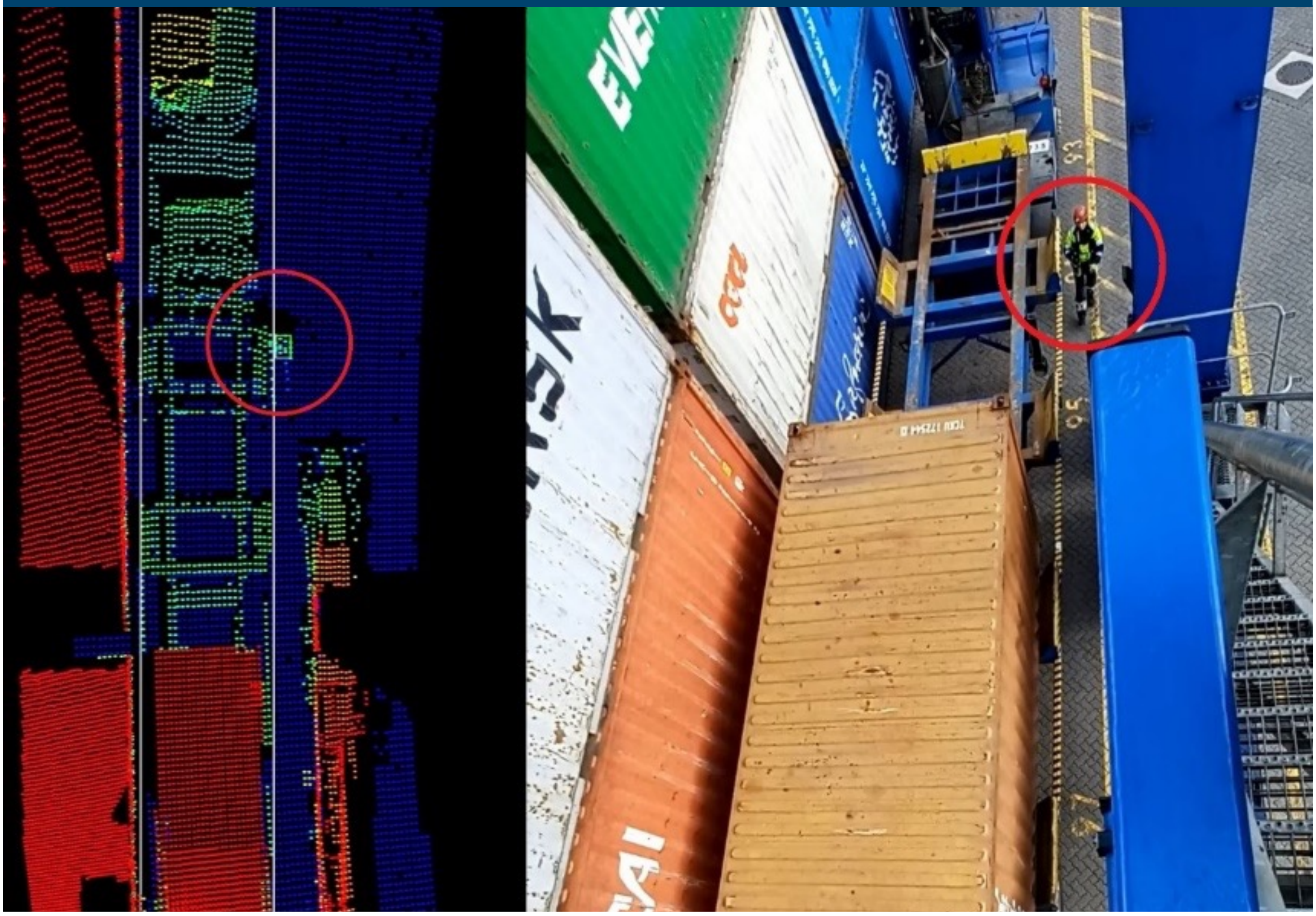


Figure 13 Notes:

- 3D-point cloud Raw data (Left), - Actual Image of the scene (Light), showing a person beside the Truck/trailer (red circle)
- Systems on the market are safety certified according to EN ISO 13849-1 - 2.
- The system also checks the position of the cabin relative to the load to ensure that the container cannot be dropped onto the cabin.
- Throughout the process, the truck's movement is monitored.

Fig 13: Person beside the truck, detected by the measurement system (Note: square around the person in the laser scanner raw data on the left side)



4.1.2. Example 2: Gantry Collision Prevention 3D Crane Gantry Path

This solution is designed to detect persons and objects using 3-dimensional lasers in the path of the machine (RTG, RMG, and STS crane) and to stop the machine if something is detected.

The sensors are placed on the outer edge of the gantry assembly at each crane corner (in total, 4 scanners/machine, one for each leading bogie). The sensors create a 3-dimensional field of view. Within this field of view, zones can be defined for pre-detection (blue), warning (yellow) and alarm (red), (see *Figure 14)*.

