Netzwerk Baumaschinen NRMM CV

# Person/object detection, warning in danger areas

## Camera and sensor systems, intelligent software for mobile machinery (construction machinery – mining)

Safety and efficiency in the use of Non Road Mobile Machinery/NRMM and Commercial Vehicles/CV – Guideline for operators, manufacturers and supervisors

**The Network Construction Machinery NRMM CV** supports the quality and cost-effectiveness of processes to improve safety in hazardous areas of mobile machinery (NRMM = Non-Road Mobile Machinery) and commercial vehicles (CV = Commercial Vehicles).

The primary focus is on "person and object detection for collision avoidance". Central tasks in this area are discussed with the stakeholders concerned - and the results are used to develop practical information and guidelines.

Essentially, the information and solutions presented in this guide apply to mobile construction machinery and commercial vehicles (also referred to collectively in the guide as "mobile machinery") that move around construction sites, quarries or even the ceramic and glass industries.

Due to similar technology and comparable hazard potential, the information can also be applied to other vehicles and mobile machines. For this purpose, the network offers separate sector specific guides – (For an overview of the guides, see page 48).

This network guide **"Person/object detection, warning in danger areas"** provides an overview of technical measures, such as

- camera monitor systems,
- warning and sensor systems, and
- intelligent software for object detection,

which can support the driver/operator in case of limited visibility and provide reliable collision protection when using mobile machinery.

Entrepreneurs, managers, works councils, occupational safety specialists (SiFAs*), safety officers (SiBes*), safety and health coordinators (SiGeKos*), drivers/operators, manufacturers and building owners receive valuable tips for safe and efficient use.

*German abbreviation

INITIATIVE NEUE QUALITÄT DER ARBEIT

**Good working conditions and economic success belong together!**

The Network Construction Machinery NRMM CV acts in the spirit of the German "Initiative New Quality of Work" (INQA) of the Federal Ministry of Labour and Social Affairs (BMAS). INQA as a practical platform for quality of work and the change of work connects companies with expertise, practical experience and a broad network with concrete offers, which are supported by social partnership.

- www.inqa.de

**VISION ZERO.**
ZERO ACCIDENTS – HEALTHY WORK.

Occupational safety is teamwork!
The network is committed to this and supports the BG RCI prevention strategy "VISION ZERO." as a cooperation partner.
"VISION ZERO. Zero accidents – Work safely!" assumes that suitable preventive measures can achieve a working environment in which no one is killed at work or injured or falls ill so seriously that lifelong damage results.

- www.bgrci.de/vision-zero

# Contents

# 1 Detecting dangerous situations safely

## Visibility and attention

During the operation of mobile machinery, deadly accidents and property damage occur repeatedly due to persons and objects in the danger area not being detected in time.

**Poor or missing visibility causes:**

- Disturbances in the work process
- Stress for those affected
- Increased risk of accidents

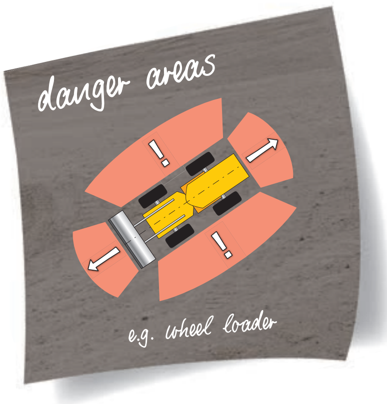
## First requirement: Ensure good visibility of the hazardous areas!

**Definition of field of vision: Totality of all directions to the front and the sides in which the driver/operator can see.**

Despite the improvements in driver visibility on mobile machinery, so-called "blind spots" can remain outside the **driver's field of view** due to the design:
the danger areas that cannot be seen directly from the driver's seat!

If the driver's direct view of his working area is not sufficient to safely recognize persons and objects there, technical measures, such as camera monitor systems (CMS), must be used as a matter of priority (see risk assessment chapter 1.1).

- **Therefore, before ordering and after delivery of a new mobile machine, as well as when renting and purchasing an existing machine, it is essential to check whether there is a clear view. If there is no visibility, technical measures must be taken first (TOP principle, see next page)!**




**Prevention - the best way to avoid accidents**

Prevention is the safest way to avoid accidents. Therefore, always prepare a visibility risk assessment before changing jobs – especially on new construction sites. According to German requirements for risk assessment, see ArbSchG (Arbeitsschutzgesetz) specified in TRBS 1111.

The risk assessment, which must be performed by the employer (according to the Occupational safety and health law), is not to be confused with the manufacturer's risk assessment/hazard analysis (according to the Machinery Directive)!

## 1.1 Performing a visibility risk assessment

**If the driver's/operator's direct view of the work area is not sufficient to safely detect persons and objects there, technical measures must be defined and implemented as a matter of priority in accordance with the "TOP principle". Examples of protective measures:**

1. **Technical:** Use means to improve visibility, such as camera monitor systems that ensure adequate visibility. Also consider whether additional warning/sensor systems are needed for person/object detection.
2. **Organizational:** Define and mark hazardous areas, establish rules of conduct (e.g., prohibition of presence, guiding, marshall, security guards or barriers) and monitor compliance with them, provide regular instruction on hazards and the protective measures to be observed.
3. **Personal:** Provide personal protective equipment (PPE), e.g. high-visibility vests as a supplementary measure, and ensure that they are used.

**The risk assessment must already be started before the selection and procurement of work equipment.**

**The requirements and criteria for the planned areas of use must be described and documented in detail. These include, for example:**

- **Application requirements**
- **Experience of the employees**
- **State of the art in personnel and object detection systems**

### Allow sufficient visibility of the roadway and hazardous areas.

**First optimize the seat setting for the driver and then check it: Is there a direct view of the machine's danger areas, and**

- Are all mirrors mounted on the machine?
- Are the mirrors in the correct position?
  - Note the following: Mirrors and monitors must be mounted in the driver's front 180° field of view.
- Is the view sufficient? (see tip in right-hand column).

**If not, implement and use the following technical measures or solutions:**

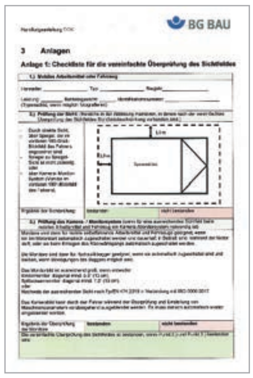
- Camera monitor system
- All-round vision camera system
- Warning/sensor system
- Intelligent, active solutions

In special, unclear situations (e.g. when loading and unloading, in flowing traffic), instruct and use traffic signaller/marshalls.

Always identify possible hazards in the area of use of mobile machines and implement and document suitable protective measures according to the **„TOP-Principle“**:

- **T**echnical measures always have priority over
- **O**rganizational and
- **P**ersonal measures

**TIP: Checklist for the simplified inspection of the field of vision**




https://www.dguv.de/medien/fb-bauwesen/bilder/erfassungsbogen_1.pdf

## Second requirement: Enable driver attention

However, no one can constantly and fully concentrate on monitoring all the operations of their mobile machine or vehicle. The best visibility conditions and additional measures to improve visibility are only of use as long as the driver has all hazardous areas in view simultaneously and attentively. A loss of concentration can severely reduce the driver's ability to react – with serious consequences.

**Identify the causes of fatigue and declining responsiveness:**

- High work intensity, time and deadline pressure
- Complex tasks
- Completely missing or insufficient risk assessments
- Unfavourable weather and visibility conditions
- Ergonomic influences
- Fatigue
- High noise levels, dense traffic
- Monotonous procedures
- Psychological stress factors*

*Further informatione "No stress with the stress"/ "Kein Stress mit dem Stress" Guide for managers and employees at www.psyga.info

**To prevent in time and enable the driver's attention, use sensory warning systems that support the camera monitor systems.**

The sensory system warns the driver in case of acute danger. It sharpens his attention, for example, by means of a clearly perceptible acoustic signal. When looking at the monitor of the camera monitor system, the driver receives precise information about who or what has appeared in his working or danger area.
In many cases, a camera is already fitted to the mobile machine upon leaving the factory. In this case, it is advisable to add a sensory system to prevent a loss of attention.

## Third requirement: Make machines smarter

Even if clear visibility is ensured and active warning systems ensure the best possible attention, many other tasks remain for the driver/operator that go far beyond the performance of an assistance system when maneuvering or driving (see also: chapter 5).

**Examples of assistance tasks that make mobile machines "smarter":**

- Intelligent collision warning
- Lane keeping for mobile machinery
- Display of fill levels (e.g. containers)
- Optimise machine performance
- Minimising downtime
- Positioning of pallets
- Warning signal transmission of machine fleets for preventive maintenance
- Support compliance with safety regulations

These and other automation tasks can be solved with a combination of robust hardware and intelligent software (algorithms). Image processing technologies and reliable 3D camera data play a key role here.
The data evaluated by the software communicate directly with the machine. Thus, they relieve the driver and reduce the risks of accidents and damage.

## Digitization provides the basis for making machines "smarter"

Whereas up to now camera/sensor systems, according to their requirement-related specifications, have been working independently on the same tasks - for example, the detection of people and objects in hazardous areas – digitized processes enable further solutions.

Digital processes combine information from several integrated sensors. The measured data is acquired in parallel from, for example, a camera, an ultrasonic sensor and a radar system, which are evaluating simultaneously. This superimposition of sensor signals increases reliability in the detection of hazardous situations across the multitude of possible environmental scenarios. The result is used to trigger a previously defined system intervention.

When danger is detected, the system actively intervenes in the behaviour of a system in order to protect detected persons and bring the system back into a safe state: e.g., through an autonomously induced braking or evasive maneuver (see chapter 5).

Digitization provides the basis for simultaneously
- making machines more intelligent and
- increasing automation of business and work processes.

Digitization supports value-creating effects by optimizing business processes. Digitization requires and brings about permanent changes, up to and including "new forms of collaboration".

| INTERVENTION IN DRIVING BEHAVIOR | INTEGRATION |
|---|---|
| ▪ Display of the environment on the vehicle monitor with hazard identification and acoustic warning | Installation of sensor technology, computing unit and visual display including visual and acoustic warning methodology |
| ▪ Putting the vehicle in a ready-to-brake state (increase braking force boosting)<br>▪ Reduce acceleration<br><br>▪ Initiate braking process (autonomous braking)<br>▪ Intervene in steering behaviour (evasive maneuvers)<br><br>▪ Autonomous driving | Monitoring and active machine control<br>▪ Functional safety<br>▪ Safeguarding |

### Functional safety

An assessment of functional safety is carried out taking into account the generally recognized rules of technology. The primary objective of "functional safety" is to reduce the risk of danger to persons. Functional safety concerns the control system of mobile machines on which a safety-relevant function depends. This is particularly relevant in autonomous systems for accident prevention.

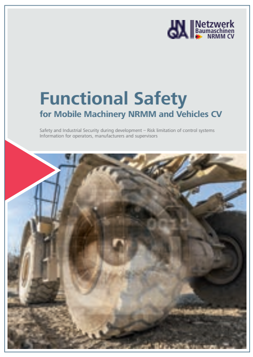
If the behaviour of a system is actively intervened in the event of danger, this must always be evaluated and implemented according to the criteria of functional safety.

### Industrial security

With the increasing degree of networking in mobile machines and, above all, the increasing opening up of previously internal data/communication networks and components, "industrial security" is also gaining in importance.
The risk of an external attack and the possible manipulation of software and data associated with it is increasing. This can have serious consequences for security. Industrial security is thus becoming the focus of attention at all levels and phases of development and operation. The main objectives of Industrial Security are confidentiality, integrity and availability of data and software functions.

**Functional Safety: Protection of people from machines (occupational safety); design measures to make machines safer so that safety-related control systems can reliably perform their safety functions.**

**Industrial Security: Protection of the machine against attacks by third parties; safeguarding of information technology in industrial plants, machines and systems (cf. VDMA: "Leitfaden Industrie 4.0 Security")**




**see "Functional Safety" brochure download at: www.safety-machinery.com**

# 2 Sight and visual aids

## Camera monitor systems (CMS)

### 2.1 Standard camera-monitor-systems

Camera monitor systems (CMS) are auxiliary devices for improving visibility in the working and movement area of mobile machines. They support the monitoring of hazardous areas in front of, behind and around a mobile machine – both during driving movements and during movements of attachments and front components.

The photo above shows the display on the monitor – using the example of an excavator.

Use Case: the rear camera on a wheel loader provides a view of the rear working area

**When using CMS, respect following requirements:**

- CMS are not intended to perform prolonged driving movements.
- They are to be used exclusively for monitoring the close-up area around the machine.
- Direct vision is prefered.

Examples for heavy duty cameras and a waterproof monitor

**Direct vision has top priority!**

## Systems for improving visibility and detecting hazards

Anyone driving vehicles or mobile machinery with poor visibility is exposed to considerable mental stress.

Standard camera monitor systems have proven their worth in improving visibility and speeding up hazard detection when using mobile machines and commercial vehicles in quarries, on construction sites, etc.

## Avoiding accidents and hazards due to restricted visibility

**The implementation of modern technology enables safer work processes, encrease of ergonomic and much more effectiveness.**

Seek qualified advice from a specialist company on the fields of application and particular advantages of the systems described for improving visibility and additional hazard detection.
This includes comprehensive information on important technical and optical requirements for camera monitor systems, such as:

- Camera opening angle
- Monitor colour fastness
- Transmission time of the image data
- External influences
- Alignment of camera and monitor

**Recommendation:**
**For ergonomic and safety reasons, monitors should have a size of min. 7 inches at a viewing distance of up to 1m (see DIN EN 1175): The driver/operator must be able to recognize endangered persons quickly.**

**Further requirement from ISO 16001: The endangered person must be shown on the monitor in a size of at least 7 mm.**

In addition to rear-view cameras, side-view cameras (see pictures above) can detect and display hazardous areas that were previously not visible - such as the (right) side of a mobile machine facing away from the driver.

Put an end to flying blind when reversing, tilting, swivelling, turning and maneuvering.
A controllable field of view for the hazardous area enables faster, more precise and safer work.

