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1. Introduction

Every year in the construction industry, people are killed or injured due to being struck by moving plant. Site personnel, site visitors and the public can all be at risk if the plant and pedestrian interface is not properly managed and controlled.

While data indicates that incidents at the plant–person interface are relatively rare, the nature of construction machinery characterised by significant power, weight, and mechanical complexity means that accidents can have severe, often catastrophic consequences. Given the substantial risks involved and the potential for serious harm, there is a pressing need to enhance safety measures.

Investments in infrastructure development, along with the standardisation of construction products and methods, provide significant opportunities to improve workplace health and safety. Moreover, advancements in technology, particularly in Human Form Recognition (HFR) systems, offer promising avenues to mitigate these risks effectively.

2. Foreword

This document is intended to generate collaboration with all stakeholders (OEM's, Supply Partners, Sub-Contractors, Clients, Main Contractors, etc.) to develop a common specification for Human Form Recognition (HFR) camera systems when installed on plant equipment.

A common specification will ensure consistency for operators and the workforce working around plant fitted with these camera systems across the construction industry.

In addition to this, it will also provide the basis for OEMs to develop these systems as a common standard for use throughout the construction industry.

3. Scope

A multi camera, modular type camera system which is capable of being installed on mobile plant that detects the human form. Detections should be communicated visually and audibly to the operator of the mobile plant and, enhancing site safety without interfering with machine operations and with an audio alert to the pedestrian that has been detected. It should utilise advanced imaging technology to provide comprehensive 360-degree camera coverage, ensuring all critical areas are monitored. HFR and continuous recording must always remain active and retrievable when the ignition is on.

The camera system must be able to collect data of all detections so that these can be easily displayed on a web-based portal for review (subject to the relevant GDPR compliance) by the end user and interested parties.

Fail safe controls must also be in place and a warning to the operator on the in-cab display as well as an alert on the portal in the event of any component failure or tampering i.e., broken wires, camera failure, obstructed camera view, etc.

Camera systems should be configured so the human form detection zones, as shown in appendix 1, can be achieved with zero blind spot areas.

Minimum scope of machine inclusion –

- Tracked Excavators 13t and above
- Wheeled Excavators 10t and above
- FT Cabbed, wheeled and tracked Dumpers 6t and above
- Articulated & Rigid Dump Truck 9t and above
- Cabbed Roller 13t and above
- Telehandler (All sizes including Roto Telehandlers)
- Dozers (All sizes)
- Wheeled Loaders
- Graders

Items for consideration in the near future –

- Piling Rigs
- Crawler Cranes
- Rail-specific applications

4. Standards

Several standards come into action for this type of technology but there is no one individual standard that encompasses everything that is required.

All HFR systems must hold CE and / or UKCA Certification.

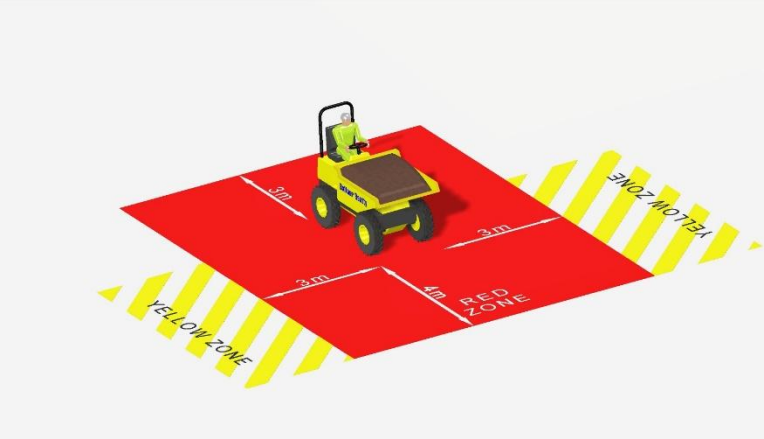
5. Camera Mounting & Installation

The supplier must provide a suitable and adaptable mounting solution, along with clear installation and configuration guides for the full range of fleet assets.

Different assets may have varied structural layouts and operational behaviours. Some equipment may be transported in modules and assembled on-site, while others operate continuously in high-vibration environments. Camera systems should be installed in a way that avoids interference with both operational functions and any setup or maintenance procedures, such as avoiding moving parts, counterweights, booms, or masts.

