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# Earth-moving machinery — Vocabulary and taxonomy for automation and autonomy

*Engins de terrassement — Vocabulaire et taxonomie pour l'automatisation et l'autonomie*



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# Foreword

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# Introduction

This document defines the terms for automation and autonomy, and provides supporting content in the form of taxonomy for levels of automation and autonomy (LAA). This document can be used to describe, in a consistent manner, the full range of automated operating system (AOS) features equipped on machines.

This document serves the following purposes:

— standardizing the levels of automation and autonomy;

— clarifying the role of the operator, if any, during automated operating system engagement;

— providing a useful framework for automation and autonomy specifications and technical requirements;

— providing clarity in communications on the topics of automation and autonomy.

# Earth-moving machinery — Vocabulary and taxonomy for automation and autonomy

## 1 Scope

This document defines terms for levels of automation and autonomy (LAA), thereby establishing the taxonomy describing the levels of automation and autonomy (LAA).

This document does not provide specifications or requirements on automated operating systems defined herein.

This document applies to earth-moving machinery (EMM) as defined in ISO 6165[1].

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

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

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

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



**3.1**
**machine control system**
**MCS**
system which responds to input signals and generates output signals causing the machine to behave in the intended manner



[SOURCE: ISO 19014-1:—[2], 3.3, modified — The input signal sources have been removed to be generic.]

**3.2**
**worksite**
job site
mine site
construction site
place where earth-moving machines are operated

[SOURCE: ISO 7130:2013[3], 3.6, modified — The preferred term has been changed from "work site" to "worksite"; the admitted terms have been added; "or where routine maintenance" has been removed at the end of the definition.]

**3.3**
**autonomous operating zone**
AOZ
designated area, or areas, within a *worksite* (3.2) in which machines operate in an autonomous mode

**3.4**
**authorized person**
person approved or assigned to perform specific tasks, at specific locations, on the *worksite* (3.2)

Note 1 to entry: Authorization can be granted by the worksite owner, manager or supervisor.

**3.5**
**operator**
*authorized person* (3.4) who performs all, or part of, the *use case* (3.20) and *fallback* (3.23) for a machine, and is aware of associated risks or hazards

Note 1 to entry: People capable of causing the machine to achieve the *minimum risk condition* (3.22) are considered operators.

**3.6**
**onboard operator**
*operator* (3.5) located in, or on, the machine

**3.7**
**remote operator**
*operator* (3.5) not located in, or on, the machine

**3.8**
**supervisor of autonomous system**
**SAS**
*authorized person* (3.4) who oversees an autonomous system

Note 1 to entry: The SAS is only in control of the machine indirectly and does not perform *fallback* (3.23).

**3.9**
**bystander**
person including non-employee, child, or member of the public with little or no awareness of machine hazards and no training

[SOURCE: ISO 19014-1:—[2], 3.4.3]



**3.10**
**co-worker**
*authorized person* (3.4) working in the vicinity of a machine and aware of associated hazards

[SOURCE: ISO 19014-1:—[2], 3.4.2, modified — "authorized" has been added.]



**3.11**
**automation**
EMM automation
operation of a *machine control system* (3.1) by automatic means, with *operator* (3.5) interaction

Note 1 to entry: Partial automation includes systems that assist the operator.

**3.12**
**autonomy**
EMM autonomy
operation of a *machine control system* (3.1) by automatic means, without *operator* (3.5) interaction, but with limited *SAS* (3.8) interaction

**3.13**
**automated operating system**
**AOS**
hardware and software capable of automatically actuating a *function* (3.18) or multiple functions

Note 1 to entry: The hardware and software can include *worksite* (3.2) infrastructure and cloud-based control and supervisory platforms.

**3.14**
**operational design domain**
**ODD**
conditions under which a machine or *feature* (3.17) is designed to operate

Note 1 to entry: The ODD is defined by the manufacturer.

Note 2 to entry: See 5.3 for further discussion on operational domains.

**3.15**
**target operational domain**
**TOD**
*worksite* (3.2) conditions which a machine or *feature* (3.17) is expected to encounter

Note 1 to entry: See 5.3 for further details.

[SOURCE: ISO 34503:2023[4], 3.7, modified — "set of operating conditions" has been replaced by "worksite conditions"; "an ADS" has been replaced by "a machine"; all examples have been removed from the definition; note 1 to entry has been replaced by a new one.]