**Further important information and tips on retrofitting CMS for contractors, specialist dealers and assembly workshops can be found at: www.safety-machinery.com**
When retrofitting, be sure to observe the manufacturer's specifications for the mobile machine **and** those of the camera-monitor system used!


**A manufacturer overview of camera monitor systems can be found at: www.safety-machinery.com**

# 2.2 Surround-view camera monitor systems

## 270° to 360° all-round view (surround-view)

Advanced camera monitor systems enable 270° to 360° surround views. Their use can support the workflows of mobile machines.

Photo above: Surround-view cameras provide the operator with an overview of the immediate surroundings. An all-round controllable field of view enables fast, precise and stress-free work, even in special applications with e.g. high capacity buckets for light materials.

## From rear to surround visibility

The big advantage is the simultaneous display of all relevant areas around the mobile machine: the operator grasps all hazardous areas of his immediate machine environment with a single glance at the monitor.

**Always under the condition that the driver/operator can quickly and clearly recognize potential hazards on the monitor display, even in the event of stress!**

Modern standard components enable a 360° all-round view on the monitor if the camera images are arranged and displayed appropriately. Individually and application-related, the camera images show areas required for hazard detection and thus offer a high degree of safety.

Individual camera images can be displayed maneuver-related as full screen or split screen. They allow a view around the entire vehicle and/or a targeted view of adjustable areas.

Among other factors, the quality of the cameras and monitor are crucial for optimal use.

Image above: display of all-round view around an excavator.

Bottom image: Components of an surround view CMS, consisting of 4 cameras, a monitor and a control unit.

**Retrofitting:**
**Starting with a rear-view camera, it can be expanded to up to four cameras and up to an surround view system.**

## System selection – solutions for different applications

All-round vision systems (also known as surround-view or 360° CMS) are available in several technical solution variants - see gray box on the right. For the driver/operator, the differences are most apparent in the way they are displayed on the monitor.

**When selecting a suitable system, it is essential to consider the respective different requirements of work environments – where and how will the system be used:**

- **on which type of mobile machine**
  **and**
- **for which specific work applications.**

In harsh environments, as with standard CMS, all components outside the cabin (cameras, cables, connectors) should be suitable to be cleaned with high-pressure cleaners, cameras and monitor should be shockproof.

**Technical options:**

- Event-controlled image switching for a separate and enlarged display of the respective area, e.g. image display of the rear camera when reverse gear is engaged.
- Optional, e.g.: Day/night switchover of the monitor (manual or automatic), brightness compensation for cameras, heated cameras.
- In addition, CMS can be supplemented by sensors (see chapters 3 and 5).

Example of an all-round vision CMS with integrated sensors: The driver/operator is warned as soon as a person or object is in the danger zone.

## Operating principle All-round vision CMS

The images from several cameras provide an all-round view.

Real-time* imaging of the environment around the machine can be achieved in different ways – based on the use of 4 cameras in each case (or 3 cameras for a 270° view, depending on requirements):

**1. all-round view in bird's eye view:**
Simultaneously generated digital images of the cameras are further processed by video stitching and combined to a 360° image. The monitor shows a bird's eye view** as a single view or optionally several views in split screen. (see chapter 2.2.1)

**2. all-round view from 3-4 single views:**
The images from four standard cameras are arranged to form an all-round view and displayed on the monitor next to/above each other. (see chapter 2.2.2)

**3. panoramic view with 3D model:**
The image data of the environment generated by the camera system are merged with the 3D image data of the machine. The monitor shows a real-looking 3D representation of the working machine in its environment. (see chapter 2.2.3)

*within the permissible latency values; **from above (top view, 2D) or "flying" around the machine (3D view)

**Which system is suitable depends on the type of mobile machine (e.g. excavator, wheel loader) and the application.**

On the following pages, the different possibilities for surround view are explained in more detail. ▶▶▶

The two illustrations show examples of HDR cameras (HDR = High Dynamic Range) in each case with and without heavy-duty housings.

Monitors are usually operated at the push of a button. There are also touch monitors (see figure below).

By touching the screen, it is possible to switch between views, among other things. The driver/operator can move the view around the vehicle in 3D views

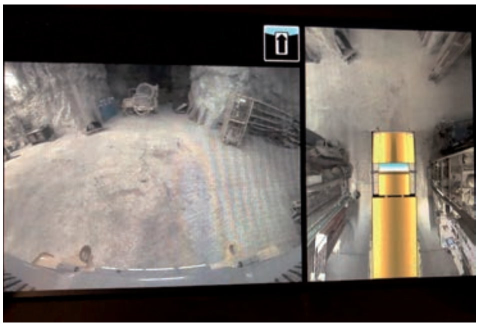
"**Latency**": time delay between what is actually happening in front of the camera and what is displayed on the viewer's screen

## 2.2.1 Four cameras – surround view from a bird's eye view (bird-view)

Component examples: Monitor, computing unit and cameras

Real-time optimized images from the CMS provide a better overview for even safer maneuvering at low speeds. Ultra-wide-angle cameras mounted on the mobile machine – front, rear and side – show the respective vehicle surroundings. **The images from the cameras are combined into an surround view via the control unit (ECU) (video stitching). The driver/operator can watch the situation and any endangered persons and objects around his vehicle at a glance.**

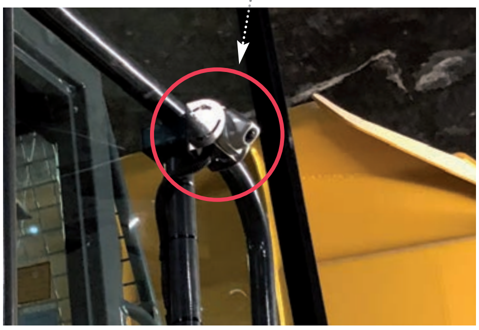
Software integrated into the CMS removes distortions and "fish-eye" effects that can occur with very large camera angles. The software produces a clear, distortion-free image in the form of an all-around bird's-eye view.



**Application examples illustrate how the bird's eye view ("bird-view") is displayed on the monitor in the driver's cab.**

- CMS gives the driver/operator a realistic surrround view of his mobile machine.
- In addition to the surrround view, he can also display individual areas – either as a full screen or in split-screen mode (upper photo on the left).
- The other practical example (photo below on the right) shows a system with three wide-angle cameras. These enable 270°-monitoring of the entire rear area around the mobile working machine.

Positioning of a 360° system – here the right side camera – on a dumper



**Please note:**
**Camera calibration is performed at ground level – objects/persons higher than the calibration level of the camera are displayed larger, as the camera angle to the object/person changes.**

**During excavation work, the raising and lowering of the excavator arm can lead to distortions in the display. An additional camera that is automatically activated when panning to the right may be helpful here.**

**Other possibilities:**
Specific requirements arising from the assigned type of work or the type of mobile machine and its attachments may call for special measures. For example, special positioning of the front camera may allow viewing across a volume bucket.

## 2.2.2 Four cameras – displaying a surround view combined from individual views

Die Bilder von vier Standardkameras werden zu einer Rundumsicht zusammengestellt und auf dem Monitor neben-/übereinander angeordnet angezeigt. **Durch die flexible Anordnung der Kameras kann individuell auf die Fahrzeug-/Anwendungssituation reagiert werden.** Monitore mit Splitscreen-technik unterstützen die optimale Sicht bei mobilen Arbeitsmaschinen wie Radladern, Bagger und die Lastesel des Steinbruchs: Muldenkipper, Dumper und andere SKW (Schwerlastkraftwagen).

Visualization of the fields of view of a surround view CMS

Example of monitor with split screen display

**Control of individual camera views can be set up manually or via vehicle signals, such as setting the turn signal or engaging reverse gear.**

### System features

- No calibration and calculation unit necessary
- Flexible choice of aperture angle and mounting position of the cameras so that all areas around the vehicle can be viewed (even at the corners)
- Fade-in guidance lines provide additional orientation
- Automatic, application-specific display of the cameras – e.g. view to the right when turning right
- Optional retrofit capability for a wide range of applications
- 3 to 4 wide-angle cameras for capturing the entire vehicle area and the surrounding area (aperture angle from 100° to 130° – selectable according to the desired camera position and machine size*)
- Integrated preset for appropriate arrangement of camera images for uninterrupted real-time playback
- Adaptable viewing areas and distances to suit vehicle type and application
- Individually adjustable triggers for different perspectives

*Depending on the machine size, cameras with a smaller angle of view may be suitable.

Component examples: Monitor with split-screen display and one of four cameras – with and without heavy-duty housing

### Surround view CMS in different working areas

**270°-/360°-CMS can be configured for different mobile machinery, commercial vehicles and multiple task areas. Depending on the environment and application, particularly robust cameras may be required.**

## 2.2.3 Multi-camera system – sourround view with 3D model

### ▶ Representation of the environment in exact detail

Image above: Split-screen display – with driving lane indication; the monitor simultaneously shows the view from above and the view of the rear working area

**The system is available for various mobile work machines in the off-highway sector.**

A sophisticated algorithm uses the image data from the multi-camera system – consisting of four digital near-range cameras and an electronic control unit – to generate a realistic-looking representation of the mobile machine in its environment.

The driver/operator observes the machine on the monitor, including the near area as a detailed 3D model.
Every movement of the machine and its vehicle parts (e.g. bucket) is displayed directly in real time, enabling precise and safe maneuvering.
Depending on individual preferences, the driver/operator, can display the single views needed and/or the 360° all-round view as a full screen or in split screen.

The driving lane indication depending on the steering angle ensures better machine control while working and facilitates maneuvering in narrow environments.

**System features and optional configurations**

Image above: Camera mounted on the mobile machine

- 360° surround view in real time
- Stitching algorithm: no "vanishing" of objects in overlapping areas of the camera images
- Top view (bird view) of the current working area up to 8 m × 8 m
- Full screen and split screen display
- Optional driving lane indication display as maneuvering and positioning aid (with colour selection for clear legibility on different surfaces)
- Seeing more than the driver can by using the full opening angle of the front or rear camera (larger than180°)
- Optionally, the field of view is automatically adjusted based on the current driving speed*
- Visualization of obstacles in top view and single views
- Simplified diagnostics and calibration procedure (makes it possible to adapt the system to different vehicle variants)
- Virtual panning: Dependent on the steering angle, the camera can pan digitally (this allows the driver to receive a display only of the area relevant)

*This helps to obtain a better overview of the surroundings while driving fast, and a more detailed view when maneuvering in tight situations.

### ▶ Video-based driver assistance systems with warning function

In further development, the multi-camera system can also be equipped directly with a warning function that alerts the driver/operator of an imminent risk of collision. Based on the same hardware, the collision warning can be applied easily and quickly.
For more information, see chapters 3.5 and 5.2.

# Person and objekt detection 3

## Warning systems for operators/drivers

### ▶ Areas of application according to function

Warning/sensor systems support person and object detection when entering/working in areas that are difficult or impossible to see in. They improve the prevention of accidents. To increase safety, detection systems can be configured for a wide variety of work tasks and hazards. Depending on the requirement profile, different sensor systems are used, subdivided according to operating principle into, for example:

- Ultrasonic systems
- Radar systems
- TAG based systems (UWB/RFID)
- 3D camera sensors
- Advanced multi-camera systems
- Lidar systems

Other technical solutions can be used for special tasks – ask your specialist company.

**Essential factors are the selection of the right system for the application according to their respective and the quality of the system used.**

### Detect hazards at all times!

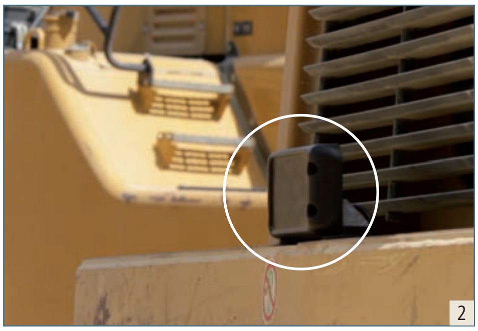
Since it is not possible to work with CMS in a permanently concentrated manner, object detection systems provide additional safety.

**Prevention is always the best way to avoid accidents. Therefore, always prepare a risk assessment – see chapter 1.1!**


1

**Person and object detection systems efficiently increase hazard detection, supported for example by means of:**

- Intelligent object detection using 3D camera sensors (Fig. 1)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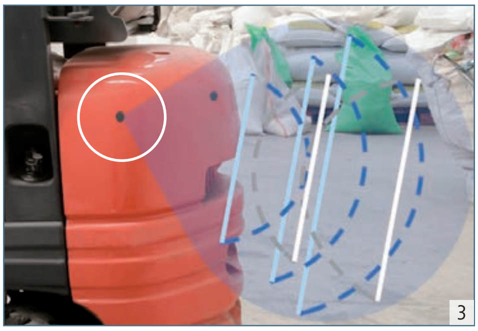
- Central radar system for rear area monitoring and with integrated camera view (Fig. 2)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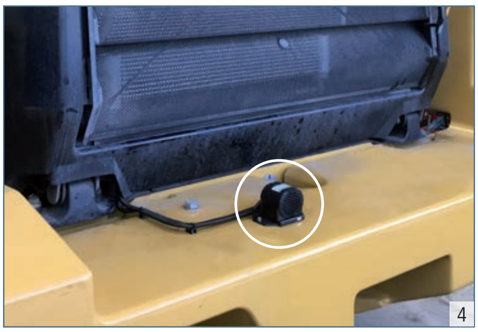
- Ultrasonic sensors for comprehensive monitoring of the rear and side areas (Fig. 3).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**Additional acoustic warning signals enable**

- a targeted acoustic warning to persons in the danger area (Fig. 4).

# 3.1 Ultrasonic systems

Figures above: Ultrasonic sensors on a concrete pump; below: Display on the monitor in combination with a CMS.

## ▶ Maneuvering safely in confined areas

Tight working environments demand special attention from the driver. Here, large-area detection of obstacles is a typical task for ultrasonic sensors in mobile applications. If persons or objects enter the detection range of the sensors, an acoustic signal warns the driver: immediate stop becomes possible!

