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Earth-moving machinery — Collision warning and avoidance —

Part 1: General requirements

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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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 Electrotechnical Commission (IEC) on all matters of electrotechnical 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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For an explanation of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety, ergonomics and general requirements,* in collaboration with Technical Committee ISO/TC 82, *Mining*, ISO/TC 82, *Mining*, Subcommittee SC 8, *Advanced automated mining systems*, ISO/TC 195, *Building construction machinery and equipment* and ISO/TC 195 *Building construction machinery and equipment* , Subcommittee SC 3 *Drilling and foundation machinery and equipment*.

A list of all parts in the ISO 21815 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is a type-C standard as stated in ISO 12100.

This document is of relevance, in particular, for the following stakeholder groups representing the market players with regard to machinery safety:

— machine manufacturers (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organisations, market surveillance etc.).

Others can be affected by the level of machinery safety achieved with the means of the document by the above-mentioned stakeholder groups:

— machine users/employers (small, medium and large enterprises);

— machine users/employees (e.g. trade unions, organizations for people with special needs);

— service providers, e.g. for maintenance (small, medium and large enterprises);

— consumers (in case of machinery intended for use by consumers).

The above-mentioned stakeholder groups have been given the possibility to participate at the drafting process of this document.

In addition, this document is intended for standardization bodies elaborating type-C standards.

The requirements of this document can be supplemented or modified by a type-C standard.

For machines which are covered by the scope of a type-C standard and which have been designed and built according to the requirements of that standard, the requirements of that type-C standard take precedence.

The machinery concerned and the extent to which hazards, hazardous situations or hazardous events are covered are indicated in the Scope of this document.

When requirements of this type-C standard are different from those which are stated in type-A or type-B standards, the requirements of this type-C standard take precedence over the requirements of the other standards for machines that have been designed and built according to the requirements of this type-C standard.

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 and ISO 17757. 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 systems are developing technologies 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 the 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.

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 the ISO 21815 series, which provide 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 of the ISO 21815 series.

This document covers collision avoidance by speed reduction or motion inhibit: it does not cover avoidance by automatic manoeuvring (e.g. steering) away from the intended object.

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

This document is not applicable to collision warning and collision avoidance systems installed to the machine before the date of its publication.

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

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13766-1, *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, *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 13849 (all parts), *Safety of machinery — Safety-related parts of control systems*

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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
interaction
situation where a machine encounters an *intended object* (3.5) when moving or about to move, placing itself or the operator at risk, or exposing the intended objects to risk

3.2
warning
transmission of alert information by visual, audible or other means of signals

Note 1 to entry: Warning is targeted to the operator and also can be for people located in close proximity to the machine in addition to operator.

3.3
evasive action
action initiated by the operator to attempt to prevent or avoid a foreseeable collision

EXAMPLE Braking, steering.

3.4
interventional collision avoidance action
automatic action initiated by a *collision avoidance system (CAS)* (3.9) to attempt to prevent or avoid a foreseeable collision

EXAMPLE Braking, inhibiting motion, slowing down.

3.5
intended object
object, such as a person, machine, vehicle or obstacle, which is intended to be detected by a *collision warning system (CWS)* (3.8) or a *collision avoidance system (CAS)* (3.9) when in the *collision risk area* (3.7)

3.6
collision risk level
value that is assigned each *intended object* (3.5) to determine if a collision is foreseeable

Note 1 to entry: Collision risk levels are described in ISO 21815-3 and a future part of the ISO 21815 series dedicated to risk area and risk level for track movement and swing/rotation.

3.7
collision risk area
space analysed to determine the *collision risk level* (3.6)

3.8
collision warning system
CWS
system which detects *intended objects* (3.5) in the *collision risk area* (3.7), determines the *collision risk level* (3.6) and provides a *warning* (3.2) to the operator

3.9
collision avoidance system
CAS
system which detects *intended objects* (3.5) in the *collision risk area* (3.7), determine the *collision risk level* (3.6) and provides *interventional collision avoidance action* (3.4)

3.10
CxS
collision warning system (CWS) (3.8) or *collision avoidance system (CAS)* (3.9) or a system providing both

3.11
detection
acknowledgement of *intended objects* (3.5) by a *CxS* (3.10)

3.12
CxS action
collision warning system (CWS) (3.8) providing *warning* (3.2) to the operator or *collision avoidance system (CAS)* (3.9) taking *interventional collision avoidance action* (3.4)

3.13
false positive CxS action
unnecessary or inappropriate *CxS action* (3.12)

Note 1 to entry: This can be caused by incorrect determination of the *collision risk level* (3.6).