Mounts and cameras must be robust enough to deliver stable, high-quality imaging across all asset types, even under demanding conditions like vibration, movement, and exposure to dust, moisture, and varying light levels.

6. Red Zones & Hierarchy of Controls



Red zones are commonly used in the construction industry to inform personnel of the dangers of working within the vicinity of plant and vehicles on site. Red zones are also linked to company hierarchy of controls and form a basis for training material.

This Human Form Recognition technology has been developed to provide assurance that red zone training is being complied with. The system's primary function is to advise the plant operator that a person has, or is about to, enter the operating zone of the plant.

It remains the responsibility of the pedestrian to never enter the red zone unless the plant operator or slinger signaller has made it safe to do so and confirmed this to the pedestrian.

7. Detection Alerts

7.1. Audible Alarms

All audible alerts should be distinguishable from other existing machine alerts.

7.1.1. Internal

HFR Outer Zone – Subtle audible alert (such as beeps) when a pedestrian enters the detection zone. This is to attract the attention of the operator to the pedestrian detection.

HFR Inner Zone – Spoken alarm e.g. "Person Detected" repeated while a pedestrian is within the detection zone.

7.1.2. External

HFR Outer and Inner Zones – Repeating spoken alarm – for example, "Danger - Move away", "Caution. Machine in operation"

Alarm must cease as soon as the pedestrians are no longer detected.

External alarms to have a supervisor level deactivation system when working in noise sensitive areas so these can be turned off - i.e., during night works or close proximity to housing.

7.2. Visual Alarms - Implementation by 01/03/27

The visual display shall highlight the pedestrian's location within the detection zones, clearly indicating the active zone and detection trigger. By default, the display shall present a 360-degree situational view. Upon detection, the display shall automatically transition to the relevant camera view showing the detected pedestrian. A visual bounding box shall appear around the detected presence, with an amber box indicating the HFR Outer Zone and a red box indicating the HFR Inner Zone. The display shall continuously track and show the pedestrian's position for as long as they remain within the detection zones. The display must be positioned at the operator's eye level to ensure optimal visibility. In machines where the operator station rotates, displays must be shown in both orientations. It should be clear in which zone the detection has occurred and the type of detection.

8. Safe State - Implementation by 01/06/26

A machine is in a safe state if the deadman lever is not engaged, i.e. the machine is isolated. HFR must always be active when the ignition is on, however video clips and incursion data should only be active when machine is in work mode. When the machine is in a safe state incursion data should not be captured.

All visual and audible notifications must continue when the machine is in a “safe” state, unless the Thumbs-Up protocol in section 9 is followed.

9. Digital Thumbs-Up Safe Approach Indicator

A digital thumbs up indicator mounted on the exterior of the machine facing the most appropriate entry zone, (see Appendix 1– Default Detection Zones) that facilitates both visual and verbal notifications controlled by a “thumbs-up” button within the cab (easy to access) at the operator station to indicate authorisation has been granted by the operator for pedestrians to approach the machine.

Allows for definitive mutual understanding between operator and pedestrians when wanting to approach a machine, as per PPI guidelines.

9.1. Engagement and Disengagement:

The operator will press the button when the deadman lever is disengaged, signalling the machine is safe to approach (no recording should occur during this mode). This button will activate a clear green indicator light placed on the outside of the machine facing the entry zone, informing personnel on-foot that it is safe to approach or enter the dedicated entry zone. When the machine is required to resume operation again the operator will disengage the thumbs up before engaging the deadman. This action will now change the indicator to red, signalling it is no longer safe to approach. It should not be possible to engage the green safe approach while the deadman lever is still engaged. Similarly, if the green safe approach is not disengaged before the deadman lever is re-engaged, the green safe approach should automatically revert to the red indication.

9.2. System Integration:

The Thumbs-Up button functionality will be integrated with the Human Form Recognition (HFR) systems. While the green ‘safe to approach’ is engaged, all audible notifications should be silenced, while visual in-cab alerts continue so the operator is aware of exactly where the personnel are around the machine.

This integration ensures consistency in safety signals across various systems and components of the machinery.

10. Zone changes – Implementation by 01/03/27

Detection zone settings may require modification based on specific operational risk assessments. These changes must be implementable in a timely and straightforward manner.

To support operational flexibility, the system shall enable rapid switching between predefined zone configurations. For example, the outer detection zone may be temporarily disabled when a competent person determines that conditions are safe, such as when robust safe systems of work are in place and personnel are authorised to operate within the exclusion area.