The system functions as follows

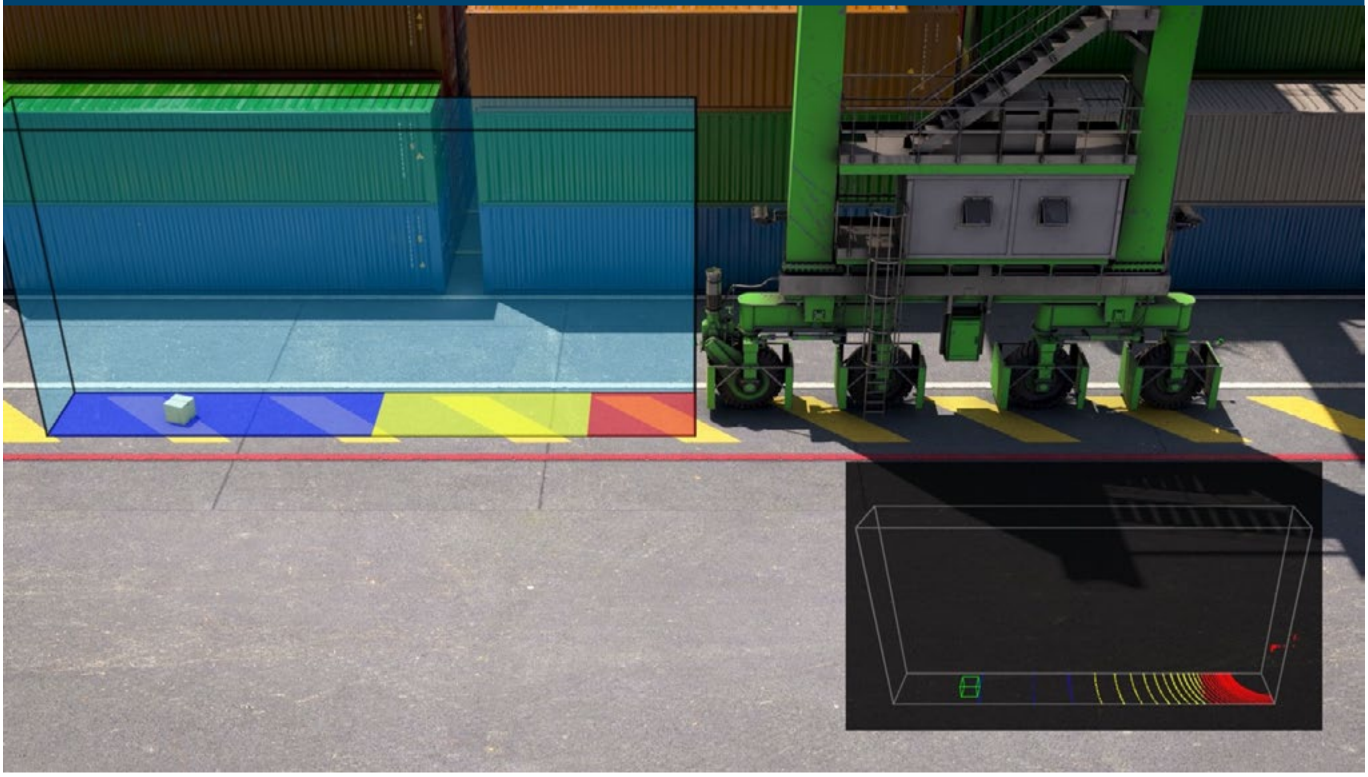
1. The 3D monitoring area is defined in front of the gantry bogie. This area is the width of the gantry assembly, and includes a safety margin, and extends in the direction of travel and at a desired height above the ground.

2. If an object or person is detected in the monitored path, the system detects the obstacle and gives a warning or alarm.

3. The information is sent to the crane's PLC.

4. The crane PLC will slow down the movement and/or stop the machine depending on the detection zone.

Fig 14: Person detection in the driving path of the machine



4.1.3 Example 3: People Detection for Railway Cranes Operation

This solution assists crane operators by using 3D Laser scanners to detect people in the areas underneath the railway crane where visibility is obscured. Laser scanners with 24 layers and an aperture angle of 120° (horizontal) and 15° (vertical) are installed under the main beam crane structure and oriented such that the aisles and railway tracks are monitored. The detection area is directly under the crane and some 30 meters left and right of the crane itself.

Object classification algorithms identify people as well as other objects, such as empty wagons, container wagons, and locomotives.

The functionality is as follows:

- A hazardous area within the monitoring area is defined.
- People entering or within the monitored area are detected. People entering the defined hazardous field generate an information signal that is transmitted to the Crane PLC.
- Similarly, should the crane move towards a person, and it reaches the hazardous field area, information is provided to the crane PLC.
- In each case, the appropriate action can be initiated to slow/stop the crane.
- Other objects, such as a locomotive entering the monitored area, are detected. When it enters the hazardous field area, information is provided to the crane, and the necessary action is initiated.