3.14
false negative CxS action
lack of necessary or appropriate *CxS action* (3.12)

Note 1 to entry: This can be caused by incorrect determination of the *collision risk level* (3.6).

3.15
CxS device
CxD
device with sensors providing *CxS* (3.10) functions to detect *intended objects* (3.5) in the proximity of the machine, determine the *collision risk level* (3.6), warn the operator of the presence of the intended object for a *collision warning system (CWS)* (3.8), and/or provide signals to the machine control system via a communication interface to initiate the appropriate *interventional collision avoidance action* (3.4) on the machine for a *collision avoidance system (CAS)* (3.9)

Note 1 to entry: CxS device is described as CxD in other parts of the ISO 21815 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* (3.10) is active and ready to provide all functions of the CxS, including *warning* (3.2) information and *interventional collision avoidance action* (3.4)

3.17
stand-by mode
operational mode selected by an authorized person, whereby a *CxS* (3.10) can be active, but *warning* (3.2) information or *interventional collision avoidance action* (3.4) or both are not provided by the system, and returns to *normal mode* (3.16) by an authorized person

3.18
override mode
operational mode selected by the operator, whereby a *CxS* (3.10) can be active, but *warning* (3.2) information or *interventional collision avoidance action* (3.4) or both are suspended temporarily and return automatically to *normal mode* (3.16) after a certain condition

3.19
system integrator
entity, providing a whole system by integrating the machine, the interface and the *CxS* (3.10) devices

4 Performance requirements

4.1 General requirements

4.1.1 General

Machinery and systems shall comply with the safety requirements and/or protective/risk reduction measures of this document. In addition, the machine and systems shall be designed according to the principles of ISO 12100:2010 for relevant but not significant hazards which are not dealt with by this document.

This document specifies the principles of operation, basic functionality, system requirements and general test requirements for collision warning and collision avoidance systems. The ISO 21815 series intends to support the operator to safely operate the machine.

The ISO 21815 series is not intended to require plug-and-play capability between CxS devices and machines. Technical details not described in this document should be agreed upon between the CxS device manufacturer, the machine manufacturer and system integrator, as applicable.

4.1.2 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 conformance of the machine to ISO 13766-1 or ISO 13766-2 and can require a combined re-evaluation of the CxS-equipped machine.

4.1.3 Environmental condition requirements

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

4.1.4 Functional safety

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

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

4.1.5 Risk assessment

A risk assessment for a CxS device-equipped machine shall be completed according to the principles of ISO 12100 by the system integrator. 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.

4.1.6 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. the ISO 20474 series, ISO 19296).

4.2 Requirements on CxS

4.2.1 General

The CxS shall detect intended objects (e.g. people, other machines, vehicles, and obstacles) within the collision risk area and provide 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. A detailed guideline of a collision risk area and for the collision risk level assessment are described in the other parts of the ISO 21815 series.

NOTE 2 The CxS does not necessarily cover all area that the machine can move.

NOTE 3 CAS can also provide warning to operator.

4.2.2 Detection of intended objects

Appropriate detection technology differs depending on the machine type and the object type intended to be detected. ISO 16001:2017, Annex A summarises existing an object detection system (ODS). The technologies should be selected, and combined as appropriate, according to the CxS design concept, with consideration to the advantages and disadvantages of differing types. Comparison of system functions is described in Annex B.

4.2.3 Collision risk levels and CxS actions

The system shall, based on the detection information of intended objects and machine operating conditions, determine 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 actions depend on the machine type (such as dumper, dozer, hydraulic excavators and others).

4.2.4 System limitations

Collision warning and avoidance systems that have limited capabilities (e.g. limited speed and distance) could have different limits of use based on the use cases that are defined in the other parts of the ISO 21815 series. The limitations for each use case shall be defined in the operator's manual.

See 7.1 for the requirements on the limitations for each use case in the operator's manual.