Only authorised personnel shall be permitted to make such adjustments using the designated software interface. For safety and integrity reasons, operators shall not have access to modify zone settings.

All changes to zone configurations must be automatically logged, including the time, date, nature of the change and the asset identification Number. These logs must be sent via API for easy accessibility for audit and review purposes.

11. Data & Recording

Any personal data that is captured by this camera system must be in line with current GDPR regulations and each company employing this technology must carry out their own Data Protection Impact Assessment (DPIA).

While most captured data is numerical or location-based, video footage is considered personal data due to the potential for identifying individuals.

In certain circumstances, data and video capture may not be authorised or allowed by the client, for example military installations and certain parts of the power generation industry. It is advisable to check with the client before any such technology is deployed on these sites.

11.1. System Error Codes and API Transmission – Implementation by 01-03-27

The HFR camera system shall be capable of generating specific error codes for all system faults, including but not limited to camera disconnection, camera obscuration, component failure, and communication errors. These error codes must be clearly defined and documented.

All generated error codes shall be transmitted via the system's API to the cloud-based portal, enabling remote monitoring, diagnostics, and timely maintenance response by authorised personnel. Any errors should also be flagged to the operator, with a requirement to confirm understanding before commencing operation.

11.2. Data Points

Below is a list of minimum data points required from the HFR camera system: -

- **Company name** – refers to the company name where the data is being collected.
- **Incident ID** – Unique detection id number
- **Machine Configuration***- Default configurations or any changes made.
- **Machine State***
    - Gear
    - Speed
    - Slew (if applicable)
- **License & Registration Details*:** Includes upcoming license renewal dates and the associated plant asset ID number.
- **Alert Tag (Outer/Inner Detection Zone)** – Classification of detection and which camera was triggered
- **Latitude** – for location of the detection
- **Longitude** – for location of the detection
- **Machine Activity Summary*** - Last online, last incursion and last signal strength
- **Date** (of alert) – in dd/mm/yyyy format
- **Time** (of alert) – in 24hr format
- **Supplier of Asset** (Plant) – Company name of the owner of the HFR System.

* To be implemented by 01-03-27

11.3. Video Footage and Thumbnail Processing – Implementation by 01/06/26

11.3.1. Thumbnail Capture and Upload

For all Inner and Outer Zone incursions, the system must automatically capture and upload a thumbnail image highlighting the trigger of the incursion.

The thumbnail shall:

- Be extracted from the exact point of incursion.
- Provide the clearest possible visual context of the event.
- Include a visible representation of the current detection zone configuration.
- Highlight the individual who triggered the incursion.

11.3.2. HFR Inner and Outer Zone Video Capture

Video footage shall be stored locally on the plant item's internal hard disk using a First-In, First-Out (FIFO) method. When storage reaches full capacity, the oldest footage shall be overwritten.

For every incursion, the system shall automatically upload a video clip to the supplier's cloud-based portal. This clip must:

- Include 5 seconds before and after the incursion point.
- Include a watermark of the date, time and location of the incursion.

11.3.3. Secure Access and URL Management

All thumbnails and video clips shall be accessible via unique randomised URLs to prevent unauthorised access through URL guessing or manipulation.
Each URL must:

- Be unique per incursion.
- Display relevant metadata.

Direct downloads from local storage shall be disabled. However, approved users may request downloads in an authorised file format (e.g. via email). The thumbnail URL shall remain hidden from end users but will be used internally to display thumbnails in reports.

Downloads will be required for authorised users to help train a generative AI model and then subsequently to feed into this tool.

11.3.4. Integration with Management Reporting System

Both thumbnails and incursion videos, along with detection data, shall be available in the Management Reporting System.
Data transmission requirements:

- Numerical detection data shall be transmitted via the API.
- Thumbnails and video clips shall also be transmitted via the API as URLs to enable rapid visual identification.
- This approach ensures efficient review and analysis by authorised personnel.

12. Data Analysis

To enhance the efficiency and accuracy of post-event review Balfour Beatty will be using further analytical tools to review the video data. These tools shall perform automated filtering and classification of detection events, including but not limited to:

- Automatically categorising each clip by risk level (e.g. High Risk or Low Risk) based on specific criteria, for instance, a detection on the rear camera while the machine is travelling in reverse gear would constitute a high risk incursion.
- False Positive Identification: Flagging clips where detections may have been triggered by non-human objects or environmental factors.
- Camera Misalignment Detection: Recognising instances where the camera may have been knocked out of position, resulting in compromised detection accuracy.
- Identification and categorisation of behaviour trends.