Fig 15: Person detection for railway operations

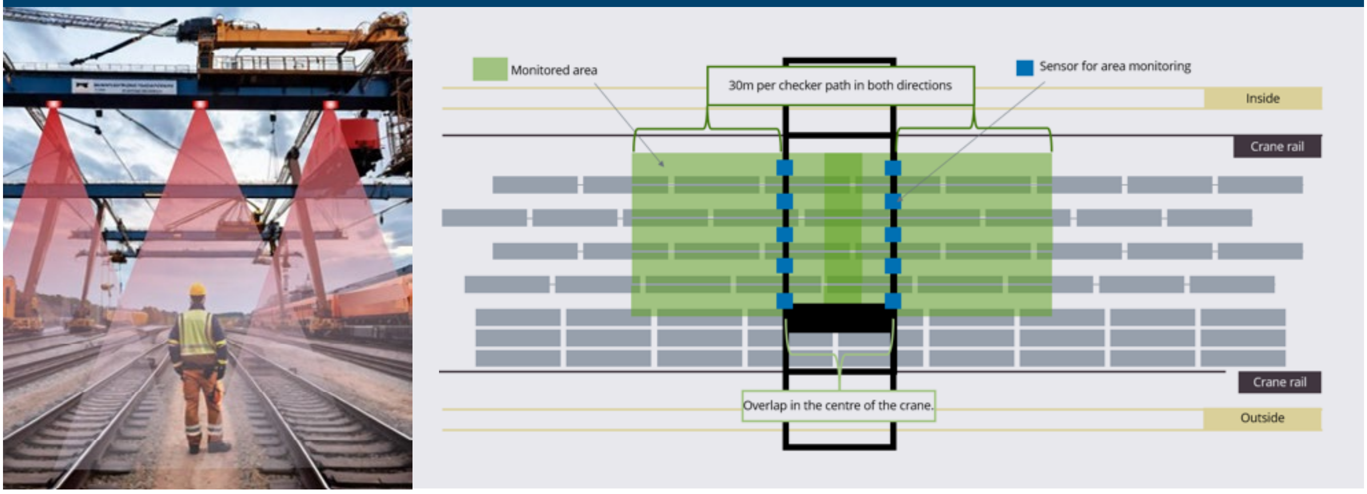


Fig 16: Person detection for railway operations

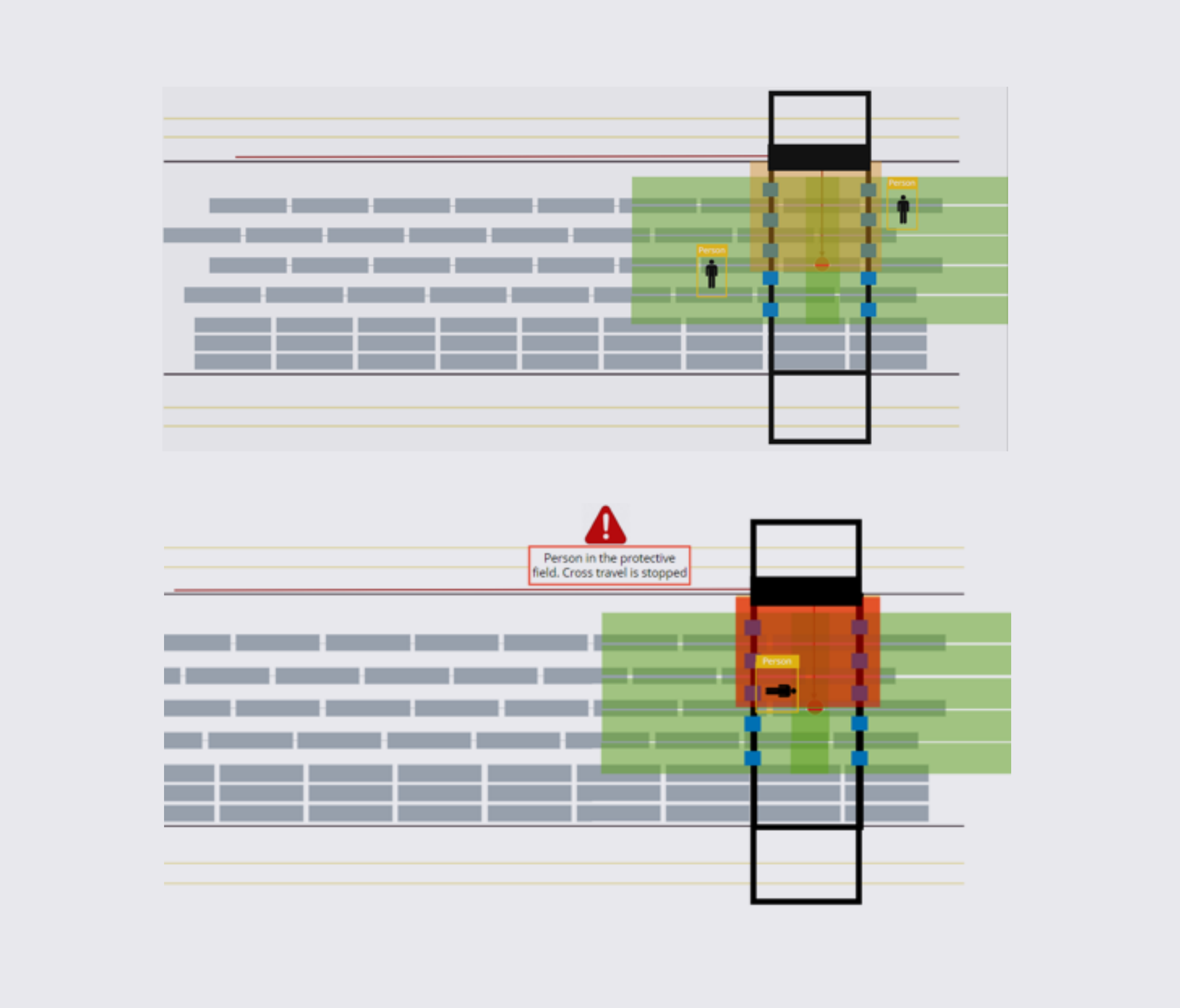
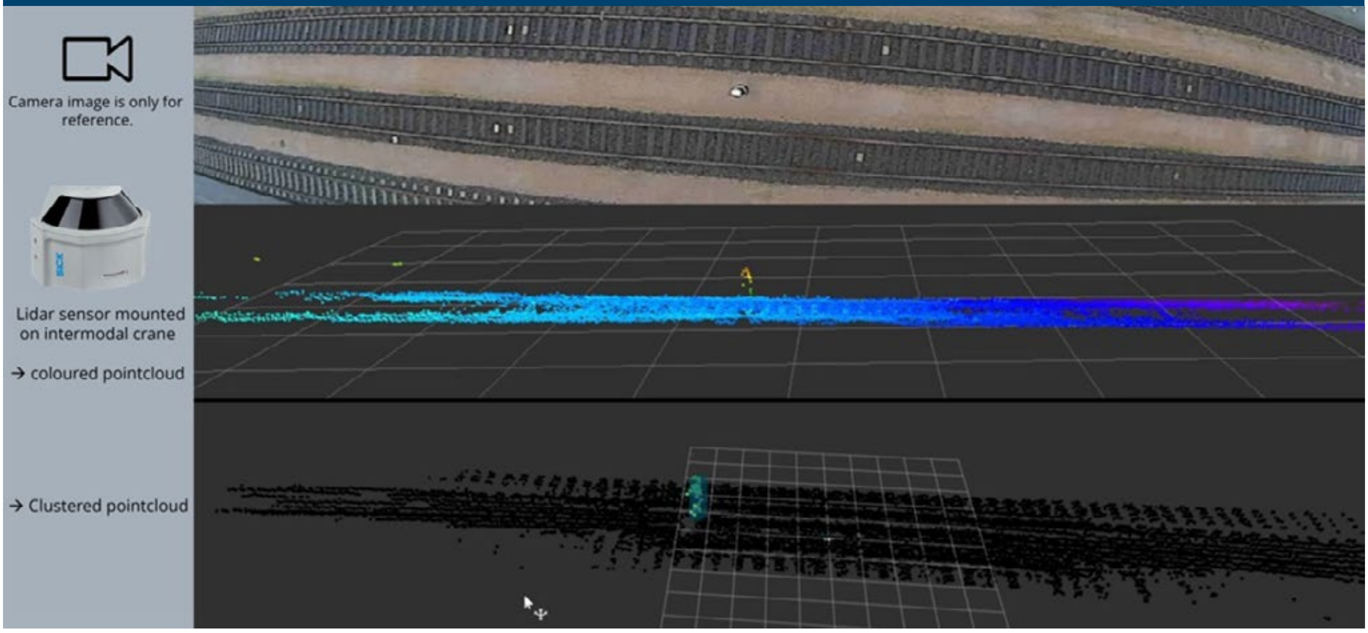