4.3 Outline of process flow for CxS

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

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

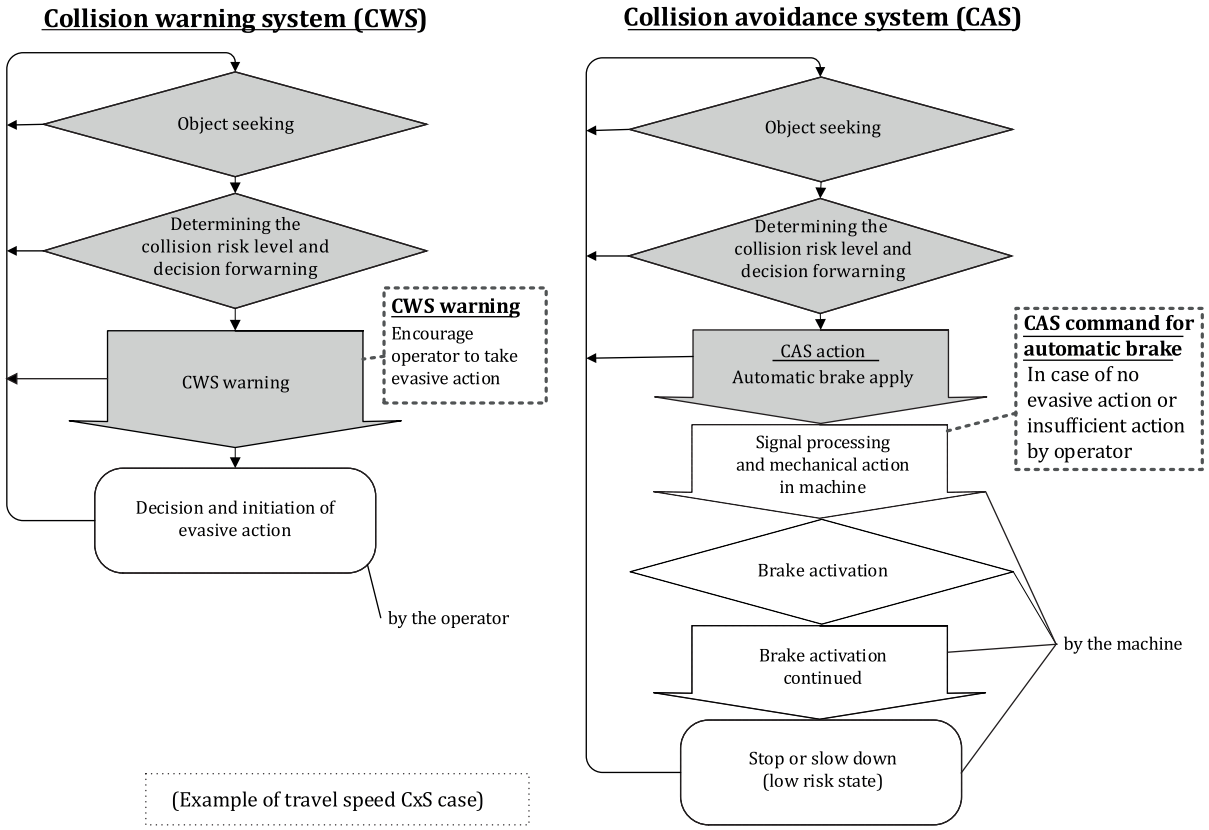


Figure 1 — Example of a high-level process flow diagram for CWS and CAS

4.4 False CxS actions

Both false positive and false negative CxS actions shall be minimized.

4.5 Operating state transition of CxS

4.5.1 General

A CxS may have different operational modes: normal mode, stand-by mode, and override mode. Figure 2 describes an example of the operating state transition of a CxS.

4.5.2 Switching between normal mode and stand-by mode

When a CxS is equipped with a stand-by mode (CxS disengage), it shall be a deliberate action by an authorized person. The CxS shall require authentication means, (e.g. password, key) to enable the stand-by mode.

A CxS shall not be able to automatically switch to the stand-by mode.

By default, a CxS should start in normal mode upon machine start up.