## ▶ Detect objects with high precision at low speed

Ultrasonic sensors detect obstacles (persons and objects) with a very high accuracy of approx. 10 cm* in the immediate vicinity: at distances of up to 3 m (in individual cases even at distances of up to 9 m) from the vehicle. The detection range can be adjusted according to requirements.

*applies depending on the travel/shunting speed; accuracies of less than 10 cm are also possible

## ▶ Proven on a wide variety of vehicles in many industries

Ultrasonic systems with their precise object detection enable a continuously monitored approach, for example when loading loading dumpers.
It makes sense to use ultrasonic systems in confined spaces, e.g. when driving into public road traffic.

Depending on the working area and the hazardous situation, ultrasonic-based distance warning systems are available in different configurations. Depending on the requirements

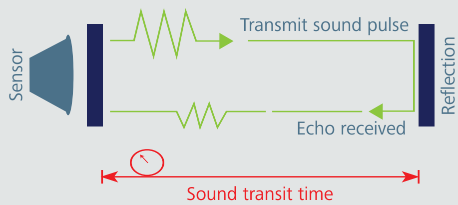
- rear,
- lateral and/or
- front

sensor systems are used.

**Example of an ultrasonic system:**

**ATTENTION:** Faulty signals can be triggered in the event of very high levels of contamination due to dust, smoke or moisture. Therefore, always check the place of use and the task area and carry out a visual risk assessment.
False alarms can impair the willingness to use and heed warning messages. Some systems detect sensor contamination and inform the driver/operator when that happens.

### Operating principle of ultrasound (ultrasonic waves)




The distance to the object is calculated from the difference time of a sound pulse* between sending and receiving.

* in sound velocity with frequency > 20 kHz (optimal 40 - 60 kHz)

Ultrasonic systems can register several objects simultaneously. For example, the object closest to the machine can be communicated via display. As soon as an object leaves the danger zone, the display reports that there may be other potential dangers in a warning zone.

Ultrasonic sensors for distance measurement

## Features for ultrasonic systems

During procurement, special attention should be paid to the following features, among others, and a specification sheet with the specific on-site requirements should be prepared beforehand:

- Detection independent of material colour, transparency, gloss and ambient light (also glass, liquids, foils).
- High accuracy due to time-of-flight measurement
- Insensitivity to light dirt and low humidity
- Multi-level, auditory distance warning system
- Measurement sensitivity flexibly adjustable
- Ambient learning mode to avoid false alarms
- Synchronization and multiplex operation, self-diagnosis, visual distance display


When driving and maneuvering in confined working areas, ultrasonic systems can help to avoid collisions.

**Ultrasonic systems consist of several sensors and an electronic control unit (ECU).**

The ECU (see figure above) processes the distance data received from the sensors.

Data is exchanged via CAN interface.
(CAN = Controller Area Network)

Figure 1: Objects/persons located in the detection zone are detected by the sensors and the driver/operator is warned via a signal on the display.


Figure 2: Ultrasonic systems with object localization determine the exact position of the detected person and transmit the information to the driver/operator.

**Ultrasonic systems can monitor the working areas of mobile machines and vehicles. In doing so, ultrasonic sensors (system-dependent) work under all weather conditions. They are able to detect objects regardless of colour, surface and environmental influences.**
The detection area can be divided into several, adjustable danger zones. Some systems allow the exact detection of the position of a detected object in space. The signals, which can be distinguished according to the respective danger zone, inform the operator/driver about the distance to the object or person in the danger zone. A complementary camera-monitor system provides the warned driver with visual information about the nature of an obstacle: he can recognize and better locate the obstacle.

**Ultrasonic systems can have numerous configuration options, such as:**

- Distance filters to mask out interfering elements in the field of view
- Sensitivity options for optimal adjustment
- Intelligent transmission and filtering algorithms to avoid signal interference or to reduce external interferences

**A manufacturer overview of person/object detection systems can be found at: www.safety-machinery.com**

## 3.2 Radar systems

Compact 77 GHz radar sensor

Radar sensor in combination with a rear-view camera

* Note on distance:
In applications such as road traffic, considerably larger ranges or detection areas are possible.

**To suppress unwanted false alarms, radar systems can be combined with 3D terrain mapping (see chapter 5.5). Here, intelligent software algorithms evaluate the detected signals. The alarm is only triggered if a dangerous or endangered object or living being is actually detected.**

### Reliable warning even in poor visibility

Radar systems detect persons and objects very reliably even in harsh environments: thanks to their high resistance to dirt, mud, dust, heavy rain, humidity, heat, cold (optionally equipped with heated sensors), UV rays, vibrations and storms. They also function reliably in darkness, fog, smoke and poor visibility in general.

**Radar systems are ideally suited for use even in the most difficult conditions on construction sites, in mining, agriculture and forestry.**

### Detecting objects in a 20 m radius at high speed

Detection and locating methods based on electromagnetic waves can reliably detect large detection areas up to distances of 20 m* away from the vehicle, even at speeds of up to 20 km/h.

### Warning with very little time delay

Warning systems with radar sensors support the driver with a very low time delay (50 ms) when detecting objects.
They help avoid accidents in the danger zone of a vehicle and make maneuvering and reversing easier. This applies to construction machinery (civil engineering, quarrying, track construction, mining) as well as mobile cranes, agricultural and forestry vehicles and industrial trucks.

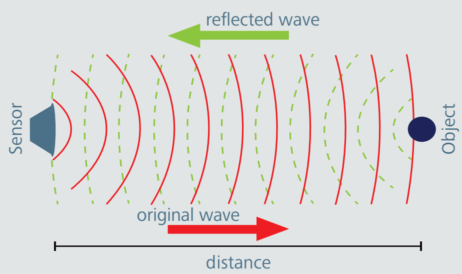
Radar systems usually comprise one or two sensors. These can be mounted specifically where the respective danger area of the machine/vehicle is to be monitored.
The detection area is divided into several zones so that the operator/driver is informed of the distance to the object or person by appropriate signals (see figure in box on right).

### Supplemented by a CMS for extra vigilance

Radar warning systems provide additional safety for field-of-view monitoring of heavy machinery and commercial vehicles. Depending on the system, they can be directly coupled to a CMS or used independently.

**CAUTION:** Check the vehicle's operating locations and task areas in advance and perform a hazard assessment: Impassable terrain can lead to unnecessary false alarms (see supplement below left).

### Operating principle of Radar (electromagnetic waves)




Electromagnetic waves transmitted by the radar as a primary signal are reflected by the object at the speed of light and received again as a secondary signal.
The measured time between sending and receiving results in the distance to the object.

Radar sensor for distance measurement

## Features for radar systems

When procuring radar systems, special attention should be paid to the following features, among others, and a specification sheet should be drawn up beforehand with the intended application requirements:

- Multi-stage distance warning system; if necessary, determination of the exact object position
- Adjustable detection areas/zones
- Low time delay for object detection (50 ms)
- Acoustic and/or optical warning signal
- Expandable for additional applications (such as rear-view alarms)
- Sensor blindness monitoring and filter for ground reflections

Radar sensors can be used on different mobile machines.

Picture above: The display in the operator's cab signals whether an object is in the danger zone of the work machine.
The distance display shows the driver/operator how close the object is to the machine and whether it is approaching or moving away from it.

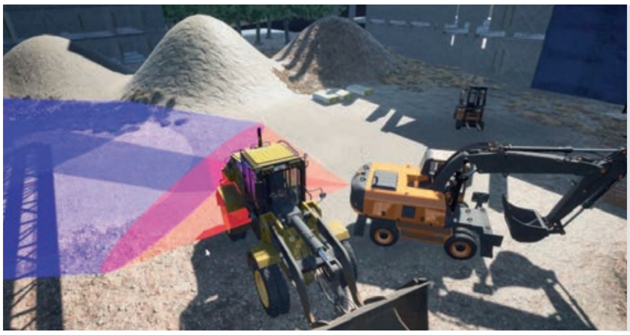


Image above: On a construction site, radar sensors attached to the construction machines detect the machines' danger zones.

**Depending on the radar technology, the position of a detected object can be output exactly or in zones.**
**In addition to position determination, modulating radar sensors also allow tracking of the collision course of detected objects and differentiation between stationary and moving objects.**

pulsating signal

modulating signal

The radar sensor detects and recognizes fixed and moving obstacles with the aid of electro-magnetic pulses. An active warning is issued to the operator/driver - as an acoustic and/or visual signal.

**The operator/driver can detect the changing distance between the machine and the object:**

- A faster sound sequence signals the approach of the endangered person(s) or the objects located in the danger zone.
- The corresponding visual representation of the hazardous situation is shown on a display in the driver's cab.

Combination of radar system and CMS: The photo shows the warning display of the radar system and the monitor of the CMS in the driver's cab.

**Additional option**
- **CAN bus-capable radar systems provide an inter-face for possible active vehicle intervention**

**A manufacturer overview of Person/object detection systems can be found at: www.safety-machinery.com**

# 3.3 TAG based systems – UWB-/RFID technology

**TAG**: A portable warning unit with which a person is equipped to be detected by a sensor located on the vehicle.

TAGs are sometimes also called "transponders".

In the raw materials- and mining industry and on construction sites mobile machinery and commercial vehicles (e.g. dumpers, delivery vehicles) are in use. These special challenges increase the risk of collisions between vehicles and persons/pedestrians and between vehicles and vehicles.
In environments such as large construction sites, quarries, mines, tunnels, etc., where entrances are monitored by access control systems, TAG based systems can provide increased security **– provided that only persons and vehicles equipped with a TAG enter the premises.**

## Approach warning

**Requirements for the use of TAG based systems:**

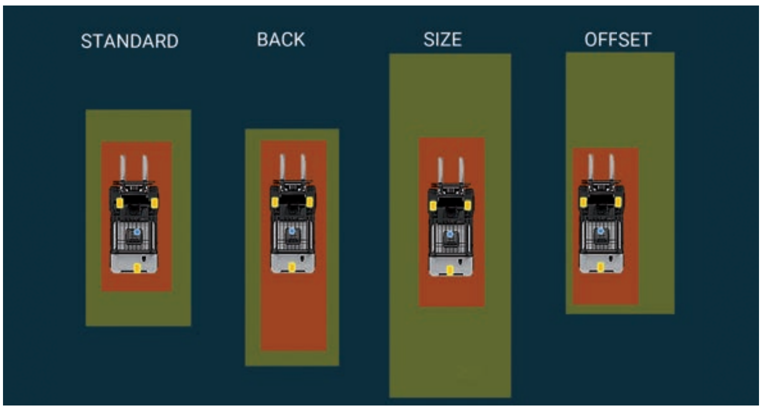
- **Closed area/premises with access control (e.g. fencing plus gatekeeper)**
- **Each vehicle must be equipped with a "vehicle" sensor/warning unit.**
- **Each person must wear a TAG/warning unit "person".**

TAG based proximity warning systems alert drivers when pedestrians are getting too close and provide two types of alerts with different detection intervals: **pre-warning** and **warning** - to give drivers the best options for avoiding collisions.

The visual and audible alarms allow the presence and position of workers equipped **with active TAGs** to be displayed in real time in hazardous situations, mitigating critical circumstances due to poor visibility on construction sites, quarries, tunnels etc.
If a person enters a danger zone:

- The **driver** is alerted with a visual and audible warning and can see on the display in the driver's cab exactly where the pedestrian is located and
- in addition, the **pedestrian** is warned by the TAG, the TAG vibrates and lights up in case of danger.

**TAG-based systems ensure a wide range of configuration options, both in terms of the shape of the release area and its dimensions, in order to be adapted to the different types of vehicles and their types of use.**




## Principle TAG System

TAG-based systems can be created in **two versions**.
Depending on the technology used, the system has different features.

**1. UWB - Ultra Wide Band**
Technology that measures distance, is accurate to the centimetre and works with a TAG with a rechargeable battery (the tag vibrates and lights up).
The trigger areas can be changed in shape (elliptical or rectangular around the vehicle) as well as in size.

**2. RFID - Radio Frequency Identification**
Technology that creates detection areas with long distances and uses a TAG with a replaceable battery with a long life (3-5 years).
The triggering areas can be configured up to a distance of 50m.

## Features for TAG based Systems

### Detection beyond obstacles

- For these systems, no optical contact between sensor and TAG is necessary.
- Detection is independent of poor visibility – for example due to obscuring cargo or environmental influences.

### Long-range detection of pedestrians

- The system's triggering range can be configured and adjusted up to a distance of 50 m depending on the respective requirements – which is particularly important in the case of large vehicles.

**Touchscreen Display**

**Active Sensor**

**Active TAG**

## System architecture – Devices


**Touchscreen Display**

- Configuration of all parameters: Triggering range – acoustic signals – displays – diagnostics modules
- Warning signals:
  - YELLOW "Pre-warning pedestrian"
  - RED "Warning pedestrian"
  - WHITE "Warning vehicle"

**Sensors**

Together, three sensors create a detection area that works all around the vehicle.

**CPU**

The CPU functions like a black box. All events/capture logs are recorded and processing of the data in the form of reports and statistics is also made possible.

# 3.4 3D camera sensors (3D snapshot vision)

## Object-specific detection

**Object-specific detection makes it possible to reliably distinguish between a curb, a pedestrian or a container, for example.**

The technology of 3D camera sensors makes it possible to detect objects three-dimensionally by means of a snapshot. Hazards can be classified in an object-specific manner, their position and volume determined and used in systems with driver assistance tasks.
The following types of camera sensors are used for person/object detection in hazardous areas of mobile machines:

- **3D stereo cameras**, see chapter 3.4.1
- **3D time-of-flight sensors (3D-ToF)**, see chapter 3.4.2

Figure on the right: Application example 3D stereo camera at the rear of a construction machine

3D camera sensors warn the operator/driver in critical situations by means of acoustic or optical signals - in addition, the situation is visualized on the monitor in the driver's cab.
The operator/driver can thus concentrate fully on his main task. 3D camera technology has long been used for environment detection and object recognition, for example in port logistics, robotics and assistance systems for passenger cars and commercial vehicles. In the development of autonomous vehicles, they are considered one of the essential key technologies.