This will support faster decision-making, reduce the manual review workload, and improve the overall reliability of the system.

The information provided from 11 Data & Recording helps us achieve the analysis above.

13. Sensitive Site Protocol – Implementation by 01/06/26

Some of our clients may not be comfortable with, or even unable to authorise data and/or video footage being captured on sensitive sites, such as Ministry of Defence locations, nuclear installations and Department of Justice locations. Manufacturers should have the option to cater for these situations.

Below shows what would be expected from each scenario:

Security Requirement	On Plant Functionality	Cloud Data Upload	Cloud Video Upload	Cellular Connectivity	GPS Location	On Plant Storage
None	✓	✓	✓	✓	✓	✓
Sensitive	✓	✗	✗	✗	✗	✓

14. Performance Parameters Summary

- 360 degree camera coverage
- Detection coverage as per appendix 1
- Suitable camera mounting
- 250 hour footage storage capacity
- Outer zone visual and audible alerts as per section 7
- Inner zone visual and audible alerts as per section 7

- Abides by ‘safe state’ protocol including ‘thumbs up’ functionality
- Ability to change detection zone configuration
- System error codes as per section 11.1
- API capability as per section 11
- Thumbnail capture and upload with visual configuration detection zone as per section 11.3
- Automatic incursion video uploaded onto the cloud-based portal
- Configurable Data Sharing Based on Site Security Level

15. Environmental Parameters

- Detection achievable in low level light (Min 0.1 Lux)
- IP68 protection
- Vibration-resistant
- 8-24V DC power range
- Ambient working conditions:
- Operating temperature between -20 ~+60°C
- Relative humidity up to 90%

16. Safety Parameters

- System health checks
- Startup check
- Camera obscuration check
- Notification to operator of any issues and sent via API
- Relevant signage supplied and fitted to alert personnel of HFR system in use

17. Testing & Compliance

All HFR systems must have been through rigorous physical testing to ensure system performance, detection accuracy and prevent false positives. Systems must have a detection accuracy above 95%.

In addition to prior due diligence carried out by suppliers through their testing, it is required that systems are also tested as per test criteria developed between BB and MIRA (Appendix 2). This testing is designed to catch any edge cases for more difficult scenarios and should be a final check. Responsibility of the system’s performance still lies with the supplier.

Performance Metrics:

- Effective detection within designated inner/outer zones in the absence of false positives/negatives.
- System responsiveness and reliability in real-world site operational conditions.

18. Documentation

- Verification of >95% accuracy from supplier testing
- MIRA test results
- Technical file to include appropriate technical drawings.
- CE marking and Declaration of Conformity
- Operation and Maintenance Manual
- Training documentation

Appendix 1 - Default Detection Zones –

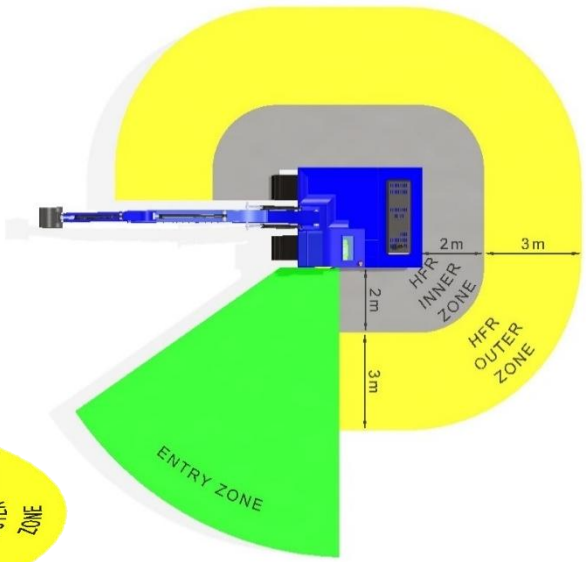
Changes made since version 3.0 of this specification to be implemented by 01/03/27