Fig 17: Person detection in the aisles around railway cranes



4.2 RFID / Radio-based Solutions

In general, this comprehensive solution for people tracking is used in environments where there is a high level of interaction between humans and machines within a defined area. Examples include train loading and unloading, pinning and lashing workers in the STS environment and Reefer container handling. In these environments, humans must be protected from coming into contact with container handling equipment. The two applications below demonstrate how this can be achieved.

4.2.1. Example 1: RFID-based Collision Avoidance Solution for Yard Cranes

This solution enhances the safety of personnel working in proximity to container handling equipment. The concept of this solution is based on identifying the position of all objects in the yard. This includes personnel, vehicles, material handling equipment and cranes.

The process flow outlined below is based on *Figure 18*:

1. Personnel Entry and Tracking:

- Persons entering the yard must wear an RFID tag.
- When entering the yard, their presence is recognised via a receiver, and the gate opens automatically if they have the necessary clearance.
- This ensures that all personnel are tracked from the moment they enter the yard until they leave.

2. Real-time Position Tracking:

- The yard is equipped with multiple receivers, including those on cranes and high masts.
- A minimum of three receivers per transmitter allows for precise position calculation, which is similar to a localised GNSS system (Global Navigation Satellite System).
- Vehicles and cranes are equipped with GNSS as the primary communications source and RFID as a secondary system, ensuring continuous tracking even when GNSS signals are lost.

3. System Functionality and Data Processing:

- The solution continuously tracks all objects in the yard, including personnel, vehicles, and cranes.
- It collects GNSS data, RFID signals, and encoder values from cranes for enhanced coordination and safety.
- This data is pre-processed using various processing units and is combined in a virtual machine infrastructure.

4. Digital Twin and Monitoring:

- The virtual machine infrastructure processes and visualises the collected data, creating a digital twin of the yard.
- This digital twin provides a real-time, detailed view of the yard's operations and allows interaction through a Human-Machine Interface (HMI). This digital twin is accessible to terminal operations personnel and provides a detailed visualisation of the workforce within the operations area. It is also possible for the operator to interact with the digital twin, e.g. set up protection zones or analyse historical data.

5. Path Optimisation:

- The Terminal Operating System (TOS) sends work orders via the system, which are passed to the cranes.
- The system optimises the crane's path, avoiding obstacles and ensuring smooth operations.

6. Advanced Anti-Collision Solution:

- The system continuously tracks the positions of all objects and personnel in the yard. Position data is enhanced with the required information for collision avoidance.
- In the case of unforeseen events, such as a person entering the crane's path, the anti-collision system initiates either a slowdown or stops the crane should it approach too close to the person.

Fully automated cranes use this detailed location data to navigate around obstacles without stopping, optimising operational efficiency.