### Features for 3D camera sensors (3D snapshot systems)

During procurement, special attention should be paid to the following equipment features, among others, and a specification sheet with the specific on-site requirements should be drawn up beforehand:

- Designed for use in harsh outdoor environments – or even industrial applications.
- Multi-stage distance warning system
- Configurable detection zones to avoid false alarms
- Configurable detection to detect specific objects
- Acoustic and optical warning signal
- Image data recording function
- Stand-alone 3D sensor: intelligent object detection with integrated CMS

### Operating principle of 3D-Snapshot

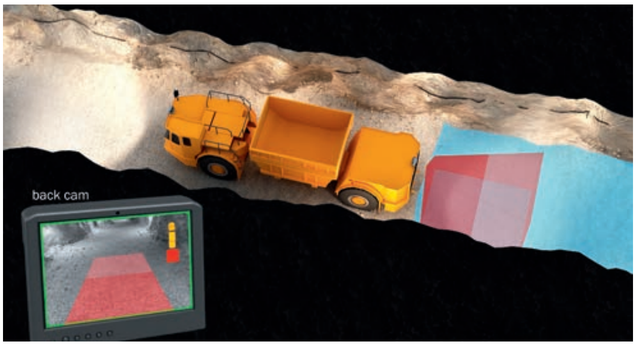
3D snapshot means capturing a scene (static or dynamic) three-dimensionally in one shot – without the presence of moving mechanical parts inside the device.

3D snapshot image of a pallet: The distance of the objects to the sensor is detected and represented by different colouring.

## ▶ 3D camera sensors can be used in wide range of vehicles types, even in harsh environments

3D camera sensors are ideal for driver assistance on heavy, all-terrain mobile machinery used in outdoor applications such as in quarries, mining and construction sites, also in forestry and agriculture.

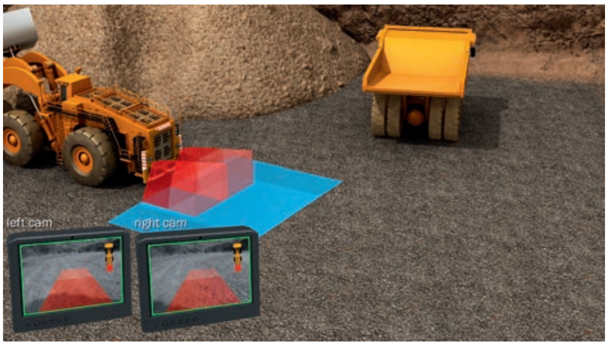
**Raw material extraction/mining**




For example, used bye following vehicle types:

- Vehicles for tunnels and underground mining
- Heavy duty vehicles
- Excavators

**Construction sites**



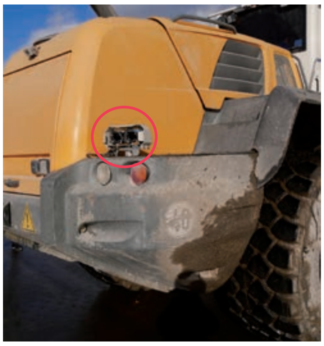

- Wheel loader
- Dump trucks
- Rollers

**Agriculture and forestry**

**Ports and Cranes**

Due to the variety of different mobile machines that exist in these fields of work, the requirements for collision warning systems also vary. The 3D camera sensors are therefore offered in different versions:

- For example, two 3D sensors can be coupled for very wide vehicles.
- Vehicles that require collision warning in alternating directions can be equipped with additional 3D sensors and activate only the appropriate one.



# 3.4.1 3D stereo cameras

## Intelligent detection of persons/relevant objects

In the case of 3D camera sensors based on the operating principle of stereoscopy, two images of objects are taken from slightly different perspectives. From these two slightly different images, depth information can be calculated: the third dimension – comparable to the human spatial vision.

The sensor head with its two "eyes" records raw 3D data and the evaluation unit is programmed – analogous to the human brain – to analyse and process what it sees.

## Avoid false alarms through object-specific detection

**Thanks to object-specific detection, the false alarm rate is significantly reduced because irrelevant objects are not classified as a danger.**

Intelligent ground detection provides a reliable warning even if the object is on an incline in rough terrain. Efficient data processing enables fast object detection.

A 3D camera system with outdoor protection class offers decisive advantages:
For example, the warning system works even in poor visibility and weather conditions, such as direct sunlight, rain, swirling dust or fog, due to the intelligent evaluation. 3D camera sensors are also suitable for use in harsh environments.

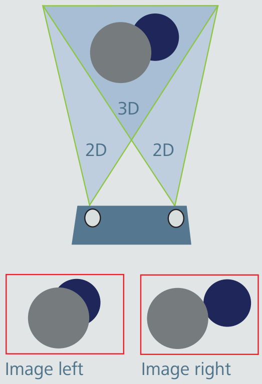
## Active 3D warning sensor – ideal for the "blind zone"

In large mobile machines, blind spots (blind zones) occur directly around the vehicles. Due to the large aperture angle of the 3D cameras, approximately 120° x 75°, they also warn of objects located directly behind the vehicle, for example..

**The interaction of configurable detection zones and intelligent object detection therefore also allows maneuvering through narrow passages without false alarms being triggered by walls or containers.**

The sensor visualizes potentially endangered objects on the monitor so that the driver can recognize their position and better assess the situation.
3D camera sensors are therefore "2-in-1 systems" consisting of an active 3D sensor and an integrated CMS.
Especially the combination of live image with visual and acoustic warning signals ensures improved hazard detection.

### Operating principle of 3D camera sensors (stereoskopy)



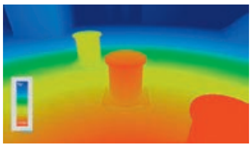

The simultaneous images of the two camera eyes are combined to form a 3D image and thus provide the spatial information ("two-eye principle")

3D sensor with integrated 2D live camera

### "Two-eye principle"

**Step 1:** Two images from slightly different perspectives.

**Step 2:** The two images are superimposed.



**Step 3:** An image with depth information is created.

# 3.4.2 3D-Time-of-Flight sensors (3D-ToF)

## ▶ Precise technology for "moderate" outdoor conditions

In dirt prone and dusty environments, such as construction sites, agriculture or mining, sensors are exposed to the harshest outdoor conditions. The rugged 3D stereo camera technology (chapter 3.4.1) fully meets these requirements.

In less harsh environments/"semi-outdoor" conditions, such as logistics facilities, IP67 housings are often sufficient, while other requirements play a key role.
This is where 3D snapshot technology based on 3D-ToF can add great value in collision warning and other assistance tasks for mobile machinery, such as forklifts.

Example: 3D collision warning using 3D-ToF in the outdoor logistics sector

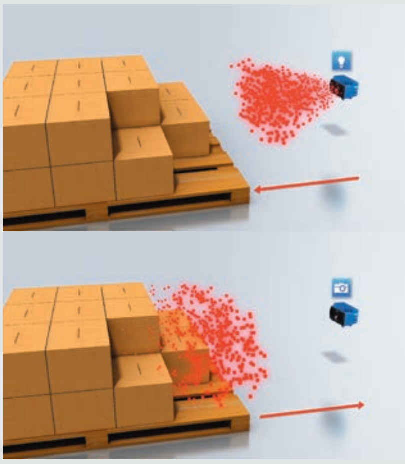
## ▶ From collision warning to pallet detection

The ToF sensor captures a 3D image of the scene in real time and processes the data directly without PC support.
ToF sensors have adjustable detection zones that perfectly match the needs of the driver/operator in each situation. If required, these configurations can be individually adapted during operation. This allows actions such as active collision warning or driver assistance during pallet positioning and picking.

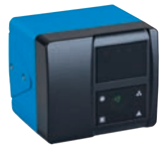
## ▶ High precision, powerful illumination and long range

- 2-in-1: active 3D sensor with integrated 2D live IR camera
(IR = infrared)
- High depth accuracy over a long sensing range of up to 60 m
- Powerful illumination for excellent detection in low light conditions
- More than 10 configuration zones and various assistance tasks via digital inputs/outputs

## Operating principle of 3D camera sensors (3D-ToF)



**The 3D Time-of-Flight camera emits an infrared light signal that is reflected by the object.**
For each pixel, the distance between camera and target is calculated from the different phase shifts of the light.
In doing so, the thousands of pixels involved in a single acquisition provide a detailed three-dimensional distance image – a 3D snapshot – of the entire image area, largely independent of the surface properties of the object.



Compact 3D-ToF sensor

3D-ToF sensor

**3D-ToF sensors have rugged IP67-housings and a long range for outdoor applications, e.g. in outdoor logistics:**

- **They provide high-quality data and process it directly in the sensor – without PC support.**
- **If required, they directly initiate appropriate actions.**

**The 3D sensor can be used around the clock and offers a robust software interface for a wide range of applications.**

# 3.5 Multi-camera system (surround view) with integrated collision warning

For further explanation, see chapter 5.

The multi-camera system described in chapter 2.2.3 provide the driver/operator with a comprehensive overview of the working area around the mobile working machine in real time. This system is a visual aid.

## ▶ From visibility to warning

In the further development of the system, the driver/operator also receives clear signalling, e.g. visually through a coloured indicator on the monitor/display, if there are standing or moving persons/objects in the near field of the mobile working machine.

**This warning function is specially adapted to the special applications:**

- Starting in a confined area
- Persons and objects in the near field
- Loading and unloading
- Obstruction of the operator's field of vision by attachments or machine parts
- Coupling and uncoupling trailers and attachments

Thanks to the advanced image processing technology, the driver/operator is warned if, for example, a person is standing, kneeling, moving behind or next to the mobile machine in the danger zone, and also if people or vehicles are approaching from the side in areas that are difficult to see.

The operator can quickly switch to different views: 360° all-round view, 180° panoramic view, individual images from the front, side and/or rear cameras

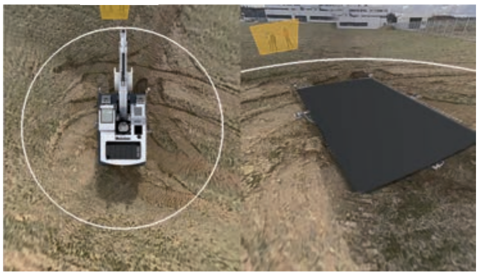


Figure above: multi-camera system top view and 3D view in split screen on the driver display.

Figure above:
Hardware components multi-camera collision warning analog sight assist

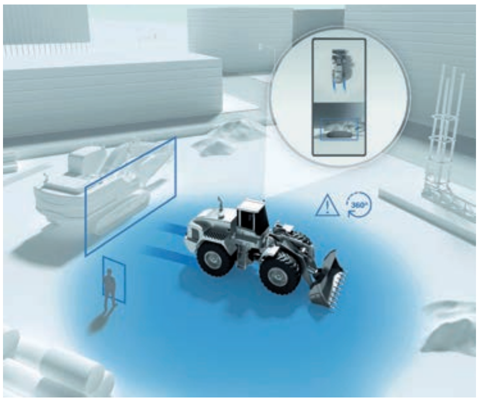


Figure on the right:
360° surround view with warning of impending collision (person and excavator in the working machine's danger zone)

### Operating principle of multi-camera system with integrated warning function

Four digital near-range cameras generate a surround view with the help of the control unit (see chapter 2.2.3 Multi-camera systems), supplemented by software whose algorithm issues a warning when a collision risk is detected, e.g. in the form of a clearly visible colour marking on the monitor.

- For static and dynamic applications
- Based on the same hardware as the multi-camera system
- Easy application via quick setup or guided dialog in the application tool
- Adaptation of algorithms for specific applications using machine learning (see chapter 5)

# 3.6 Lidar systems

## ▶ Laser scanning for precise detection

Lidar or Ladar ("Light/Laser Detection and Ranging") is a method for optical distance measurement using a laser beam and delivers very precise results. The detection is robust to lighting conditions of the environment and can be used even in complete darkness.
It is characterized by:

- Large measuring range
- Large horizontal aperture angle
- High resolution

Depending on the quality of the measurement process, the system is insensitive to dust and precipitation.

## ▶ Data fusion

Based on object measurement and classification by laser pulses, the signals from the lidar system can be used directly for person/object recognition. By means of a software interface, a large number of parameters can be directly processed and visualized.

## ▶ Key technology for assistance systems

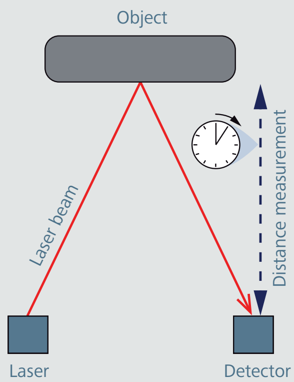
Lidar systems have long been used for environment detection and object recognition in port logistics, robotics and automotive assistance systems for passenger cars and commercial vehicles. In the development of autonomous vehicles, they are considered one of the key technologies.

Continuous further development is leading to increased use of lidar systems in mobile machines such as construction, mining and agricultural and forestry machines. The decisive factor for off-road applications is a robust sensor in which external influences, such as vibrations, do not impair the measurement result.

The example shows a driverless mining vehicle analysing its surroundings with the aid of a 3D LiDAR sensor.

**For off-road use, the sensors are installed in robust IP67 housings.**

## Operating principle of Lidar (pulsed laser beam)




The laser emits a pulsed – i.e. not continuously, but in temporal portions – laser beam which is reflected by the object.
The reflected beam is received by a detector and the time between transmission and reception of the reflected light beam is converted into a distance indication.
Unlike a continuous wave laser, the pulsed laser has a higher power density.
Lidar's optical power density is designed to be eye-safe (laser class 1).