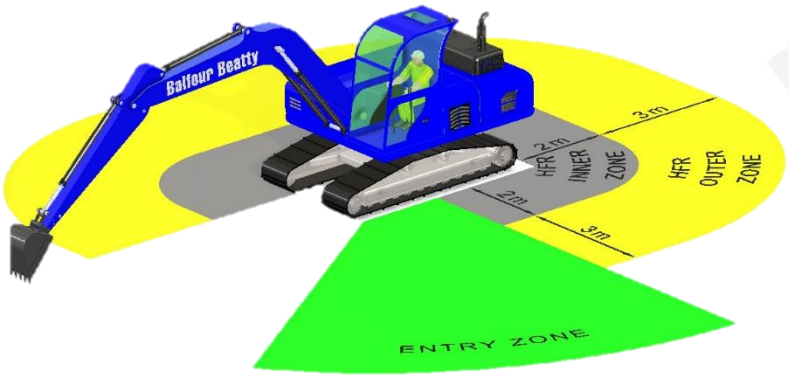
Excavators 13t and above

270° Detection Coverage + 360° recording.

5m Detection Zone

- 2m – 5m Zone (HFR Outer Zone)
- 0m – 2m Zone (HFR Inner Zone)

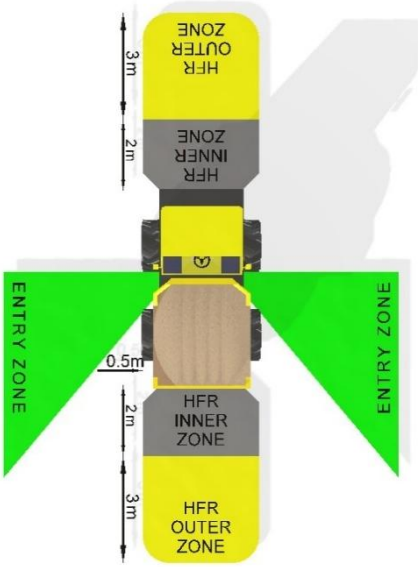


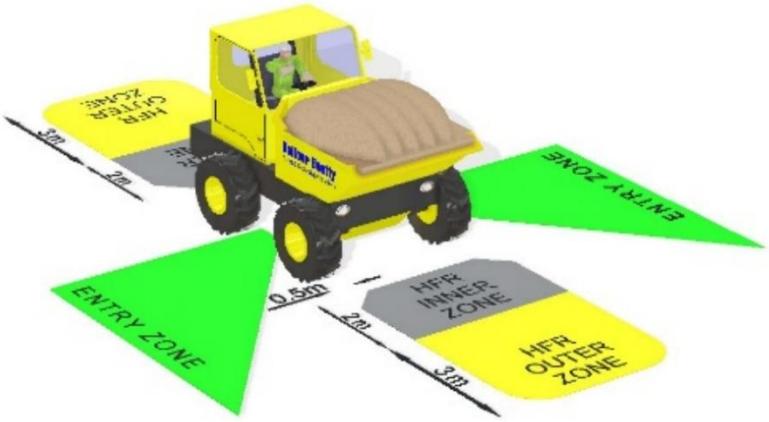


FT Dumper 6t and above

Front & Rear Detection Zone + recording

- 2m – 5m Zone (HFR Outer Zone)
- 0m – 2m Zone (HFR Inner Zone)