Fig 18: RFID System Overview

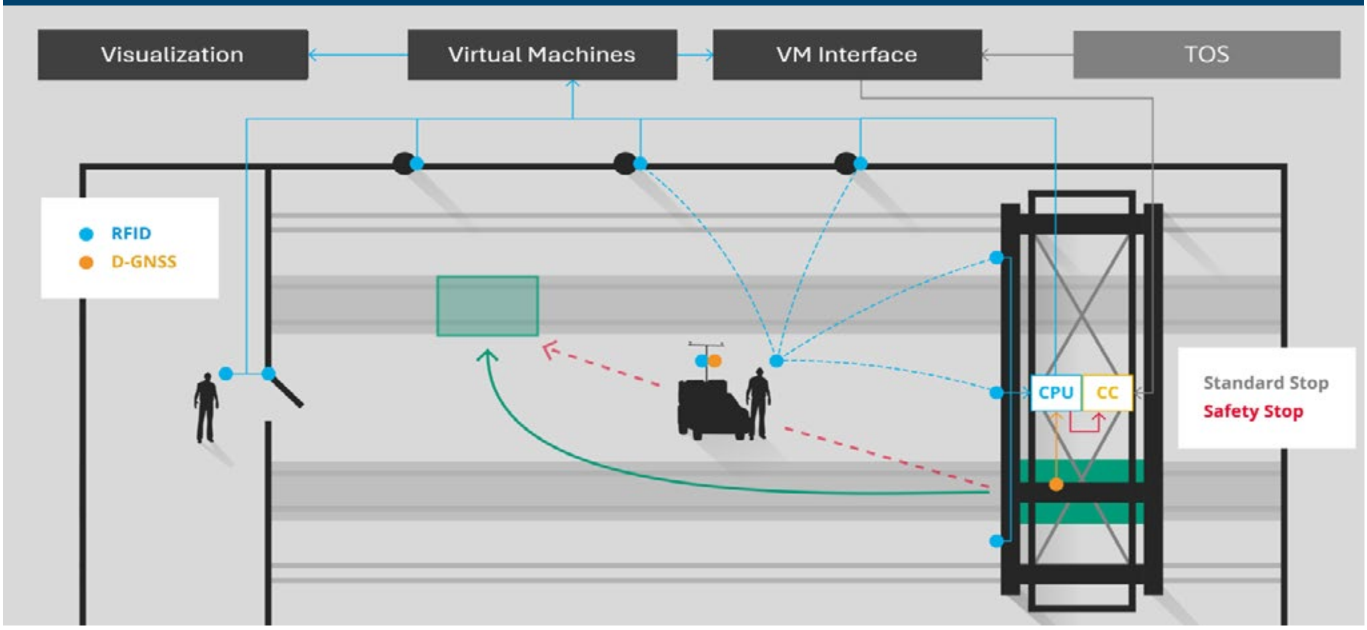
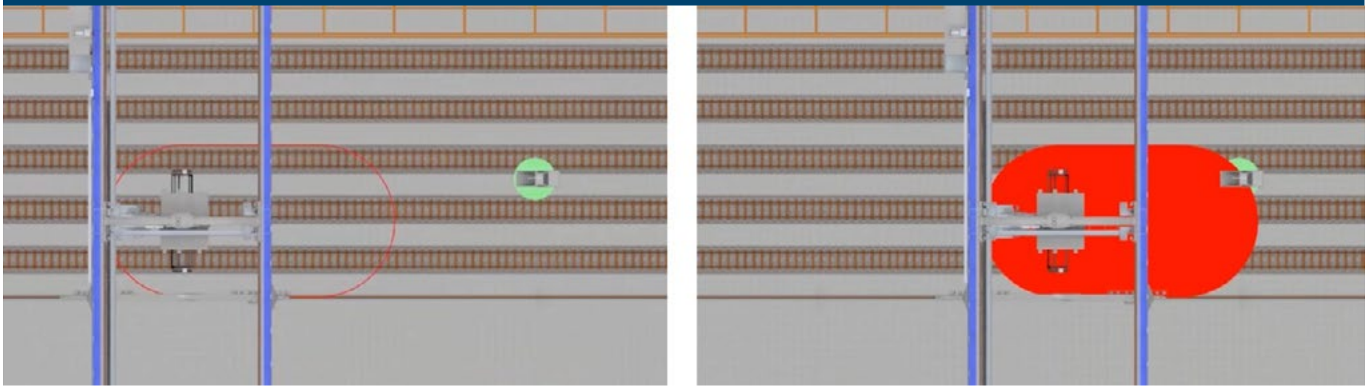


Fig 19: Anti-collision zone of the crane hits a protection zone of a vehicle



4.2.2 Example 2: RFID-based Collision Avoidance Solution for STS Cranes

This solution is designed to enhance the safety of personnel working underneath an STS crane, specifically in situations involving incoming straddle carriers. Workers are provided with helmet tags as part of this safety protocol. Anchor receiver/transmitter units are affixed to the rear legs of the STS crane and establish communication with a processing unit responsible for data analysis and transmission. To optimise safety and operational efficiency, the backreach area is typically subdivided into two distinct zones (see *Figure 20*).

1. The first zone, illustrated as the green zone, is designated as a static area where vehicle movement is prohibited, ensuring continuous protection for workers.

2. The second zone, which is designated as the red zone, is where straddle carriers regularly enter and exit as part of the terminal operation.

When a worker enters the red zone, a potential hazardous scenario is created due to the possible presence of moving straddle carriers. In this situation, the system triggers a traffic light mounted on the STS crane. The Traffic light serves to alert approaching manually driven straddle carriers to pause their movement, thereby mitigating the risk of collision and ensuring the safety of workers (see *Figure 21*). In the case of automated Straddle Carriers, the system signal can be used to slow and stop the machine via the automation control network.