4.5.3 Switching between normal mode to override mode

When a machine is equipped with a means to shift a CxS to an override mode, it shall require a deliberate action by the operator to engage the override mode:

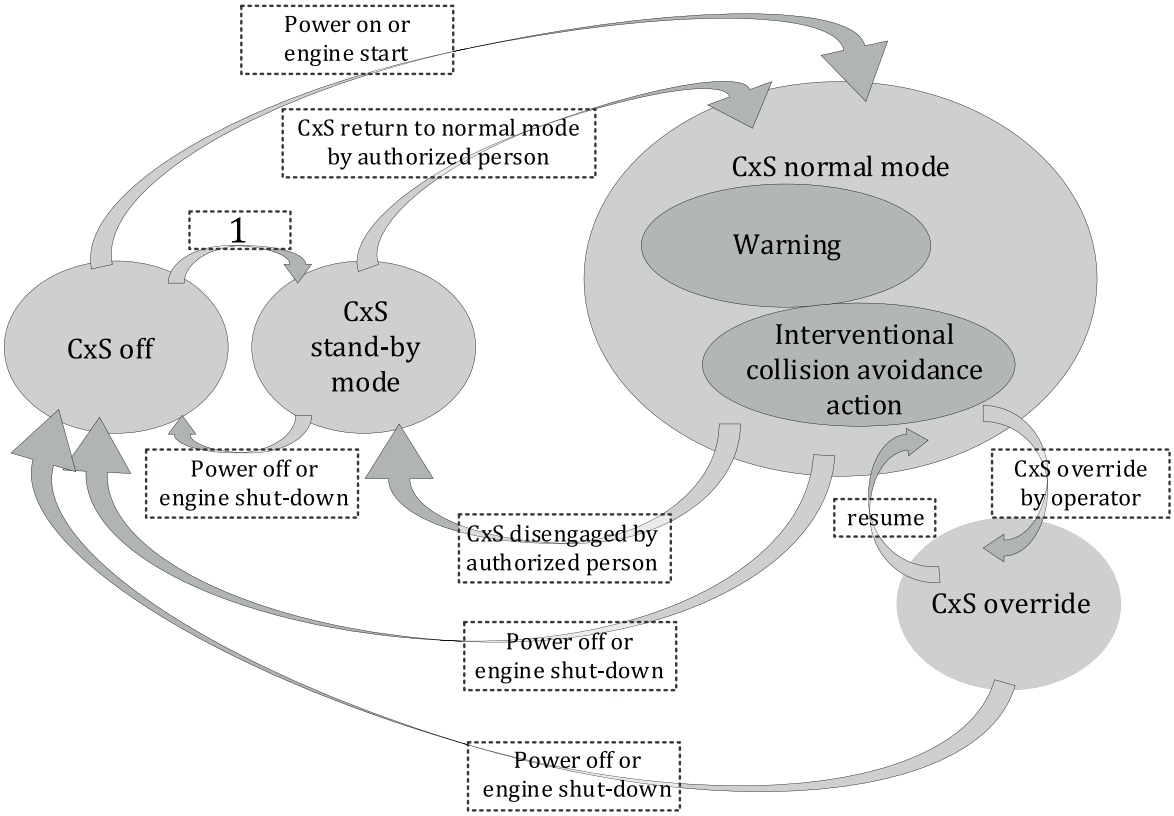
— a CxS shall not be able to automatically switch to the override mode,

— by default, a CxS should start in normal mode upon machine start-up.

— staying in an override mode unintentionally shall not be possible.

4.5.4 Status information

Continuous status indication of operational mode of the CxS shall be provided to the operator. The method of the indication should be according to the principles of ISO 6011.



Key

1 power on or engine start, during stand-by mode selected by an authorized person

Figure 2 — Example of CxS transition diagram

4.6 Self-checking, status indication and failure warning

Upon power on, a CxS shall perform an initial system check. While the initial system check is being carried out, the system shall provide an indication showing the status. After completion of the initial system check, the system shall give an appropriate system function indication. Throughout operation, the system shall perform self-diagnosis at a frequency as determined by the manufacturer's risk assessment**.** When a CxS detects a loss of its function**,** the system shall inform the operator. When CxS

capability is detected as not available because it is outside of its specified limits of use (e.g. speed), the operator shall be informed. The method to indicate the operating status should be according to the principles of ISO 6011.

4.7 Protection against unauthorized modification of system functions

A CxS shall be designed to prevent unauthorized modification of the CxS internal parameters or software.