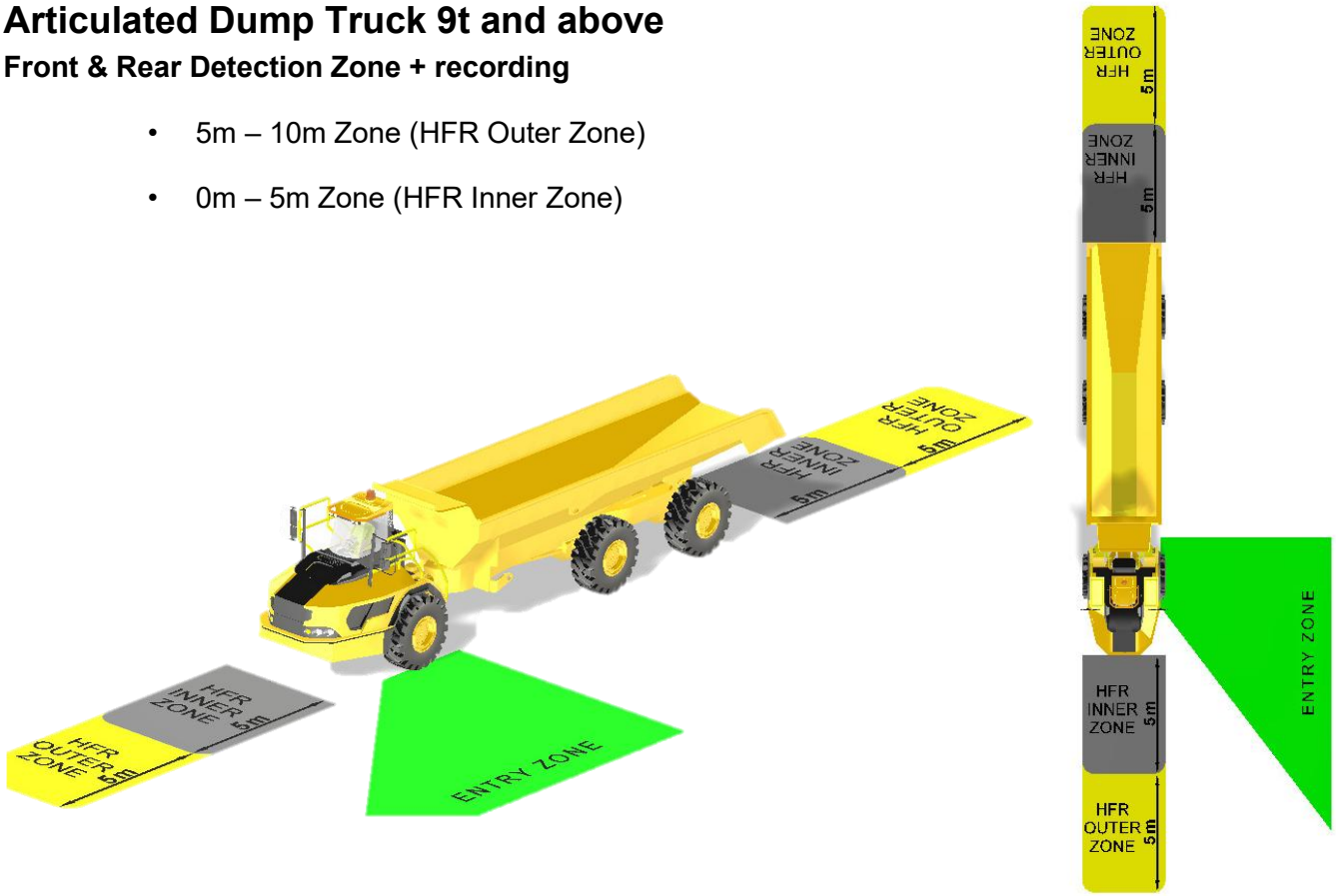




Articulated Dump Truck 9t and above

Front & Rear Detection Zone + recording

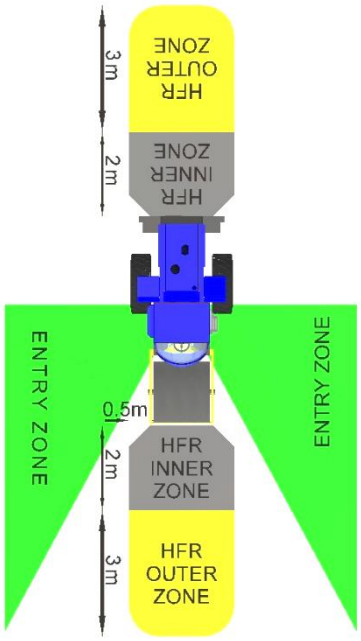
- 5m – 10m Zone (HFR Outer Zone)
- 0m – 5m Zone (HFR Inner Zone)



Roller 13t and above

Front & Rear Detection Zone + recording

- 2m – 5m Zone (HFR Outer Zone)
- 0m – 2m Zone (HFR Inner Zone)



Telehandler all sizes

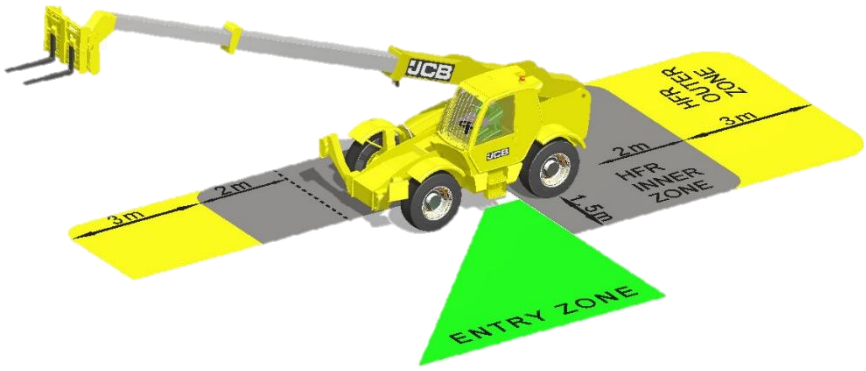
270° Detection Coverage + 360° recording