Fig 20: Worker in the green zone Straddle Carrier allowed to drive

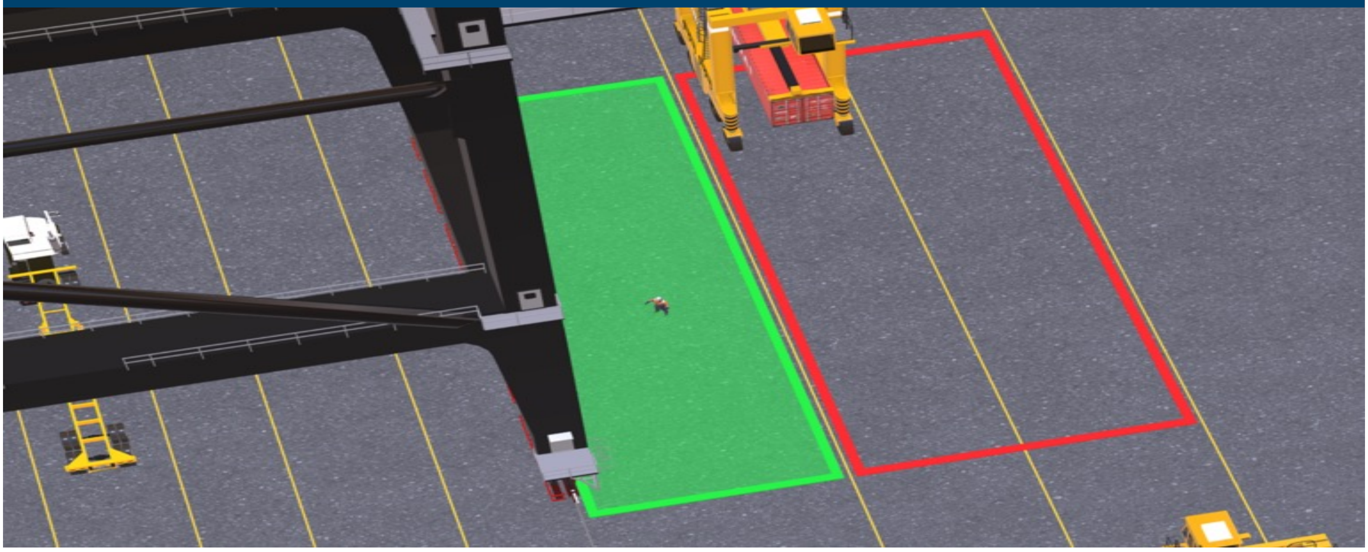
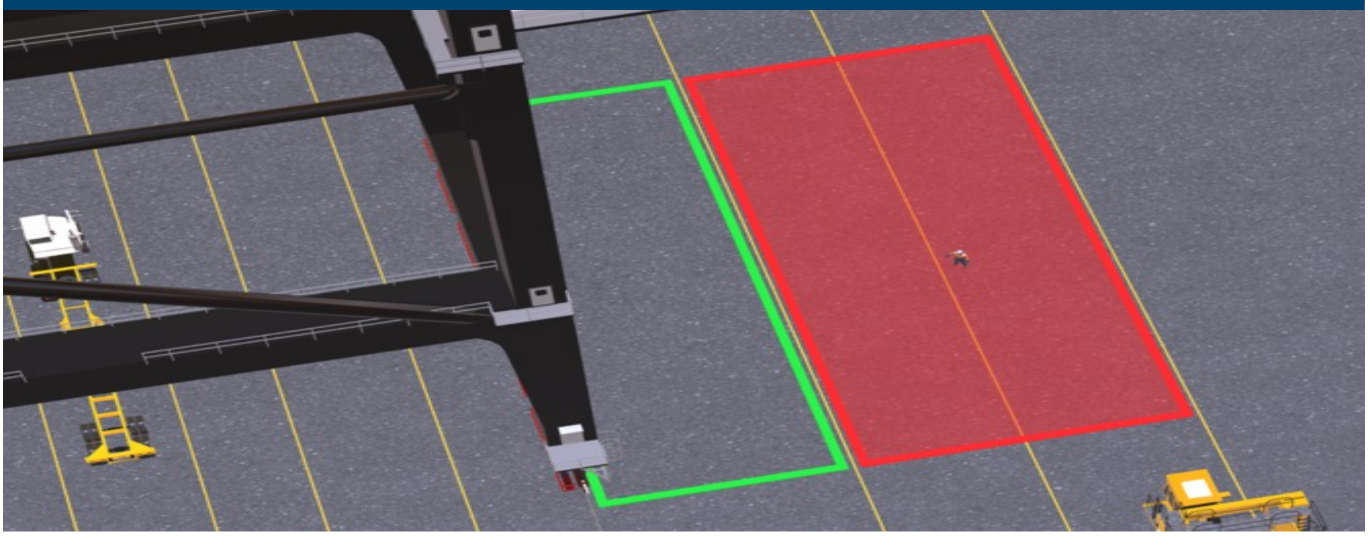


Fig 21: Worker in the red zone Straddle Carrier must wait



4.3 Camera-based Solutions

4.3.1 Example 1: People Detection in Remote Control Operations with 2D Cameras

This solution assists remote operators in recognising and identifying people when controlling the crane movements remotely.

Remote control of a crane without a direct view of the work area requires that the work area be visible to the remote operator on HD monitors using camera streams. To simplify the operator's task and alert him to dangers such as people in the vicinity of the work area, the camera streams are scanned for people. If one or more people are detected, they will be highlighted using overlays in the original camera stream without impacting the latency time of the operational activity. The detected person(s) is identified using a coloured box or circle in the overlay. Functions such as detecting and tracking people are used in this application.

The detection system uses specific algorithms to recognise people as specific objects in a camera image. These algorithms utilise technology such as machine learning and trained models to distinguish people from other objects.

Having detected a person, these solutions can track him/her across multiple camera images. This enables continuous monitoring of the person's position and movements in multiple subsequent frames. Multiple frame tracking overcomes the limitations of single frame systems, such as missing detections when the AI system generates a false negative. The accumulated data from the previous frames ensures that a person is detected. In addition, tracking facilitates detection in more challenging situations. For example, in the scenario where a person is hidden by a passing vehicle, he/she cannot be seen by any camera. Knowing the previous and future path of the person, however, allows the interpolation of the position even if not immediately visible.

Zones can also be defined to provide additional warnings to the remote operator.

The advantage of integrating people detection on a remote desk operation is that only an additional processing unit is required, since the camera infrastructure already exists.

It is important to note that when employing camera-based solutions for people detection, legal and privacy-related issues must be considered. Before implementing such solutions, it is necessary to review the applicable laws and regulations regarding surveillance and data privacy legislation in the country or region of use.