EXAMPLE Protections against unauthorized modification such as passwords, key locks.

5 System classification

5.1 General

The CxS can provide either CWS or CAS or both. Systems can be built to provide multiple different capabilities. Additional capabilities that are not listed are possible. Annex A describes common examples of machine interaction scenario.

5.2 System capability types

There are four types of system capabilities: take-off inhibition CxS (TIC), swing inhibition CxS (SIC), manoeuvring speed CxS (MSC), and travel speed CxS (TSC).

5.2.1 Take-off inhibition CxS (TIC)

A TIC is a CxS that determines that the collision risk level before movement (e.g. forward, reverse) is initiated followed by providing CxS action. A CAS system inhibits machine movement.

NOTE 1 Typical machines are dumper, grader, wheel loader, dozer excavator.

NOTE 2 Motion inhibition prevents a machine from moving while stationary.

5.2.2 Swing inhibition CxS (SIC)

A SIC is a CxS that determines that the collision risk level before swing movement (e.g. rotation) is initiated followed by providing CxS action. A CAS system inhibits machine movement.

NOTE 1 Typical machines are excavators and backhoe loaders.

NOTE 2 Motion inhibition prevents a machine from moving while stationary.

5.2.3 Manoeuvring speed CxS (MSC)

An MSC is a CxS that determines the collision risk level at low manoeuvring speeds (e.g. below 10 km/h) and provides CxS action. An MSC needs to work in all possible directions of travel (e.g. forward, reverse). The system may be designed only to work below the manoeuvring speed.

NOTE Typical machines are dumpers, graders, wheel loaders, dozers, excavators.

5.2.4 Travel speed CxS (TSC)

A TSC is a CxS that determines the collision risk level at high travel speed and provides CxS action. The system may be designed to operate at speeds only above the manoeuvring speed (e.g. above 10 km/h) and only in the forward direction.

NOTE Typical machines are dumpers, graders, wheel loaders.

5.3 System types

There are two system types of CxS: CWS and CAS.

NOTE A CxS can provide both warning and avoidance CxS actions.

5.4 Types of detection

A CxS can passively detect (e.g. camera, radar) intended objects that are not instrumented or a CxS can require the intended object to be instrumented (e.g. RFID).

5.5 Description of systems

CxS can be described by combining multiple classifications.

EXAMPLE 1 Provides warning and avoidance for take-off for intended objects of large machines, small vehicles, and human using a passive system.

EXAMPLE 2 Provides avoidance when manoeuvring when the intended object is instrumented.

6 Test procedures

6.1 General

The system integrator shall conduct testing based on technical information provided by the machine manufacturer and the CxS device manufacturer. The test procedures described here provides minimum requirements of a CxS for typical operational situations, and do not represent all situations in all conditions.

The test procedures prescribe test conditions to assure that the process can be repeated and produce stable results. Detection technology, the type of earthmoving machinery with the system, and the shape of the test object define the test methods. Detailed test procedures are described in other parts of the ISO 21815 series.

The test condition shall be recorded.

6.2 Test condition

6.2.1 Test environment condition

There shall be no precipitation that affects the testing.

EXAMPLE Rain, snow, sleet, hail.

There shall be no wind strong enough to affect the testing.

Ambient temperature during test shall be within the operating range of the tested machine and CxS devices.

The system integrator can design the test based on the information about the environment condition provided by the CxS device manufacturer and the machine manufacturer.

6.2.2 Test surface conditions

The test surface shall consist of a hard, dry surface with a well-composed base, and the ground moisture may be present to the extent that it does not adversely affect the test. The test surface shall not have a slope of more than 3 % at right-angles to the direction of travel.

The slope in the direction of travel shall be no greater than 1 %, or as specified for the test being carried out.

6.3 Subject machine conditions

The test configuration of the subject machine that is within the scope of ISO 3450:2011 shall be according to ISO 3450:2011, 5.4.

The test configuration of the applicable braking or safety standards (e.g. ISO 18758-2, ISO 19296, ISO 10265) should be used for subject machines outside the scope of ISO 3450:2011.