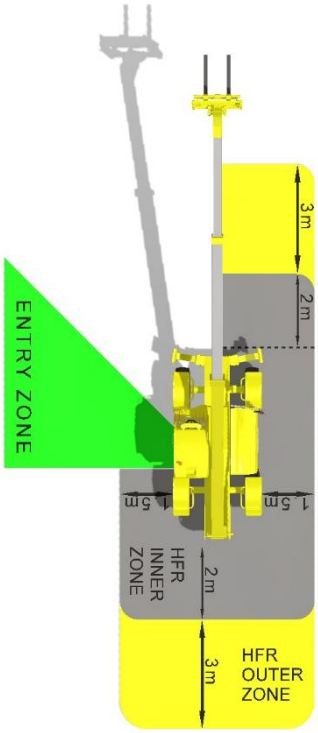
Front & Rear Detection Zone

- 2m – 5m Zone (HFR Outer Zone)
- 0m – 2m Zone (HFR Inner Zone)

Body Sides Detection Zone

- 0m – 1.5m Zone (HFR Inner Zone)





Dozers

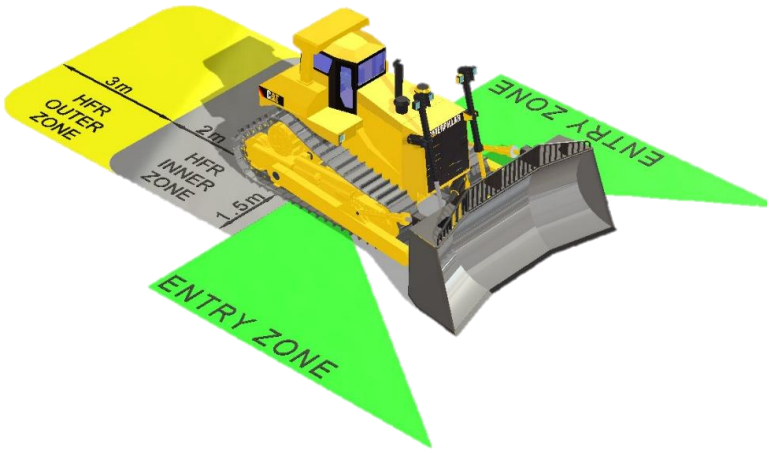
180-degree Detection Coverage + recording

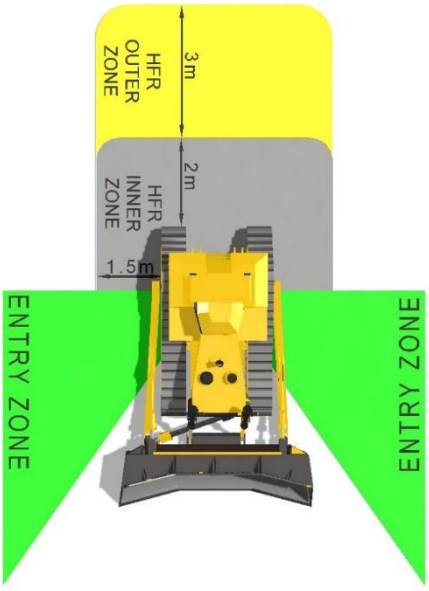
Rear Detection Zone

- 2m – 5m Zone (HFR Outer Zone)
- 0m – 2m Zone (HFR Inner Zone)

Body Sides Detection Zone

- 0m – 1.5m Zone (HFR Inner Zone)

