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Earth-moving machinery — Collision warning and avoidance —

Part 1: General requirements

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electro technical Commission (IEC) on all matters of electro technical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety, ergonomics and general requirements*.

ISO 21815 consists of the following parts, under the general title *Earth-moving machinery -- Collision warning and avoidance*

- Part 1: *General requirements*
- Part 2: *On-board J1939 communication interface*
- Part 3: *Risk area and risk level*

Introduction

Increasing use of detection systems and avoidance technology in the area of earth-moving machinery has been supporting operators to safely operate machines in the field of mining and construction. At the same time, there are demands to set standards for machines and systems detecting, alerting and intervening to mitigate collision risk.

There are currently two existing standards in the field: ISO 16001:2017 Earth-moving machinery – Object detection systems and visibility aids – Performance requirements and tests, and ISO 17757:2017 Earth-moving machinery – Autonomous machinery system safety. These standards provide guidance for visibility aids and object detection systems and for autonomous and semi-autonomous machines, however, there is currently no standard that describes collision risk awareness, warning signals and collision avoidance actions of the machinery operated by humans when there is a risk of collision.

Collision warning and avoidance system is a developing technology and algorithms are not yet mature and well understood. This document is intended to foster innovation and accelerate the pace of improvements in new collision warning and avoidance technologies. The performance requirements of this document are technology neutral and do not specify technologies to make the requirements.

The systems described in this document are intended to assist the operator of the machine. As current technologies are unable to achieve full collision warning/avoidance in every situation the responsibility for safe operation of the machine remains with the operator of the machine .

This document is a part of ISO 21815-series relating to: communication interfaces, collision risk areas and collision risk levels, specific requirements for collision warning and collision avoidance systems, and specific use case requirements.

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Earth-moving machinery — Collision warning and avoidance —

Part 1: General requirements

1 Scope

This document provides terminology and general guidance on the principles of collision warning and collision avoidance systems for:

- earth moving machinery as defined in ISO 6165,
- mobile underground mining machinery as defined in ISO 19296, and
- road construction machinery as defined in ISO 22242.

This document provides general requirements for detection of objects, warnings to the operator, automatic intervention control to avoid collision, and test procedures. It is intended to be used in conjunction with the other parts of ISO 21815, which describe detailed guidance and requirements for collision warning and collision avoidance systems and determining risk areas and risk levels. The specific requirements and definitions for particular types of machines are defined in the use case parts.

Collision avoidance systems described in this document address inhibiting, slowing down or stopping machine movement and do not address steering.

The system described in this document is only intended to assist the operator of the machine. The responsibility for safe operation of the machine remains with the operator of the machine.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6165, *Earth-moving machinery — Basic types — Identification and terms and definitions*

ISO 19296, *Mining — Mobile machines working underground — Machine safety*

ISO 22242, *Road construction and road maintenance machinery and equipment — Basic types — Identification and description*

ISO 16001:2017, *Earth-moving machinery — Object detection systems and visibility aids — Performance requirements and tests*

ISO 13766-1:2018, *Earth-moving and building construction machinery — Electromagnetic compatibility (EMC) of machines with internal electrical power supply — Part 1: General EMC requirements under typical electromagnetic environmental conditions*

ISO 13766-2:2018, *Earth-moving and building construction machinery — Electromagnetic compatibility (EMC) of machines with internal electrical power supply — Part 2: Additional EMC requirements for functional safety*

ISO 19014-1, *Earth-moving machinery — Functional safety — Part 1: Methodology to determine safety-related parts of the control system and performance requirements*

ISO 19014-3, *Earth-moving machinery — Functional safety — Part 3: Environmental performance and test requirements of electronic and electrical components used in safety-related parts of the control system*

ISO 13849, *Safety of machinery — Safety-related parts of control systems*

ISO 3450:2011, *Earth-moving machinery — Wheeled or high-speed rubber-tracked machines — Performance requirements and test procedures for brake systems*

ISO 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at <http://www.iso.org/obp>

— IEC Electropedia: available at <http://www.electropedia.org/>

3.1 interaction

situation where a machine encounters another object when moving or about to move, placing itself or the operator at risk, or exposing the objects to risk

3.2 warning

transmission of alert information to the operator by visual, audible or other means of signals

3.3 evasive action

action initiated by operator to attempt to prevent or avoid a foreseeable collision

EXAMPLE Example: braking, steering

3.4 interventional collision avoidance action

automatic action initiated by the system to attempt to prevent or avoid a foreseeable collision

EXAMPLE Example: braking, inhibiting motion, slowing down

3.5 intended object

an object, such as people, machine, vehicle or obstacle, which is intended to be detected by CWS or CAS when in the collision risk area

3.6 collision risk level

value that is assigned each intended object based on the analysis of the state of the machine to determine if a collision is foreseeable

Note 1 to entry: collision risk levels are described in ISO 21815-3

3.7 collision risk area

space analysed to determine the collision risk level

3.8 collision warning system CWS

system which detects intended objects in the collision risk area, evaluates the collision risk level and provides a warning to the operator

3.9**collision avoidance system****CAS**

system which detect intended objects in the collision risk area, evaluate the collision risk level and provides interventional collision avoidance action

3.10**CxS**

CWS or CAS or a system providing both

3.11**detection**

acknowledgement of intended objects by a CxS

3.12**CxS action**

CxS providing warning to the operator or CAS taking interventional collision avoidance action

3.13**false positive CxS action**

unnecessary or inappropriate CxS action, caused by an incorrect determination of the collision risk level

3.14**false negative CxS action**

lack of necessary or appropriate CxS action, caused by an incorrect determination of the collision risk level

3.15**CxS device****CxD**

device with sensors providing CxS functions to detect objects in the proximity of the machine, assess the collision risk level, warn the operator of the presence of the object for a CWS, and/or provide signals to the machine control system via a communication interface to initiate the appropriate interventional collision avoidance action on the machine for a CAS

Note 1 to entry: CxS device is described as CxD in other parts of the standard series.