**3.16**
**current operational domain**
**COD**
*worksite* (3.2) operating conditions which exist presently in the immediate vicinity of a machine

Note 1 to entry: See 5.3 for further details.

[SOURCE: ISO 34503:2023[4], 3.8, modified — "specific set of operating conditions" has been replaced by "worksite operating conditions"; "an ADS" has been replaced by "a machine"; all examples have been removed from the definition; note 1 to entry has been replaced by a new one.]

**3.17**
**feature**
design-specific functionality of a system capable of a given level of *automation* (3.11) or *autonomy* (3.12)

Note 1 to entry: A given *AOS* (3.13) can have multiple *features* (3.17), each associated with a particular level of automation or autonomy and *ODD* (3.14).



**3.18**
**function**
real-time regulation of movement about, or along, a single axis

EXAMPLE The following are single functions that involve movement: propulsion, steering, braking, machine direction, boom up or boom down, boom swing, arm in or arm out, bucket dump, or bucket curl.



Note 1 to entry: Movement can be that of the base machine, equipment or an attachment.

**3.19**
**dynamic operating task**
**DOT**
intended work that the machine was designed to perform by executing a single *function* (3.18) or multiple functions

EXAMPLE 1 Digging a trench using an excavator: the excavator uses a single function or multiple functions, such as propel, swing, raise the arm, extend or curl the bucket, to complete the DOT of digging a trench. In this example, none of these functions, by themselves, constitute a DOT.

EXAMPLE 2 An excavator loading a dumper, backfilling a trench, and object handling are also DOT.

Note 1 to entry: Activities consisting of a single function or multiple functions, and which are incidental to operation, may be considered DOT. These activities contribute to *use cases* (3.20) which are assigned the LAA. Examples of incidental activities include fuelling, transport and repositioning.

**3.20**
**use case**
collection of *DOT* (3.19) within an *application* (3.21) and *operational design domain (ODD)* (3.14)

EXAMPLE Cycle of operations: dozing, ripping, and travel, are use cases of a dozer within the earth-moving application.

Note 1 to entry: Use cases that consist of, or include, DOT incidental to operation may be assigned the LAA using Table 1.

**3.21**
**application**
EMM application
different industries in which a machine is used and which can have different hazardous situations

Note 1 to entry: Applications can include earth-moving, mining, road construction, waste management, quarrying, etc.

[SOURCE: ISO 19014-1:—[2], 3.9, modified — The admitted term "EMM application" has been added; "from one another" has been removed from the end of the definition; in note 1 to entry, "general construction" has been replaced by "earth-moving, mining".]

**3.22**
**minimum risk condition**
operating state of the machine where risk is at an acceptable level

EXAMPLE A level 4 *feature* (3.17) designed to operate a machine at rated speed on haul roads experiences a system failure and automatically removes the machine from the active haul road before coming to a stop.

Note 1 to entry: The minimum risk condition typically relates to safety of the *operator* (3.5), *co-worker* (3.10) or *bystander* (3.9).

**3.23**
**fallback**
action to achieve the *minimum risk condition* (3.22)

Note 1 to entry: Fallback can include performing, or continuing to perform, the DOT if the hazard has been mitigated.

**3.24**
**AOS operational performance**
performance of the *AOS* (3.13) compared to the performance of manually-operated machines or another AOS

Note 1 to entry: AOS operational performance can indicate efficiency, reliability, and stability of the AOS compared to a manually operated machine. Performance can be evaluated using factors such as operation time and work output during the evaluation period.

In addition to the quantitative measurement method, qualitative measurement methods can be used.

**3.25**
**indeterminate control system**
**ICS**
complex system
non-deterministic system
system with uncertainty
probabilistic system
system that produces uncertain outputs in response to variable inputs

# 4 Taxonomy and LAA

## 4.1 General

The taxonomy of automation and autonomy refers to two primary entities in operating: the operator and the automated operating system (AOS). The levels of automation and autonomy (LAA) are defined by reference to the specific role played by each entity in performing the machine operation and fallback.

This document assumes that the operator is a person who is trained, qualified and authorized. An operator assistance feature can be used to mitigate a hazard or enhance the performance; however, for levels 1 to 3, even when a feature is used to mitigate a hazard, the operator still has the ultimate responsibility for safe operation of the machine.