# 4 Acoustic warning signals for persons in the vicinity

## Warning of persons at risk

**Audible warning signals do not replace visibility of the driving and working area!**

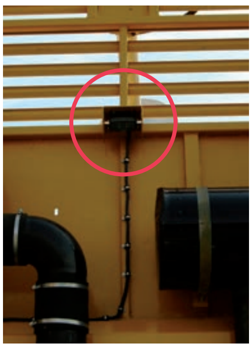
In many areas of application of mobile machines, it makes sense that not only the operator/driver is warned of hazardous situations, but also the people who are **in the immediate vicinity**, who walk into the hazardous area (such as work colleagues or passers-by) and who could be in danger without a warning.

### Effectively generate attention

A variety of audible alerts are available to improve the perceptibility of mobile machinery, either:

- Are permanently activated when the machine is in motion (e.g. when reversing) or
- are activated situationally, e.g. when a sensor system with intelligent software detects persons/objects (see chapter 5).

The alarm sound generated is perceived as "hissing" or "beeping" and can optionally adapt to the ambient volume. While broadband tone alarms use a directional alarm tone to warn people who are approaching the danger area or are already there, beeps are heard in the entire environment. Therefore, caution is advised!
"Beepers" cause noise nuisances that trigger annoyance and stress among employees and residents. Possible consequence: desensitization to the continuous beeping – an actual threat of danger is no longer assessed as such. Since the beeping sound is difficult to localize, persons at risk must first orient themselves as to the direction from which the danger is imminent.



Depending on the work application, a combination of CMS and broadband sound alarms is useful: the driver has a view of the work area and endangered persons are warned.

**Advantages of a broadband tone reversing alarm**

- Only perceptible in the danger zone (wide frequency spectrum)
- No nuisance due to noise to third parties
- No stress for employees/residents
- No desensitization
- Fast localization
- Can optionally be activated by sensor

**Broadband sound alarms forcefully alert people at risk. They switch on as soon as the vehicle starts moving and can be individually configured.**

## 4.1 Broadband acoustic warning systems

### ▶ Warn surroundings in a targeted manner – avoid unnecessary noise pollution

Broadband tone alarms represent a new generation of warning systems. They cause less noise nuisance – the iintensive alerting hissing signals are heard where it matters: in the danger zone of the mobile machine.

For workers, residents and passers-by, there is no (continuous) stress caused by shrill beeps, and the operator/driver is not tempted to switch off the warning system to spare his nerves. There is less risk of desensitization to warning signals.

### ▶ Quickly detect the direction of the source of danger

Broadband sound frequencies convey directional information to the ear, thus enabling the listener to better localize the sound. This gives time to avoid the danger.

### ▶ Can be used in many fields

Broadband acoustic warning systems can be used in a wide range of applications, including construction site vehicles and mobile construction machinery, baggage vehicles at airports, trucks, heavy vehicles used in quarries or recycling plants, agricultural and forestry vehicles, and road vehicles.

Different models of broadband sound warning devices are designed according to the wide range of applications.

A quarry environment has to be assessed differently than a vehicle traveling in an inner-city area, for example. The same applies to the requirements for telescopic handlers in enclosed warehouses, barns as well as production environments and for baggage transport vehicles at airports.

### Operating principle of broadband noise

Broadband noise – also known as "white" noise – is created by the composition of several frequencies. It acts as masking sound in that sound pulses "disappear" in the noise.

By adjusting the sound level ratios accordingly, the listening threshold is set to the required level..

Significant for the human perception of the sound produced in this way are the

- spatial limitation and
- fast, perfect localization.

Used as a warning tone, the broadband noise can be adjusted so that the volume adapts to the noise level of the environment.

Wideband sound warner

**Technical options:**

Among other factors, the noise level in the surrounding area plays a role in selecting the appropriate system. For some applications, it is therefore advisable to automatically adjust the warning tone volume: the warning intensity increases as soon as this is required.

**A manufacturer overview of Person/object detection systems can be found at: www.safety-machinery.com**

# 5 Person and object recognition

## Intelligent software and AI

**The possible uses of software, networked systems and AI-based solutions are pushing into practice, being intensively developed and advanced. This applies to both sector-specific and cross-sector solutions for applications in person and object recognition, for process improvement and increasing safety on construction sites, in mining and in road traffic.**

While camera/sensor systems, according to their requirement-related specifications, work independently on the same tasks, digitalized processes enable further and networking solution paths.

**Digital processes can integrate information from multiple sensors.**

The measurement data acquired in parallel from, for example, a camera, an ultrasonic sensor and a radar system are evaluated simultaneously. The superimposition of sensor signals increases reliability in the detection of hazardous situations across the multitude of possible environmental scenarios.

The result can be used to trigger a previously defined system intervention – for example, an autonomously induced braking or evasive maneuver to protect detected persons and bring the system back to a safe state.

**Digitization provides the basis,**
at the same time

- **using AI-based algorithms,**
- **making machines "smarter" and safer**

as well as an

- **increasing automation of business and work processes**.

Digitalization supports value-creating effects through process optimization. It supports and accelerates permanent change. In the process, it brings about "new forms of collaboration".

**Detecting accident black spots through "data analytics":**

- In addition to supporting the driver (see chapter 5.2), accident black spots can also be detected using deep learning.
- For this purpose, the date, time and GPS position of the mobile machine are recorded anonymously each time a potential collision is detected.
- Over a certain time and data volume, "hotspots" can thus be identified and preventive measures, such as improving visibility or braking, can be initiated.

### AI (Artificial intelligence)

**Generic term for programs for simulating and automating cognitive abilities and human intelligence (perceiving, learning, adapting, reasoning, acting).**

### ML (Machine learning)

**Subfield of "AI"; algorithms that learn patterns from large amounts of data, optimize themselves and find solutions to a given problem (without the solution path being explicitly programmed). Example: recognizing objects from learned image data.**

### Deep learning (method of AI)

**Subfield of "ML"; use of "deep" – means complex, multi-layered neural networks that learn from large data sets. Enables, among other things, classification of detected objects. Example object detection: characteristic Doppler effects* distinguish whether the objects are people or other objects, for example..**

*Perceptible frequency change when a passing vehicle (e.g. train) approaches and moves away.

# 5.1 Artificial intelligence (AI)

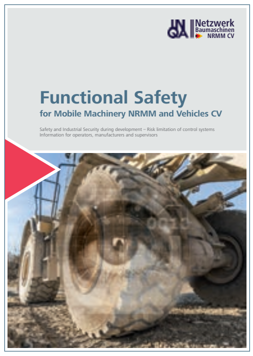
## ▶ Solving tasks quickly, error free and autonomously

**Artificial intelligence (AI), as a branch of computer science, deals with the simulation and automation of human intelligence and cognitive abilities (competence to perceive and recognize information from the environment) to enable "intelligent" behaviour.**

Using a large amount of data, AI enables machines to **make "plausible" decisions quickly and autonomously**. In order to act autonomously, algorithms process and analyse the experiences made by the system, can remember them, and **learn from trial and error**. The system can **train based on detected errors, evolve autonomously, and improve***.
The goal for a respective AI is the ability for the machine to react to all possible challenges in its field of action, to behave "intelligently".
In doing so, AI-based controllers can act as far as possible independently with their environment, make decisions. In an emergency, for example, **they must reliably recognize a person in danger and initiate protective measures such as braking**.

Here we are entering new legal territory in terms of operational safety when it comes to **evaluating the framework conditions of AI systems**. At the time of procurement, the operator must be able to convince himself in a comprehensible manner that the intended solution or technical measure is "functionally safe".

***The system is trained in advance in a training phase. No independent further development takes place during the operating phase.**




www.safety-machinery.com

## ▶ Neural networks

Whereas in classical programming, manually created instructions enable control structures and deliberately incorporate them, an AI system replaces the manually created programming sections with self-learned neural network structures.

Neural networks represent one of the most powerful families of algorithms in AI. They learn complex relationships from training data that are not readily comprehensible to humans. Neural networks can recognize patterns and improve each other, including by independently collecting data and using it to perpetuate the improvement process.
An AI system is equipped with the respective sensors that are assumed to be able to collect the required data for further processing and learning.

**One particular application of AI that is relevant to person and object recognition is what is known as Machine Vision or Vision AI.**

Machine vision captures and analyses visual information with 2D and 3D cameras and is often compared to human vision, as it virtually enables a machine to see (see also pages 22 to 25 and 32 to 41). The aim is to be able to use the visual information captured in this way to draw conclusions.

### ▶ AI systems depend on their data

For learning, AI systems make use of extensive data from various sources:

- the **master data** (the already existing, grown data),
- the **metadata** (containing information about data from other sources) and
- the **new data** generated in the AI system deployment.

**Neural networks are trained by a large set of example images of specific object classes. For many object classes, especially for person recognition, there are very well-trained networks that can be relied upon and thus the training effort can be significantly reduced.**

**New object classes can be trained very quickly to high recognition rates based on artificially generated data (3D renderings of the objects and simulation of the environment) and many variations of existing images.**

# 5.2 Person and object detection using artificial intelligence (AI)

## Camera-based collision warning

**360° all-round vision system with object recognition by learned neural networks:**

System components: Ethernet cameras, computer unit and touch monitor (7"- or 10")

**Camera-based collision warning described in chapter 3.5 is based on the application of "artificial intelligence". With the help of so-called "artificial neural networks", a wide variety of objects are recognized and classified by camera images.**

Neural networks learn to identify certain object classes by their appearance through a large number of sample images. These can be, for example, people and objects in the area of a construction machine. The number of examples required to teach/train the system depends on the desired use case.
This corresponding number of example images can also be used to identify persons and objects in other industries and use cases.
**The trained neural network can thus recognize the static and dynamic objects in the camera image in real time and determine their position** (for examples of system components, see figure on the left in the middle)**.**

Example: The driver is specifically warned acoustically and/or visually of particularly endangered persons or objects.
To minimize the rate of false alarms, however, he is not warned about object classes that have not been taught, such as signs and other static objects.

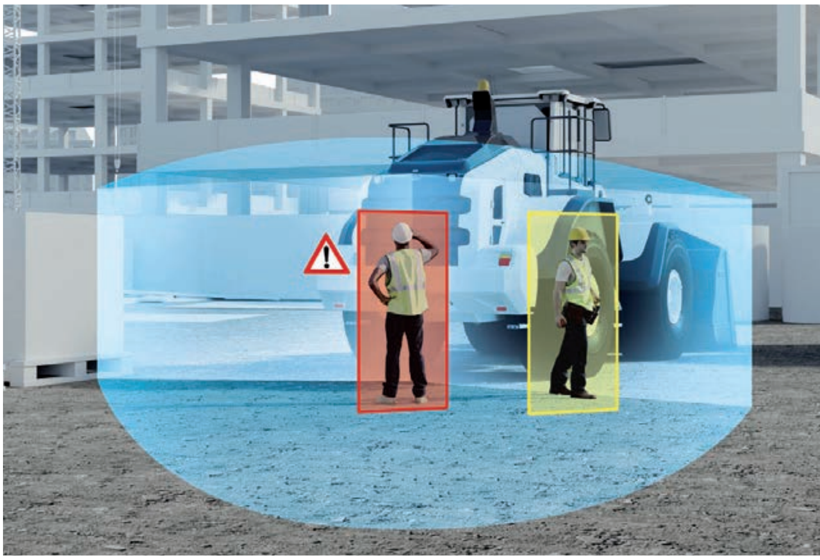


Figure above - Person detection application example:
The camera positions mounted on the wheel loader and thus known are used to provide a sufficiently accurate distance estimate to enable timely warning. A prerequisite for this is a one-off calibration process when the cameras are mounted.

## Classification with CMS

**In cooperation with a computing unit and implemented application software (neural network), a CMS can become an active safety support for the driver.**
The CMS recognizes the previously classified objects and persons in the camera image section – see figure on the right.

**Visualized warning zones define when the system detects objects and persons and warns the driver. These can be configured flexibly and individually.**

The system can be "taught" or "trained" for additional new object classes on an application-specific basis, so that the solution can be used in many different industries and areas.

**In combination with radar/ultrasonic sensors or stereo camera technologies, further improvements for the recognition of objects or persons can be achieved.**

## Deep learning offers a wide range of possibilities

Camera-based collision warning using "embedded" AI is finding an ever-increasing range of applications in various mobile working machines and commercial vehicles in different fields and environments..

**In all areas where objects are in (permanently) dynamic processes, there is a particularly high risk potential. In addition to classifying and determining the position of detected objects, the embedded AI here can also calculate predictable movement patterns, detect impending collisions in advance before they occur and issue a warning.**

**Depending on the system and application, the AI software can be applied either directly in the sensor or in an intermediate control box.**

Image above: Example of a digital camera with person recognition directly on the camera (embedded), without additional hardware.

### Intelligent motion detection

Specially developed via deep learning processes, the AI evaluates the images from the camera sensors and calculates the future movement course of the endangered objects. In parallel, the direction of movement of the own vehicle is also determined, among other things. If the two vectors/movement lines overlap, the system warns the driver of a collision hazard.

### Extended detection range

The detection range can be significantly extended by combining the camera and AI so that, for example, objects/persons to the side of the front of the vehicle and even in the second row, for example behind parked cars, can also be detected.

### Further system features

- AI-based camera systems also work in limited lighting conditions
- They are applicable to various vehicle types*, are easy to install and
- can be easily updated through software updates.
- The use of the vehicle's CAN signals and
- customizing of the system are possible.

Large image above: "Camera wings" mounted on the sides of the operator's cab with camera sensors that detect the areas next to the wheel loader.

Picture above: "camera-wing" with **camera sensor** (heated for full functionality in low outdoor temperatures).

Bottom image: In the **control box,** camera data is processed with the help of AI.

Image left: **Monitor** for left- and right-side-area monitoring using AI (see control box) – and additional monitor as a visual aid for the rear area

## Classification with radar systems

For further applications of object detection using AI, see brochure:


"Turning/Assistance Systems (Blind Spot Information Systems) for Heavy Commercial Vehicles, Buses and Mobile Machinery" (www.safety-machinery.com)

**Special radar systems, in conjunction with targeted algorithms, can also distinguish between moving and static objects. In logistics, for example, these are frequently used in turn-off assistance systems for trucks.**

Radars offer the possibility to additionally measure the distances of the detected objects to the mobile machine in the form of coordinates as well as the speed of the objects. Location and direction of movement are determined and object tracking as well as prediction of the movement path can be performed. The object location is determined by time-of-flight measurements and the object velocity by the Doppler effect.