Note 2 to entry: Proximity Detection System (PDS) is a colloquial industry term for a physical device providing CWS or CAS functionality.

3.16**normal mode**

operational mode whereby a CxS is active and ready to provide all functions equipped in the CxS, including warning information and interventional collision avoidance action.

3.17**stand-by mode**

operational mode selected by an authorized person, whereby a CxS can be active, but warning information or interventional collision avoidance action or both are not provided by the system, in an extended period of time, without automatic return

3.18**override mode**

operational mode selected by the operator, whereby a CxS can be active, but warning information or interventional collision avoidance action or both are suspended temporarily and return automatically to normal mode after certain condition

3.19**system integrator**

entity, providing whole system by the integrating the machine, the interface and the CxS devices

4 Performance requirements

4.1 General

This document specifies the principles of operation, basic functionality, system requirements and general test requirements for collision warning and collision avoidance systems. This standard series intends to support the operator to safely operate the machine.

This standard series is not intended to require plug-and-play capability between CxS devices and CxS device-ready machines. Technical details not described in this document should be agreed upon between the CxS device manufacturer, the CxS device-ready machine manufacturer and system integrator, as applicable.

4.1.1 Electro-magnetic compatibility (EMC)

A CxS device providing CWS capability shall be in conformance with ISO 13766-1. A CxS device that provides CAS capability shall be in conformance with both ISO 13766-1 and ISO 13766-2. The EMC testing of the CxS device may be performed treating the CxS device as an electronic sub-assembly or with the CxS device incorporated into the machine.

NOTE the addition of a CxS device could negatively impact ISO 13766-1 or ISO 13766-2 conformance of the machine and could require a combined re-evaluation of the CxS-equipped machine.

4.1.2 Environmental condition requirements

Safety-related parts (SRP) of a CxS device providing CAS capability identified per definition in ISO 19014-1 or ISO 13849 shall meet the requirements of ISO 19014-3.

4.1.3 Functional safety

The addition of a CxS device with CWS or CAS capability shall not negatively impact the performance level achieved (e.g. ISO 19014, ISO 15998, ISO 13849) of the safety control system of the original machine.

NOTE The addition of CxS device could require a combined re-evaluation of the CxS device-equipped machine.

The consequence of adding CxS device shall be analyzed using a risk assessment.

4.1.4 Risk assessment

A risk assessment process for a CxS device-equipped machine shall be completed according to the principles of ISO 12100. All identified risks shall be mitigated to acceptable risk levels as part of the risk assessment process. The results of the risk assessment shall be formally documented.

4.1.5 Analysis on machine modification

The addition of CxS device shall require an analysis to be completed as it could negatively impact the original machine's safety and performance characteristics (guidance can be found in standards e.g. ISO 20474-series, ISO 19296).

4.2 Requirements on CxS

Collision warning systems (CWS) and collision avoidance systems (CAS) shall detect intended objects (e.g. people, other machines, vehicles, and obstacles) within the collision risk area and take CxS action as defined below:

- CWS shall provide a warning to instruct the operator to maintain the machine in a stationary state if an intended object is present or to immediately apply evasive action.

- CAS shall provide interventional collision avoidance action without requiring an operator action.

NOTE 1 The collision risk areas can be in front, beside or behind machines along the travel path of the machine. For excavators and other machines where all or part of the machine can rotate, the risk area also includes the area where the machine can rotate. Detailed guideline of collision risk area and for the collision risk level assessment are described in the later parts.

4.3 Detection of objects (objects and conditions for detection)

Appropriate detection technology differs depending on the machine type and the object type to be detected. ISO 16001:2017, Annex A summarises existing ODS. The technologies should be selected, and combined as adequate, according to the objectives, with consideration to the advantages and disadvantages of differing types.

4.4 Collision risk levels and CxS actions

The system shall, based on the detection information of objects and machine operating conditions, assess the collision risk level and provide at least one of the CxS actions, as appropriate, as shown below:

- warning signal to the operator (CWS)
- interventional collision avoidance action (CAS)

Interventional collision avoidance actions provided by the system depend on what functions are installed in the system. Collision risk level judgement criteria and interventional collision avoidance action/s depend on the machine type (such as dumper, dozer, hydraulic excavators and others).

Collision warning and avoidance systems that have limited capabilities (eg. limited speed and distance) could have different limits of use based on the use cases that are defined in the later parts of this standard series. The limitation for each use case shall be defined in the operations manual.

4.5 Outline of Process flow for CxS

The CxS process flow outline in Figure 1 uses braking as an example of the CxS action.

The CWS searches for objects in the collision risk area and confirms the existence of object. When an intended object is detected, the CWS will provide a warning to the operator as determined by the collision risk level.

The CAS searches for objects in the collision risk area and confirms the existence of objects. When an intended object is detected, the CAS will provide an interventional collision avoidance action as determined by the collision risk level.