6.4 Specification of test objects

The test object may be an actual intended object or a substitute test object giving equivalent detection results as the actual intended object. When a collision risk is foreseen in the test procedure, the test object may be replaced by the substitute test object. Even when same substitute test object is selected, results could vary depending on the detection system used. Therefore, an appropriate method should be selected to reproduce the characteristics of the test object.

Record the details of the test object.

6.5 Performance test

6.5.1 General

Testing shall be carried out under the conditions determined in 6.5. The results shall be recorded for evaluation. The test shall be performed three times with each test condition, as defined in 6.3 and 6.4.

6.5.2 Test object installation

The test object installation method, orientation and movement shall be defined in detail.

6.5.3 Subject machine

The operating conditions for the subject machine based on the limitations of the CxS shall be defined. The operating test condition of subject machine should simulate real operating condition as closely as possible within safe limits. When the subject machine is tested for traveling condition, the travel position which is defined by the machine's manufacturer shall be used.

6.5.4 Test result judgement criteria

Determine if the set judgement criteria have been achieved. The judgement criteria could be set by the system integrator under the given machine condition based on information provided by the machine and/or the CxS devices' manufacturer. Judgement criteria should be able to ensure that the CxS warns the operator as intended, initiates interventional collision avoidance action, and/or stops the machine before colliding with the test object or inhibits machine motion, at the standard test condition described in Clause 6.

Detailed requirements will be described in other parts of the ISO 21815 series.

6.6 False positive CxS action test

The test shall verify that the system does not provide unnecessary warnings under the test conditions based on the defined system limitation and specifications, nor give false warning and false interventional collision avoidance action when the risk of collision is not foreseen. The test shall be performed to set simulated situations where the system could mistakenly judge the risk of collision when there is no risk.

7 CxS information for use

7.1 Information for the operator

CxS-equipped machines shall be accompanied with an operator's manual, provided by the system integrator. The system integrator shall compile the operator's manual based on the technical information provided by the machine's manufacturer and the CxS device's manufacturers. The operator's manual shall contain technical and safety instructions and limits of use, aiming to explain the intended use of the system (see ISO 12100:2010, 6.4.5). Annex C shows examples of information.

7.2 Information about residual risks

A risk assessment of integrating the CxS devices into the machine shall be conducted according to the principles of ISO 12100. Information regarding residual risks shall be communicated through the information for use documentation.

Annex A
(informative)

Machine interaction scenario common examples

A.1 General

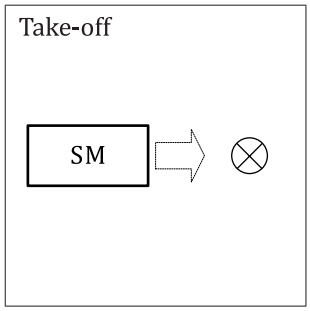
This annex shows examples of machine interactions occurring during machine operation, with descriptions of possible scenarios of interaction, in three categories.

Manufacturers may refer to this to categorize collision cases or to define intended objects and machine performance while a CxS is developed. The scenarios are not limited to the categories listed below.

A.2 Machine interaction scenario definitions

A.2.1 Take-off

The intended object is in the collision risk area around the subject machine. The subject machine is stationary and intending to move (Figure A.1).



Key

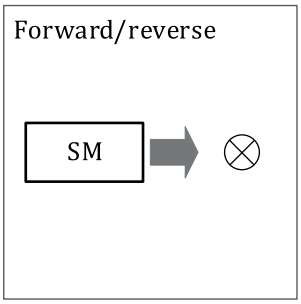
SM subject machine

⊗ intended object

Figure A.1 — Machine interaction scenario example – Take-off

A.2.2 Forward/reverse

Subject machine is moving forward or in reverse and interacts with an intended object in the collision risk area (Figure A.2)



Key

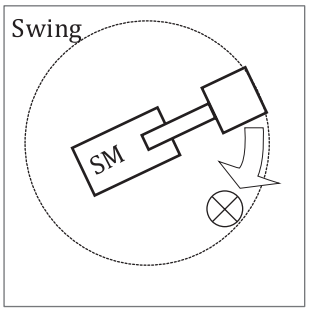
SM subject machine

⊗ intended object

Figure A.2 — Machine interaction scenario example – Forward/reverse

A.2.3 Swing

The subject machine with rotating structure is operating near an intended object. The subject machine is stationary and intending to rotate (Figure A.3), e.g. excavator, backhoe loader.