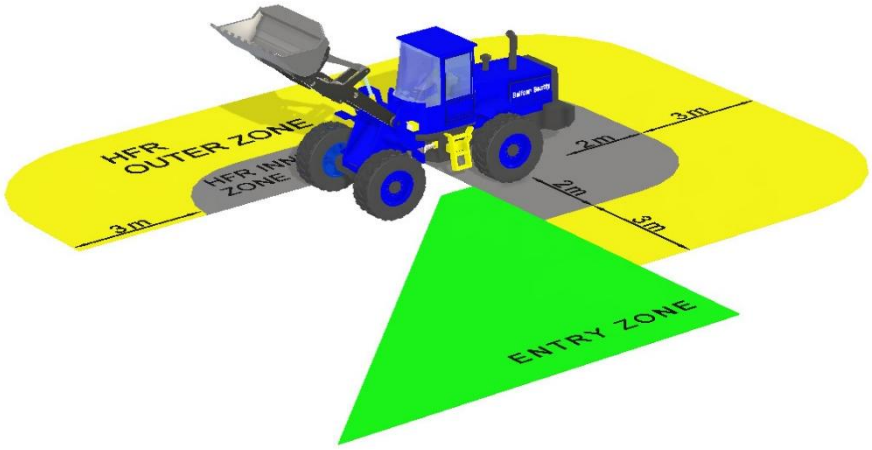


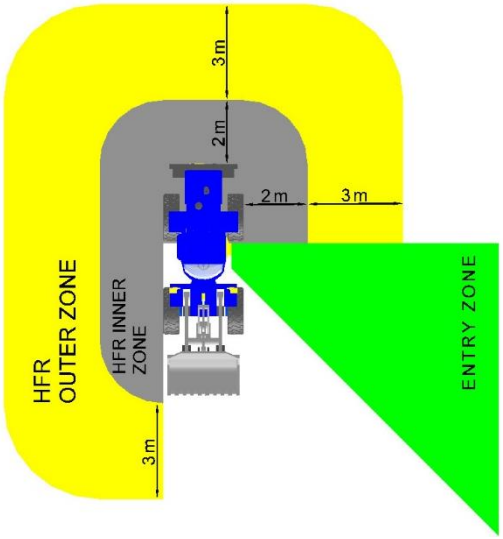


Wheeled Loaders

270-degree Detection Coverage + 360º recording

- 2m – 5m Zone (HFR Outer Zone)
- 0m – 2m Zone (HFR Inner Zone)

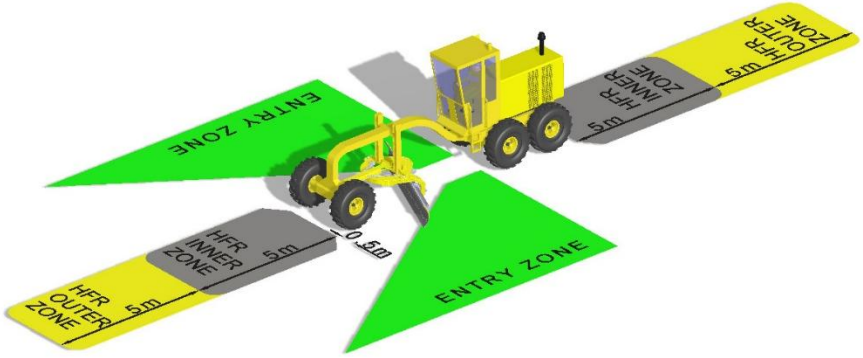


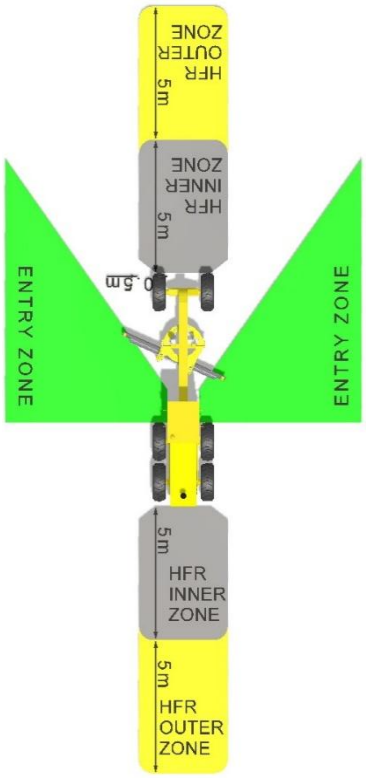


Graders

5m Front & Rear Detection Zone + recording

- 5m – 10m Zone (HFR Outer Zone)
- 0m – 5m Zone (HFR Inner Zone)





Appendix 2 - MIRA testing documentation

A copy of this Test Criteria can be requested by e-mailing HFRSupport@balfourbeatty.com