Fig 22: Example for remote operator desk showing live video streams

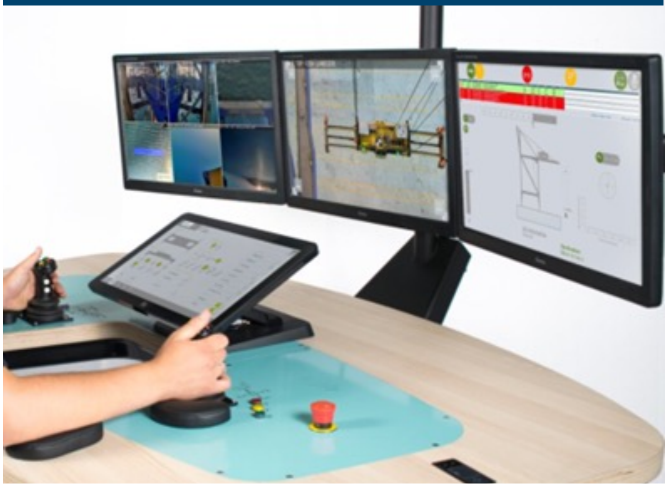


Fig 23: Example for people detection on a remote operator desk during unloading a vessel

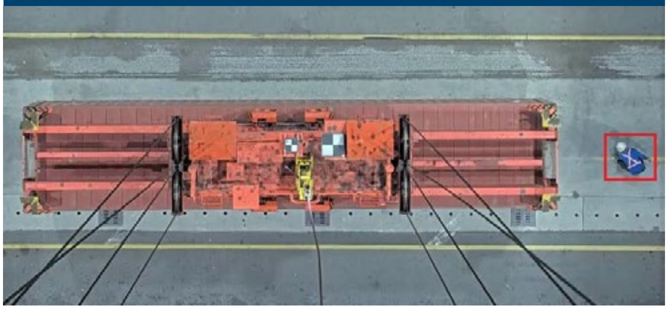


Fig 24: Example for people detection on a remote operator desk during loading a vessel

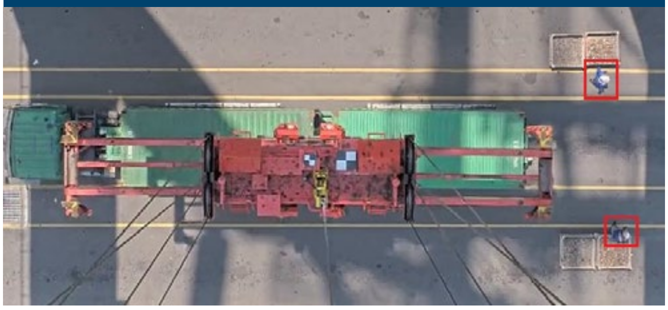


Fig 25: Example for people detection on a remote operator desk including zones to provide additional warnings

Fig 26: Example of people detection with the probability of detection

4.3.2 Example 2: People detection at Railway Crane Operation

This solution assists crane operators by using 3D Cameras to detect people and objects in defined areas of the railway crane operational area where visibility is obscured.

Operation principles of the System:

- 3D Cameras installed on crane structure (each leg of the crane at approx. 8m height)
- 3D spatial areas of interest are defined (*Figure 27*, yellow & blue areas). Up to 16 spatial areas, e.g. one per each track and aisle, is possible.
- Several spatial areas per track and aisle can be defined, optionally split into near field (stopping field) and far field (warning field).
- Information about person detection can be transmitted either by the infringed field and/or by X-Y-Z coordinates. Using this data, the crane can continue to operate by changing its planned route.
- The camera detects persons entering the field (AI) and generates the following:

– **Object list:** Detailed information is transmitted to the crane, such as object class (person) and X-Y-Z coordinates

– **Field infringement:** Alternatively, information on a field infringement can be provided

Based on this transmitted information, warning and stop signals as well a 2D RGB visualisation images can be used to influence he operation.

Duplicating this system on the opposite side of the crane leg can further increase the safety and reliability of person detection.

Fig 27: Left warning field infringed by person (yellow), right warning field free (blue)

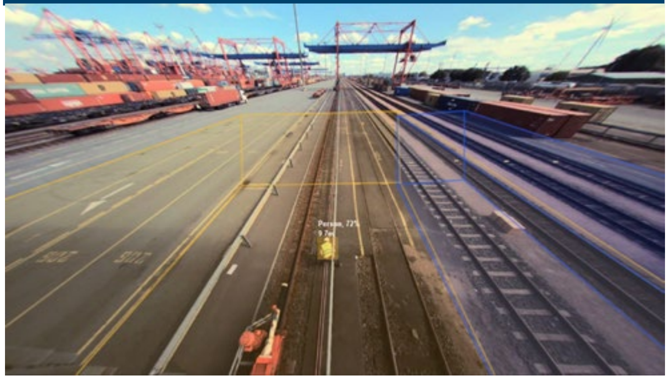
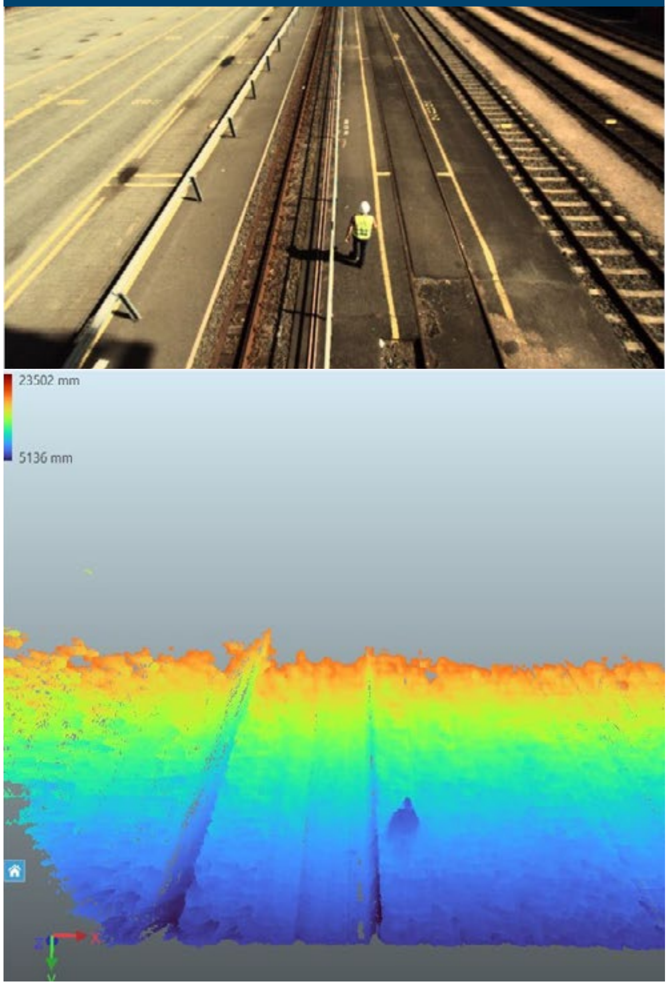