Key

SM subject machine

⊗ intended object

Figure A.3 — Machine interaction scenario example - Swing

Annex B
(informative)

Comparison of system functions

This annex describes the difference between CxS and other systems defined in ISO 16001.

— Visibility aid (VA) according to ISO 16001 only provides visual information and no warning signal.

— Object detection system (ODS) according to ISO 16001 has no intelligence for determining collision risk level, but only provides warning signals with the condition that intended objects are in the detection zone.

CxS has an appropriate level of intelligence for determining collision risk levels with the existence of intended objects. Appropriate CxS actions are defined on each collision risk level, including warnings and interventional collision avoidance action. Table B.1 shows the comparison of system functions.

Table B.1 — Comparison of VA, ODS, CWS, CAS

	Visibility aid (VA)	Object detection system (ODS)	Collision warning system (CWS)	Collision avoidance system (CAS)
Standard	ISO 16001	ISO 16001	ISO 21815	ISO 21815
Description	Provides indirect visibility (visual information) without warning	— Detects intended objects — Provides warnings (not defined when/what/how to provide for warning)	— Detect intended objects — Determines collision risk levels — Provides appropriate warnings according to the collision risk levels	— Detect intended objects — Determines collision risk levels — Provides appropriate interventional collision avoidance actions according to the collision risk levels
Object detection by	Operator (by using VA as required)	Operator (with reference of ODS)	Operator and CWS	Operator and CAS
Collision risk level determined by	Operator	Operator	Operator and CWS	Operator and CAS
Evasive/interventional action by	Operator	Operator	Operator	Operator and CAS
Sensors	None	Sensors for detecting intended objects	— Sensors for detecting intended objects — Sensors for machine status (e.g. machine speed)	— Sensors for detecting intended objects — Sensors for machine status (e.g. machine speed)
Intelligence	None	None (No ability to decide when/what/how to provide for warnings. It means no intelligence.)	Intelligence for collision risk level determination	Intelligence for collision risk level determination and for intervention collision avoidance action

Annex C
(informative)

Example of operator's manual

Table C.1 shows examples of an operator's manual containing technical and safety instructions, aiming to explain the intention of use of the system.

Table C.1 — Example of contents in operator's manual

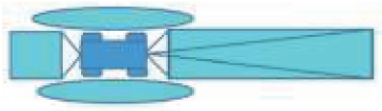
Item	Contents
Description of system performance	To assist the operator of the machine by warning of a foreseeable collision and to give interventional collision avoidance action below 10 km/h, within system limitations
Classification	The classes listed below are examples of the intended objects to be detected by CWS and CAS: — large machines, — small vehicles, — humans. NOTE Intended objects of CxS depend on the application and the machine type, and additional intended object classes that are not listed will be described on other parts of the ISO 21815 series. EXAMPLE 1 Provides take-off inhibition collision warning and avoidance for intended objects of large machines, small vehicles, and human using a passive system. EXAMPLE 2 Provides manoeuvring speed collision avoidance system using an instrumented system. Size and shape of an intended object (e.g. similar size machine and small vehicle) shall be defined and described by the CxS devices manufacturer.
Detection range (travelling or standing)	Shape of detection area and size for each capabilities (functions) should be described, as shown in Figure C.1.  **Figure C.1 — Detection area and size**
Speed range covered by the system (with stationary intended object)	TSC: forward only (no load) >10 km/h and <X km/h (rated load) >10 km/h and <Y km/h MSC (rated load): forward <10 km/h backward <10 km/h

Table C.1 *(continued)*

Item	Contents
External factors affecting system performance and system limitation	EXAMPLE fog, dust; light, sunshine; darkness; obstacles of visibility; terrain condition; payload.
Operating instructions	Operating instructions of the system Safe operation instructions Handling instructions Operating instruction at failure
Maintenance	Instructions for performance verification Routine for regular performance checks of the system Countermeasures for external conditions which could influence detection performance of the system
Instruction of system equipments	Instruction for installation and setting up (including location) Power supply requirements Influence of installation (location, height, angle, etc.) Information to connect with other equipment (if necessary) Proof of regulatory compliance Countries with type approval certificate
Jobsite organization	Instruction for jobsite organization for use (including job site preparation)

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