A classification of the detected objects is also possible. Characteristic Doppler effects are used to distinguish whether the objects are people or other objects, for example.

## A mobile-compatible ethernet camera also for images in full HD quality and integrated image processing

**Mobile digital cameras act as smart sensors in a wide range of applications on mobile machinery as well as in industry.** Whether with integrated and intelligent image processing or in combination with an intelligent video control unit, they are available as ethernet camera, BroadR-Reach camera or LVDS camera.

Mobile digital cameras function "embedded" with the software or algorithms integrated by the manufacturer **and** with a connected "intelligence" - such as a video control unit or other computing unit.

Integrated FPGA-based video processing for customized functions such as image processing, object tracking, active overlay insertion, inspection and measurement of objects, reading of coded info (QR codes/ OCR), binary image processing and augmented reality.

A mobile-compatible full HD ethernet camera can be used for stationary and semi-stationary applications in IEEE 802.3 (LAN) networks. Equipped with intelligent image processing, high optical dynamic range (HDR) and dynamic overlays, it acts as a smart sensor in a variety of applications – such as an integration into existing video surveillance systems or video streaming over long distances.

**BIM support:**
**Digital cameras with specially developed image processing software can also be used for BIM support through a variety of evaluated data, thus facilitating the planning and implementation process of projects.**
**(BIM = Building Information Modeling)**

**BroadR-Reach camera:** ethernet standard for connectivity applications. Enables multiple vehicle on-board systems to access information simultaneously over just one unshielded wire pair..

**LVDS camera:** Standardized interface for high-speed transmission of serial data over a differential wire pair.

**FPGA** (Field Programmable Gate Array): Digital technology integrated circuit (IC) in which a logic circuit can be loaded. By configuring the internally available elements, various circuits and functions can be realized in an FPGA. These range from circuits of low complexity, such as a simple synchronous counter or interfaces for digital components, to highly complex circuits such as memory controllers and complete microprocessors.

**IEEE 802.3 standard** (LAN): Most important specification for the local area network (LAN). Defines the ehernet mechanisms by which data is exchanged between network subscribers and network components on a cable basis.

**HDR** (High Dynamic Range Image): Various techniques for capturing and reproducing images with large differences in brightness from around 1:1000.

# 5.3 Active person detection with brake assistant when reversing (wheel loader)

**The next step towards even greater safety in the use of large mobile machines is the development of active brake intervention for earth-moving machines.**

Despite being equipped with a CMS, serious to fatal accidents occur when using mobile machinery. Particularly when reversing large earth-moving machines, there is an increased potential hazard.

The warning provided by sensor systems described in chapter 3 offers additional safety, but still requires active action by the driver/operator. Mistakes can happen even with great care and experience.

**Important to know: Even with an active assistance system, the driver bears the responsibility!**

**Therefore, increased attention is absolutely necessary when reversing/maneuvering even with the assistance system.**

**An active assistance system - which functions independently of human response – can provide even more effective protection in the event of field of vision impairment. The system comprises a**

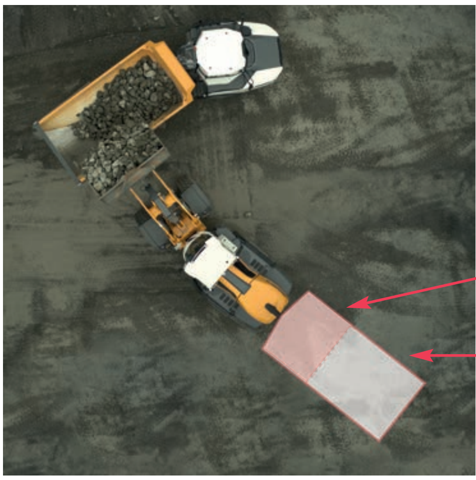
| combination of | camera sensor technology + data evaluation + reduction of speed |
|---|---|

## ▶ If there is a risk of collision, the wheel loader decelerates automatically

**The active person detection** monitors the rear area of the wheel loader and warns the driver of impending collisions. The intelligent sensor system distinguishes between people and objects: **If persons are detected in the rear maneuvering area, the system alerts the driver earlier than in the case of objects.** (Avoiding unnecessary warning signals.)

**The brake assistant** automatically reduces the wheel loader's speed to a standstill as soon as a source of danger is detected. **Braking is initiated earlier and faster than conventional braking – as human reaction time is eliminated.**

Image above: Illustration of the person detection system in the rear area of the wheel loader, which triggers both the warning to the driver and the automatic braking of the machine; plus illustration of the display on the monitor in the driver's cab (small image on the bottom right).



Picture on the left: The warning to the driver and the reduction of speed take place when:

- **persons or objects are up to approx. 2.5 m**
- **persons are approx. 2.5 m to approx. 6 m**

behind the wheel loader.

**Technical options:**

The active rear personal recognition system plus brake assist can also be combined as an option, e.g. with

- a front camera to monitor the front working area or
- a 360-degree system for bird's-eye view of the entire working environment and/or
- an adaptive working light for working in the dark.

# 5.4 Individual data processing and apps in 3D camera sensors

**For operators/drivers of mobile machines, the evaluated data from 3D camera sensors are an important aid for collision warning tasks (see chapter 3.4).**

**In most industrial work scenarios, the tasks of an operator/driver go beyond pure driving and maneuvering.**
**The raw or intelligently pre-processed data from such 3D camera sensors can also perform a variety of other assistance and automation tasks, such as navigation support or automatic container level checking.**

## 2D data, 3D data, intelligent object classification

- 3D stereo camera hardware for harsh outdoor applications
- Both depth data (3D) and grayscale/color images (2D) with one snapshot
- Intelligent data processing in the camera, such as object positioning and classification software to support guidance and navigation

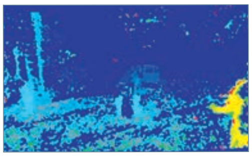
## Flexible integration into mobile machines

- Specially developed software can be implemented and executed on 3D camera hardware
- Data streaming and object recognition possible via TCP/IP and Ethernet
- C++ programming interface for Windows and Linux systems
- Simple and intuitive configuration
- Output signal can be connected either to a PLC or directly to an actuator, such as a robot or an AGV
- Provides a real image with active warning signal

## Applications of intelligent software on 3D stereo cameras

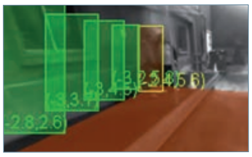
- Collision warning for operators/drivers of mobile machines
- Navigation support
- Swath tracking in agriculture
- Control of container fill levels
- Further image processing tasks for mobile machines

**Data stream:**



- **Depth data (3D),**

- **grayscale data (2D),**

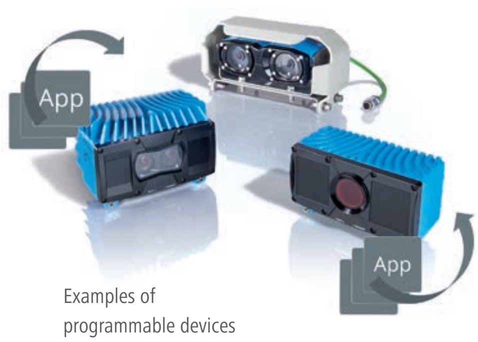


- **object position and object classes**

**can be used for a wide range of automation tasks.**

## Programmable devices – a new level of flexibility

**Based on proven technologies, programmable 3D camera sensors offer the freedom and flexibility to implement specific requirements with apps.** This enables completely new and adaptive solutions in industrial automation and in the Industry 4.0 context. The measured values required for the application are pre-processed on the sensor, evaluated and then transferred to the controller of an automated vehicle, for example, or even directly to the cloud.



Examples of programmable devices

The whole range of 3D snapshot technologies for machine vision is available – such as 3D-ToF or 3D-Stereo with structured light (see chapter 3.4).

**Thus, there are two starting points:**

### Programming by software specialists:

3D vision specialists can develop sophisticated applications according to their own needs based on 3D data and execute them directly on a device.

- Enables fast and efficient development of customized apps that are specifically tailored to the user's own requirements.
- Offers great flexibility through a high degree of freedom in app development.

### Ready-to-use apps:

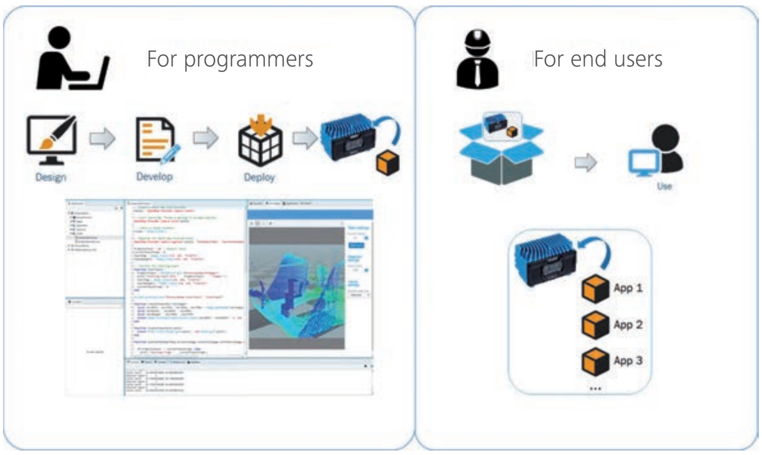
Here, the 3D camera sensor acts as an "app enabler", so to speak, i.e. ready-to-use key apps* developed to solve a specific application can be run directly on the device.

- Suitable for users who want to operate a specific application without having to develop their own solution for it.
- Saves not only costs but also the effort of additional programming and integration and further reduces the amount of data on the network.

***Key App: Is ready-to-use closed-loop software that runs on a 3D device and solves specific key application(s) for automation**

Ready-to-use sensor apps can be installed on the respective programmable devices. A central processing unit, to which different sensors can be connected, enables:

- the combining of algorithms,
- the combination of the functions of different technologies,
- the fusion and the evaluation of the relevant data.



The end user (operator/manufacturer) receives a solution that is specifically tailored to his needs and can be expanded to meet future requirements

# 5.5 3D Terrain Mapping (3DTM)

## Intelligent software for terrain and object recognition

**Functions based on 3D terrain mapping provide an important building block for supporting the driver and preventing accidents. 3DTM represents an innovative method for terrain and object recognition (e.g. vehicles, living beings, obstacles). It now paves the way for active assistance systems in the off-road sector/NRMM as well.**

**Terrain detection - 3D Terrain Mapping (3DTM)**
To compute a 3D terrain map, an elevation map is generated based on a grid structure.
In successive calculation steps (spline approximation), the terrain is modelled so precisely that it represents reality. In addition to environmental information such as the presence of hills, slopes, etc., finer terrain details are preserved.

**Object Detection - Generic Object Detection (GOD)**
On the modelled terrain, the slope information is used to determine the trafficability. In addition, the terrain map is used to identify obstacles: With the help of algorithms, objects are detected and their distance to the mobile machine is calculated, as well as the direction of movement and the speed of the objects are determined.

### Innovative image processing supports safe working

Based on sensor information – such as that from a digital camera or lidar – people, objects, obstacles and even the most difficult terrain are detected automatically, enabling the driver and the mobile machine to derive clear information. If necessary, the fusion of different sensors or sensor technologies is also possible. The driver is informed by a real-time display on the monitor about the specific conditions, such as:

- where is the terrain passable/not passable?
- what obstacles are located where and at what distance from the mobile working machine?
- in which direction are people and/or objects moving?

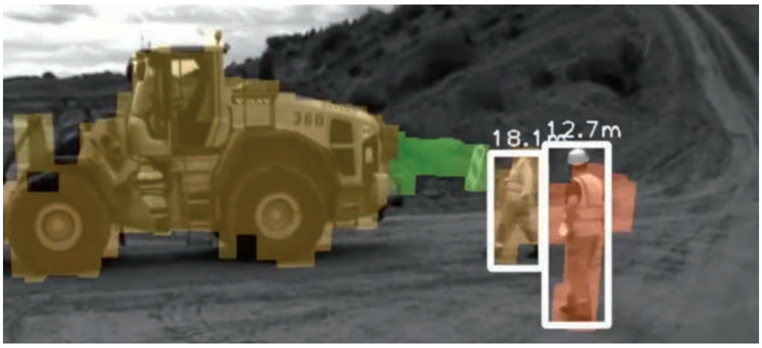



Image above: Clear color scheme and exact distance information enable the situation to be quickly detected.

**Exact terrain and object classification**
By applying deep learning methods, the system trains and learns, among other things, how to safely distinguish between people and objects. The targeted training in the specific working environment of the mobile machine (e.g. quarry) enables a very accurate interpretation of the delivered data and thus increases safety and efficiency.

Depending on the application, the image data supplied can be combined/configured with existing systems or new systems to be integrated, and precisely fitting "actions" can be defined. If there is an imminent danger of collision, for example:

- the driver is additionally alerted by e.g. an acoustic signal and/or additionally
- persons entering the danger zone are warned by a directional broadband tone.
- If the legal framework permits, active intervention in the machine control system – such as automatic braking/evasive maneuvers – can also be triggered.

# 5.6 Opportunities of digitalization for occupational safety for mobile machinery and stationary equipment

## Practical example of safety protection device for dragline systems of concrete mixing plants

For further information DEQ see on page 44.

With the aim of digitizing quarry processes and thus making them more efficient, safer and environmentally friendly, 25 cooperation partners are working together in the EU-funded project **DigiEcoQuarry** (DEQ for short). One central question is:

Photo above: Dragline system of a concrete mixing plant during operation.

**How to reduce the number of hazardous situations?**
Currently, dragline systems* (see photo on the left) of concrete mixing plants are being considered in particular.