Fig 28: 2D RGB and 3D Point cloud



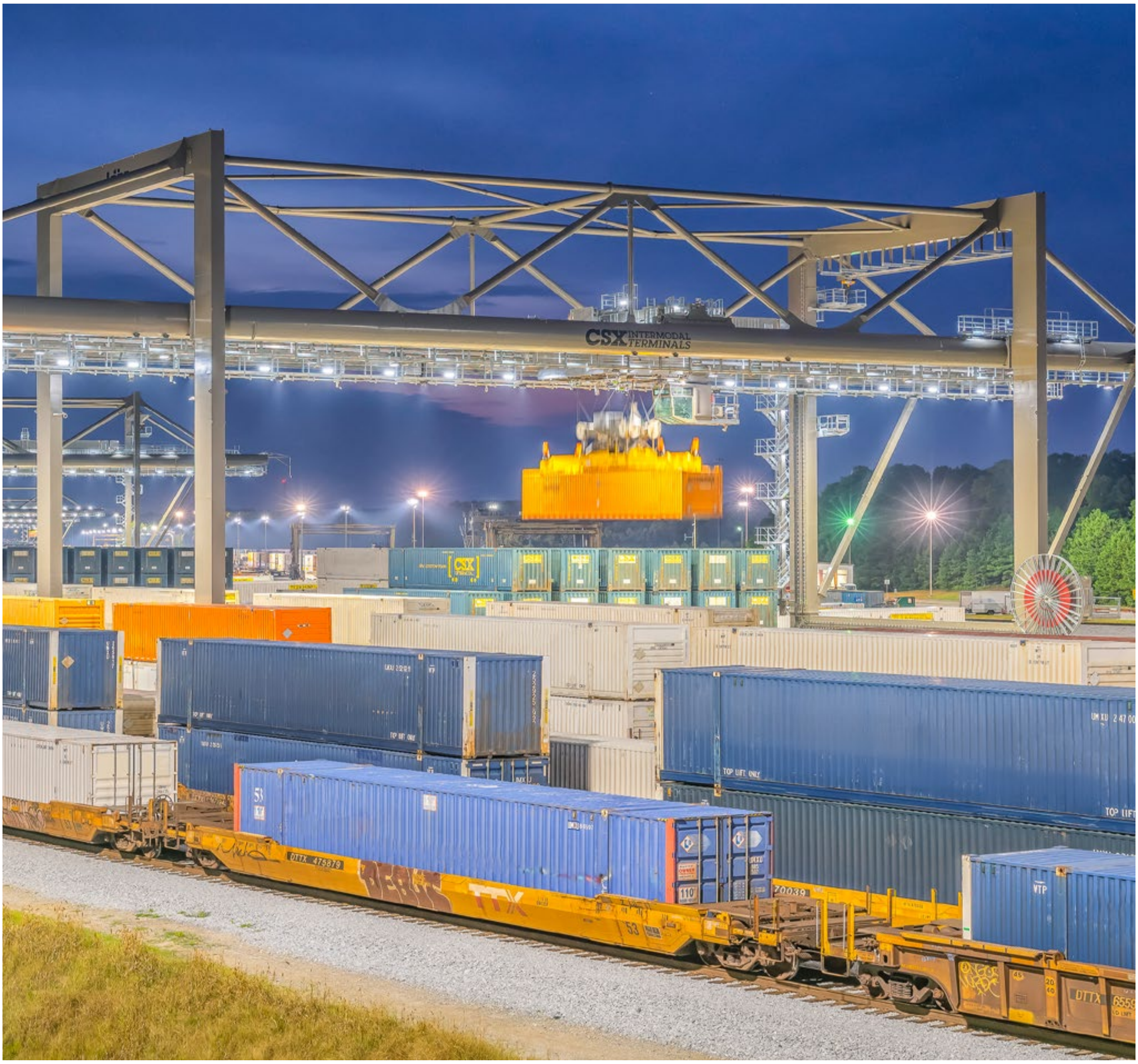
5. Conclusion

The integration of personnel detection technologies on both machines and in the port environment generally plays a major role in a safe operation, especially when automation is employed.

As container terminals continue to adopt higher levels of automation, while still requiring on-site personnel, it is essential to implement personnel detection as a safety measure. Such people detection systems also greatly enhance personnel safety on manually operated terminals.

Various technologies and concepts are available on the market that provide seamless information about the position of people in the terminal and monitor specific risk areas for hazard situations.

It is necessary to carefully evaluate the envisioned mode of operation and the associated risks. Based on this analysis, the appropriate solution must be implemented to protect human life.



List of Illustrations

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