In the development of dragline systems, cabins were originally used for control, in which the machine operator sits during operation and controls the system. This allowed him to see the scraper bucket and also monitor the main danger area of the plant. In this way, the machine operator had the possibility to stop the plant immediately in case of a hazardous situation (e.g. person takes samples from a box).

## Automation processes in the raw materials industry require new safety concepts

***Explanation of terms: Dragline systems are also known as scraper plants or bucket systems.**

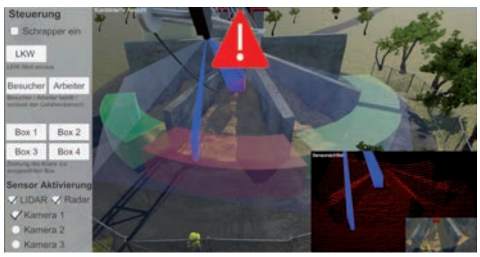
Then the plants became increasingly automated. In automatic mode, the bulk material is dumped from the truck as close as possible to the foot of the respective bunker. The scraper transports it upwards fully automatically. There is no longer any need for a machine operator to sit in the cabin. Controlling of the hazardous area now only takes place from a random basis, e.g. by briefly looking at a monitor in the machine operator's room – without a direct view of the bucket.

The use of a **functionally safe system** (see also page 7), which detects hazardous machine movements by using appropriate sensors and triggers a safe stop could thus give plant operators more legal assurance.

**Objective**
However, there is currently no solution available on the market for this purpose. Developing such one, including all relevant parameters, is one of DEQ's intended goals.

**The development process shown integrates various internal and external stakeholders from the beginning.**

The development process described below has become established for such kind of applications.




Visualization of hazard risks detected by various sensor data.

## Safeguarding human-machine interaction – development of intelligent algorithms for reliable sensors

Concept approval by the German Social Accident Insurance (DGUV/IFA)

**Functional Safety**
- HW metrics
- Monitoring and diagnostic functions

&

**Use case evaluation**

Definition of
- Machine/vehicle's behavior
- Areas to be safeguarded
- Safety-relevant objects
- Environmental conditions
- Object detection safety integrity level

**Definition of system architecture**
- Define the system functions
- Select the components (sensors & logic)
- Define the detection zones
- Determine the HW and SW architecture

**Prototype and investigation of object detection capability**
- Define and validate the test objects
- Investigate the ability to detect the objects
- Analyze the systemic influences
- Analyze the environmental influences
- Define the system's limits

**System development**
- Implement the system on the target platform
- Test the system
- Validate the system functions
- Validate the achieved PiL, SIL etc.

**Validation at machine level**
- Integration of the system into the machine/vehicle
- Vehicle tests
- Validation

### Step 1: Analysis of the use cases

In the first step, together with operators and the Employer's Liability Insurance Association Raw Materials and Chemical Industry (BG RCI), the relevant use cases are analyzed and defined, also with regard to occupational health and safety requirements. The main focus is to identify and understand the system, its capabilities and limitations, as well as any hazards and associated risks.

There are many requirements which have to be met, depending on the use case. Examples include among others, dust, wind wheather, difficult light conditions, different types of vehicles/machines, open terrain or 24/7 operation – must be taken into account as parameters in the development of the system.

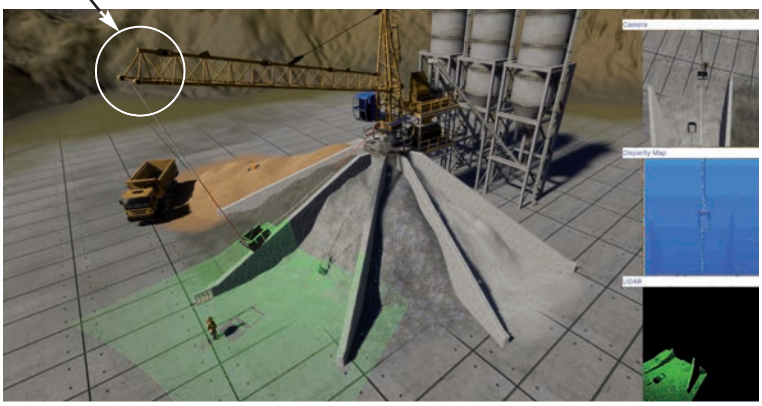
### Step 2: System design and simulation

The next step is to make decisions regarding the required architecture and system design in order to be able to select the right sensors.

Here, the use of a simulation environment ("Digital Twin", s. Fig. right) can provide helpful initial indications of which sensor types are suitable for the specific use case (also taking into account the various environmental conditions).

This approach saves a great amount of time and effort, since, for example, the time-consuming assembly of prototypes on the cantilever is no longer necessary.

Figure below: "Digital Twin" – Simulation of a dragline system with visualization of camera/ sensor data



### Step 3: Development of prototype

In the final step, the prototypes will now be tested on real plants and further developed so that, by the end of the project at the latest, significantly improved accident protection can be achieved in all concrete mixing plants.

**Perspective:** A transfer to other outdoor machines that have to be safeguarded under the same difficult environmental conditions is already foreseeable.

**This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101003750.**

# 6 General principles

## for procurement and operation*

*Please note:
This information applies to operations in Germany and refers to German regulations.

For the configuration of the system, it is essential to observe the respective manufacturer's instructions and to commission a specialist company!

The maintenance routine is increasingly supported by modern diagnostic methods and digital aids.

**12 VDC ≠ 24 VDC**

- For compatibility of the systems, be sure to check the on-board power supply voltage! – especially for trailers, semi-trailers and attachments.

### Potential and limits of technical aids

If the direct vision of the driver is not sufficient to ensure safety, technical means or technical measures (cf. TRBS 2111 Part 1, Clause 3.2.1 Para. 3 and 4 – see p. 45) must be used primarily to improve visibility, such as camera monitor systems (CMS).

Camera technologies, warning and sensor systems are technical aids for detecting persons and objects in the danger zone of mobile machinery and commercial vehicles.
These systems support the monitoring of the working and movement area of the mobile machines in case of machine movements and if necessary also in case of movement of attachment components.
Extended systems can additionally warn persons in the danger area.

**CAUTION:**

- Warning systems are not intended to perform driving movements without visibility!
- The systems are intended in particular for monitoring the danger area around a machine.
- Displays, camera images, warning signals must remain clear and manageable for the driver – so that imminent hazards can be recognized immediately.

### Operational readiness

Warning and sensor systems, as well as a camera monitor system, must function properly when the mobile machine is started.
A functional check is therefore mandatory before starting work.

### Retrofitting: Selecting, mounting and aligning mounting points

Determining the optimum mounting location and the correct alignment of the camera, sensor and monitor/display for the application depend on several factors, for example:

- the location, the operating conditions, the resulting necessary detection range of endangered persons and objects,
- the design and ergonomic requirements of the machine.

For more information, see the guide "Camera monitor systems – sensible and safe retrofitting" (www.safety-machinery.com).

### Traffic signaller/guide

**As long as no sufficient view is possible (neither directly, nor by means of technical measures such as mirrors, CMS, sensor technology), temporary guides/marshalls are required!**
Only if the use of suitable equipment, such as CMS or sensor systems, ensures unrestricted monitoring of the route, a guide may no longer be required. Technical measures have priority – the traffic guide is the exception!
**If you have any questions, contact your employers' liability insurance association or accident insurance fund!**

### Inspections by a "person qualified to inspect"

The "person qualified for testing" in the sense of the Ordinance on Industrial Safety and Health (German §2 (6) BetrSichV) is someone who has the necessary specialist knowledge for testing work equipment due to his professional training, professional experience and recent professional activity.

**The subsequent installation of a CMS, warning and sensor system is a change to the mobile machine that requires testing.** Therefore, after assembly, the system must be inspected by a **"person qualified to inspect"**.
According to TRBS 1201 "Tests and inspections of work equipment ...", a so-called "order test" and a "technical test" must be performed as part of the test by the qualified person:

The **order test** determines, for example, whether
- the required documents are available and conclusive,
- the technical documents are consistent with the design, and
- the required test parameters have been defined (scope of testing, test intervals).

As part of the **technical inspection**, the safety-relevant features of the system are checked for condition, presence and, if necessary, function using suitable procedures. This includes, for example
- the external or internal visual inspection and
- the functional and effectiveness test.

## Visual and functional check by the operator/driver

**Before starting work and before each work shift**, the operator/driver checks
- the function and effectiveness of the operating and safety devices,
- mirrors, CMS, warning and sensor systems for completeness, function, correct setting and cleanliness.

**During operation**, the mobile machine must be
- observed by the operator/driver for safe operating condition and obvious defects.
- Defects found must be reported immediately to the supervisor - and also to the relieving employee if there is a change of operator/driver.
- For reasons of safety, document any defects!

- **In the event of defects** in the CMS, warning or sensor systems that endanger operational safety, the operation of the machine must be stopped until the defects have been rectified.

## Instruction

Instruction must be based on the different operating conditions and the systems used. The scope of application and the limits of the systems must also be explained and their handling must be specified!

- When using technical aids, drivers/operators must be instructed on the intended use and the necessary measures for setting, checking the functionality and maintenance.

- In the case of TAG based systems, also observe the following: Establish rules of conduct for drivers/operators and all persons on site*, monitor compliance and enforce.

*locked and with access control - see page 20/21

**Task of the employer**
The employer shall ensure that work equipment (including mobile machinery and vehicles) is inspected. The purpose of the inspection is to convince himself of the correctness of a proper assembly and safe functioning of the work equipment. The inspection may only be carried out by persons qualified to do so.

**Recurring inspections of the mobile machine:**

- **Within the scope of the periodic inspections, the view must also be taken into account by the person qualified for the inspection!**

**Always take into account occupational safety principles, e.g.:**

- **establish organisation and delimitation of responsibility in a binding manner (who is specifically responsible for which tasks;** see German § 13 ArbSchG)
- **monitor compliance,**
- **carry out instructions in the appropriate languages in a way that is comprehensible to users and document them in a traceable manner;** see § 12 ArbSchG, § 81 Works Constitution Act, § 4 DGUV Regulation 1,
- **always ensure that no one is endangered; if necessary, use guides!**

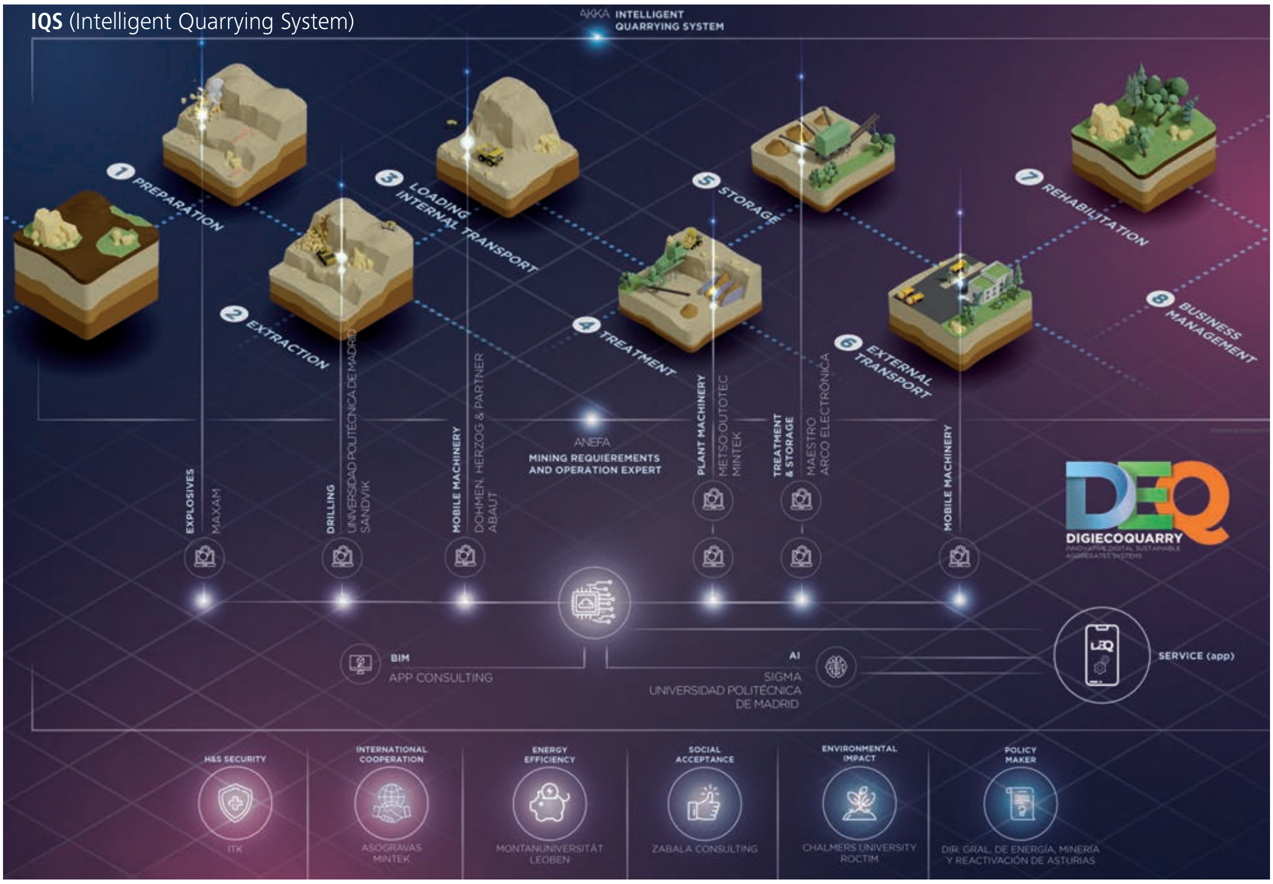
# European project DIGIECOQUARRY (DEQ)

## DEQ addresses the quarry as a whole from small up to multi-site quarries, comprising 8 processes

**As a result, the project will generate positive Environmental, Social, Health and Safety (H&S) and Economic impacts related to quarries, contributing to expand and strengthen the EU aggregates industry.**

https://digiecoquarry.eu/

This figure shows the overall collaboration logics between partners and the performance of data collection throughout the quarrying operation. The **network of IoT sensors** gathers data about machines, materials, the environment and other important parameters on the field. Sensor data is collected by on-the-field sub-platforms and a cloud-based main platform: the **IoT smart mining platform**. This interoperability platform provides the necessary interfaces to accommodate heterogenous data and offers data storage capacity (data lake) for each site.
As such, the main platform enables standardised exchanges of all relevant data with the BIM and sub-platforms (the latter being implemented as a data warehouse including the AI processes and algorithms). These sensors, sub-platforms, IOT smart platform, BIM models, AI components and services comprise the Intelligent Quarrying System (IQS).
**The IQS will thus ensure that all the quarry management is optimised from a global and holistic perspective in quasi real-time, defining priorities between process interaction, leading to a decision-making support framework.**
This ensures a market potential and a competitive advantage that will be gained through the pilot sites, leading to a business case which can be implemented and replicated across the EU and worldwide in the coming years.

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# Regulations and standards

7

## Concerning operators/employers

(German)

- **ArbSchG** – Occupational Health and Safety Act
- **BetrSichV** – Ordinance on Industrial Safety and Health
- **TRBS 1111** – Risk assessment
- **TRBS 1112** – Maintenance
- **TRBS 1151** – Hazards at the man-machine interface – ergonomic and human factors, work system
- **TRBS 1201** – Testing and inspection of work equipment and systems requiring monitoring
- **TRBS 1203** – Persons qualified to carry out inspections
- **TRBS 2111** Part 1 – Mechanical hazards – Measures to protect against hazards when using mobile work equipment
- **EmpfBS 1113** – Procurement of work equipment
- **EmpfBS 1114** – Adaptation to the state of the art in the use of work equipment
- **DGUV Regulation 38**, UVV "Construction Work" with associated **DGUV Regulation 101-038**
- **DGUV regulation 100-500**, chapter 2.12 – Operation of earth-moving machinery
- **DGUV regulation 101-604** "Civil engineering sector"
- **StVO** – Road Traffic Regulations

**BetrSichV Appendix 1**

Excerpt: "1.5 **Before** mobile self-propelled work equipment is used for the first time, the employer shall take measures to ensure that it ...
e) has suitable auxiliary devices, such as camera-monitor systems, to ensure monitoring of the travel path if the direct view of the driver is not sufficient to ensure the safety of other employees ..."

**TRBS 2111 Part 1**

Excerpt: "3.2.1 (3) The employer shall take technical measures to avoid or, if this is not possible, to reduce the risk to workers from being hit, run over or crushed by mobile work equipment due to insufficient visibility (...), especially when reversing. (4) Such measures may include:

- use of camera-monitor systems, 360-degree camera systems, auxiliary mirrors, ...
- warning of operators of mobile work equipment by systems for the detection of persons or obstacles, e.g. radio-based applications, transponder and TAG based systems."

**StVO § 9 para. 5**

Excerpt: "Anyone driving a vehicle must also behave in such a way when turning into a property, when turning and when reversing that there is no danger to other road users; if necessary, he must be instructed.

**Recommendations for improving visibility –**
**As an operator/employer, keep up to date with the latest technology.**

- Direct vision must always have priority.
- Attach visual aids in forward direction.
- Do not allow moving parts to interfere with visual aids.
- Do not allow conversions or attachments to interfere with visual aids.
- Do not use mirror-to-mirror systems.
- Visual aids must be visible in the driver's 180° field of vision.

**Checks for practical use,** e.g.:

- Checklist for simplified inspection of field of vision, DGUV-Sachgebiet Tiefbau
- Sight on earth-moving-machinery, VBG action guide
- Wheel loader with light material bucket, DGUV „Fachbereich AKTUELL“ (FBHM-109)

## Concerning manufacturers

(German, international)

*Note on DIN EN 474 and ISO 5006: Since 2019, "presumption of conformity" applies again to field of view requirements; Exception: hydraulic excavators!

- **ProdSG** – German Product Safety Act (Produktsicherheitsgesetz)
- **MRL** – EU Machinery Directive 2006/42/EG
- **DIN EN 474*** – Earth-moving machinery safety
- **ISO 5006*** – Earth-moving machinery – Field of vision – Test procedures and requirements criteria
- **UN ECE R46** – Devices for indirect vision and their installation
- **UN ECE R125** – Front field of vision
- **ISO 15008** – Requirements for display systems in vehicles
- **ISO 14401** – Parts 1 and 2 – Earth-moving machinery – Mirrors
- **ISO 16001** – Earth-moving machinery – Object recognition systems and visual aids – Performance requirements and test methods
- **ISO 13766** – Earth-moving and building construction machinery – Electromagnetic compatibility (EMC) of machines with internal electrical power supply
- **EN 300 328** – "Radio directive"

**Functional safety requirements**, e.g.

- **EN ISO 12100**
  Safety of machinery – General principles for design – Risk assessment and risk reduction
- **EN ISO 13849**
  Safety of machinery – Safety-related parts of control systems
- **ISO 15998**
  Earth-moving machinery – Machine control systems based on electronic components – Requirements and tests for functional safety

For further information see brochure "Functional Safety" – Download at: www.safety-machinery.com

## Concerning employees

(German)

**ArbSchG (Arbeitsschutzgesetz)**

**§ Section 15, Paragraph 1, Sentence 1**

Employees are obliged to ensure their safety and health at work to the best of their ability and in accordance with the employer's instructions and directives.

**§ Section 15, Paragraph 1, Sentence 2**

Employees are obligated to ensure the safety and health of persons affected by their actions or omissions at work to the best of their ability and in accordance with the employer's instructions.

**§ Section 16 (1)**

Employees shall immediately report any immediate significant risk to safety and health they identify to the employer.

**Report of overload/overload notification**

A report of overload is open to any employee who is who is overburdened in any respect or feels overburdened. feels overburdened. For basic principles, see e.g. § 618 BGB, general civil law § 241 Paragraph 2 BGB, occupational health and safety law § 15 and § 16 Paragraph 1 ArbSchG. If the employee can therefore see that he is no longer able to perform his work under his own steam in such a way that damage or legal infringements can be ruled out, he must report this to his employer without delay. The employer is then in turn obliged to take remedial action. However, the employee is not released from his responsibility by such an overload notification! He must do everything within the bounds of what is possible and reasonable for him to prevent damage.

**Duty to support:**

Employees, together with the company physician and the occupational safety specialist, must support the employer in ensuring the safety and health protection of employees at work and in fulfilling his duties in accordance with the official requirements – see § 16 Para. 2 ArbSchG.

**Right (and duty) to report:**

If, on the basis of concrete indications, employees are of the opinion that the measures taken and resources provided by the employer are not sufficient to ensure safety and health protection at work, and if the employer does not remedy complaints from employees directed to this end, they may turn to the competent authority – see Section 17 (2) ArbSchG.

**For your own safety and to protect your colleagues, always wear personal protective equipment (PPE)!**

Ensure good visibility, for example, with a safety vest.

### Duties of the employee (driver)

- Only authorized employees may use the mobile machine.
- Observe the manufacturer's operating manual and operating instructions.
- Check the mobile machine for visible defects daily before starting operation.
- Mobile machines with defects that impair safety must not be started up or continued to operate.
- Defects in the machine must be reported immediately to the employer or supervisor.
- Use existing restraint systems.
- No persons may be transported with the working equipment of earth-moving machines.
- Only operate the mobile machine from the driver´s seat.
- Employees and other third parties must not be endangered by the mobile machine.

- **The machine operator may only carry out work with the mobile machine if there are no persons in danger zones.**

- **The following applies to colleagues:**
  **Do not stay in the danger zone of the machine!**

**If work is to be carried out where persons are in a hazardous area, the employer must specify special protective measures!**

**Take advantage of our demonstration possibilities of the different systems at your events such as in-house exhibitions, training events, congresses...**
**Contact us directly: info@safety-machinery.com**

# Collision avoidance for mobile machinery and commercial vehicles - Network publication

## Person/object detection, warning in hazardous areas

Camera, sensor systems, intelligent software for mobile machinery:

- » Construction machines*; and special edition for the mining industry
- » Tractors and mobile machines in agriculture and forestry
- » Forklifts and industrial/conveyor trucks

▶ Guides for operators, manufacturers and supervisors


## Turning/assistance systems

- » For heavy commercial vehicles, buses and mobile machines
- » Trucks, municipal vehicles, agricultural and forestry vehicles

▶ Guidelines for operators, manufacturers and supervisors


## Camera monitor systems – useful and safe retrofitting

Tips for installing camera monitor systems

▶ Guide for companies, specialist dealers and installation workshops

## Professionals take care

Recognizing and avoiding hazards due to restricted vision

▶ Practical help for employers, employees and interest groups

## Using earth-moving machines economically and safely

Knowing measures – working productively – profiting

▶ Practical guide for operators, contractors and managers

## Functional safety for mobile machinery and vehicles*

Safety and industrial security in the development and use of control systems

▶ Information for operators, manufacturers and supervisors


* also available in English

# Glossary, abbreviations 8

## Explanation of terms (in alphabetical order)

### A, B, C

- **AAS** – Turn assistance system (see BSPS) (Abbiegeassistenzsystem)
- **AI** – Artificial Intelligence
- **ArbSchG** – German Occupational Safety Act (Arbeitsschutzgesetz)
- **BetrSichV** – German Ordinance on Industrial Safety and Health (Betriebssicherheitsverordnung)
- **BIM** – Building Information Modeling
- **BMAS** – German Federal Ministry of Labour and Social Affairs (Bundesministerium für Arbeit und Soziales)
- **BMDV** – German Federal Ministry for Digital Affairs and Traffic (Bundesministerium für Digitales und Verkehr, formerly BMVI)
- **BSPS** – Blind Spot Information System (see AAS)
- **CAN bus** – Interface for serial data exchange between control units (Controller Area Network)
- **CV** – Commercial Vehicles

### D, E, F

- **DGUV** – German Social Accident Insurance (Deutsche Gesetzliche Unfallversicherung)
- **ECU** – Electronic Control Unit
- **EmpfBS** – German Recommendation on operational safety (Empfehlung zur Betriebssicherheit)
- **Functional Safety** – Safety of electronic control systems

### G, H, I

- **INQA** – New Quality of Work Initiative (Initiative Neue Qualität der Arbeit)
- **IP67** – Protection class for dust and water tightness
  **IP69K** – ...for high-pressure cleaning

### J, K, L

- **Lidar** – Detection based on pulsed laser beam (Light/Laser Detection and Ranging)

### M, N, O

- **NRMM** – Non Road Mobile Machinery

### P, Q, R

- **PPE** – Personal Protective Equipment
- **Radar** – Detection based on electromagnetic waves (Radio waves/ Radio Detection and Ranging)
- **RFID** – Detection based on radio waves/electro-magnetic waves (Radio Frequency Identification)

### S, T, U

- **sfA** – Self-propelled machine (selbstfahrende Arbeitsmaschine)
- **SiBe/SiB** – Safety officer/representative (Sicherheitsbeauftragter)
- **SiFA** – Occupational safety specialist (Fachkraft für Arbeitssicherheit)
- **SiGeKo** – Safety and health protection coordinator (Sicherheits- und Gesundheitsschutzkoordinator)
- **SOTIF** – Safety Of The Intended Functionality
- **Splitscreen** – Split monitor view for simultaneous display of several camera images
- **StVO** – German Road Traffic Regulations (Straßenverkehrs-Ordnung)
- **StVZO** – German Road Traffic Licensing Regulations (Straßenverkehrs-Zulassungs-Ordnung)
- **ToF** – Time-of-flight measurement with focused light beam/infrared
- **TOP principle** – Priority of technical measures over organizational and personal measures (see risk assessment; BetrSichV)
- **TRBS** – German Technical rules for operational safety (Technische Regeln zur Betriebssicherheit)
- **UVV** – German Accident prevention regulation (Unfallverhütungsvorschrift)
- **UWB** – Ultra Wideband

### V, W, X, Y, Z, 1,2,3...

- **WiFi** – Wireless data transmission by radio (Wireless Fidelity)
- **3DTM** – Three-dimensional environment mapping (3D-Terrain-Mapping)

# Acknowledgements, legal Information

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### Network Construction Machinery NRMM CV

**For more than ten years, the members of the network have consistently supported the development towards the state of the art in personnel and object detection in mobile machinery and commercial vehicles for almost all areas of application – construction sites, agriculture and forestry, operational traffic, logistics and road traffic.**

The network is effective wherever collisions and accidents between people, machines and materials need to be prevented. Manufacturers and suppliers for mobile machinery, commercial vehicle and automotive industries, experts from science and research, occupational safety and market surveillance authorities, as well as employers' liability insurance associations/accident insurance funds and trade unions are all involved in the network. Among other things, the Construction Machinery Network is a Vision Zero cooperation partner and an official supporter of the BMDV's Turning Assistant campaign. Further information and brochures of the network are available on the homepage: www.safety-machinery.com

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# Network construction machinery NRMM CV – New Quality of Work Initiative (INQA)

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**www.inqa.de**

## ▶ In cooperation with:

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BGHM – Employer's Liability Insurance Association Wood and Metal
BGHW – Employer's Liability Insurance Association Trade and Merchandise Logistics
BG RCI – Employer's Liability Insurance Association Raw Materials and Chemical Industry
BG Verkehr – Employer's Liability Insurance Association Transport, Post-Logistics and Telecommunications
BMAS – Federal Ministry of Labour and Social Affairs
BV MIRO – Federal Association Mineral Raw Materials
IG BAU – Industrial Union Construction, Agriculture and the Environment
KAN – Commission for Occupational Health and Safety and Standardization
UK NRW – Accident Insurance Fund of North Rhine-Westphalia
VBG – German Employers' Liability Insurance Association
VDGAB – German Association of Trade Inspectors

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Gender reference: For better readability, the masculine form of language is used in this guide.
Of course, all statements refer to all genders.



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we participate in the prevention strategy
**VISION ZERO.**
**ZERO ACCIDENTS – HEALTHY WORK.**

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