International Standard

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Autonomous system and fleet management system interoperability

Interopérabilité du système autonome et du système de gestion de la flotte

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 82, *Mining*, SC 8, *Advanced automated mining systems.*

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

A strategic objective for the global mining industry is to develop standards to support holistic, integrated and interoperable mine operating automation that will improve mining operations efficiency. Interoperability enables many benefits; optimal interaction of mine operating equipment and processes, integration of upstream process information (e.g. exploration, resource modelling and planning), minerals extraction and downstream processes (e.g. refining, smelting and transportation) to increase levels of operational efficiency. This document progresses interoperability in the global mining industry.

The purpose of this document is to define a reproducible integration of an autonomous haulage system (AHS) and a fleet management system (FMS) to avoid customized implementations at every site. It allows a supplier with a narrow product coverage but highly valuable core mining competencies to participate and deliver open-autonomy components in the overall autonomy technology stack.

This document defines a software API, an open-autonomy interface, that allows independent vendors to supply an FMS to dispatch an AHS autonomous fleet. The API allows for future innovations and a wide variety of implementations without requiring a modification to the protocol.

This document interface aims to create an API that will deliver:

— system wide source of truth digital map and machine positions on this map

— dispatch functionality of autonomous trucks to support material movement, fuelling, and parking.

— generate autonomous equipment production monitoring.

The scope for viable interoperability between the AHS and FMS is the API and that is the focus of this document.

Autonomous system and fleet management system interoperability

1 Scope

This document defines the interfaces required between the fleet management (FMS) and autonomous haulage (AHS) systems for dispatch of haul trucks and coordination of production information, including communication protocols, message structures, telemetry signals, map sharing and task assignments.

This document applies to surface mining. It specifies requirements and recommendations to achieve the following:

— realtime computer system communication;

— message definition and semantic;

— mine map sharing;

— truck dispatching;

— truck production monitoring.

This document does not address computer system authentication, authorization and cyber security. These methods and technologies are already covered by best practice IT deployments.

The specific requirements for safe operation of machines, including execution of task assignments issued by the FMS to the AHS rely on additional information that is agreed between the FMS and AHS supplier which is outside the scope of this document.

2 Normative references

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

ISO 8601 (all parts), *Date and time — Representations for information interchange*

ISO 11992-2, *Road vehicles — Interchange of digital information on electrical connections between towing and towed vehicles — Part 2: Application layer for brakes and running gear*

3 Terms, definitions and abbreviations

For the purposes of this document, the following terms and definitions 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 Terms and definitions

3.1.1
all-stop function
function that brings all autonomous machines under the operator's supervision to a halted state when initiated

[SOURCE: ISO 17757:2019, 3.1.18, modified — The word "system" was replaced by "function".]

3.1.2
actor
software involved in communication over a connection, either providing a service or using a service

3.1.3
attribute
<JSON object> term attribute referencing to a key as opposed to an "object"

3.1.4
operator
person having control and responsibility for operating a machine or the autonomous haulage system

3.1.5
manual mode
mode of operation in which a machine is controlled by an *operator* (3.1.4) who is responsible for monitoring the surroundings and for safe operation of all machine controls

[SOURCE: ISO 17757:2019, 3.1.13]

3.1.6
pose
machine position and orientation (heading)

Note 1 to entry: The pose needs a standard frame of reference {0,0,0} for each machine so they are properly placed in space for any coordinate systems.

3.1.7
tray
<dumper body>that portion of a dumper which carries material

3.1.8
risk assessment
overall process comprising a risk analysis and a risk evaluation

[SOURCE: ISO 12100:2010, 3.17]

3.2 Abbreviations

AOZ	autonomous operating zone
API	application program interface
AHS	Autonomous Haulage System
FMS	fleet management system
GNSS	global navigation satellite system
GUID	globally unique identifier
IANA	Internet Assigned Numbers Authority

JSON	Java Script Object Notation
LV	light vehicle
UID	unique identification
TLS	transport layer security
SOP	Standard Operating Procedure
SSL	secure socket layer. Synonymous with TLS. TLS is the newer version of SSL
TUM	time usage model
wss://	web socket secure

4 Computer communication

The goals of the protocol design shall be

a) event based (no polling),

b) bi-directional,

c) cloud friendly (leverage web technologies),

d) rapid disconnection detection, and

e) events are sent immediately,

Standard IT infrastructure is not the primary focus of this document. This document does not specify:

— security,

— authentication,

— redundancy,

— scaling,

— encryption, and

— certificates.

These functions should be implemented to support the demand of each specific deployment. See Annex B for more details.

4.1 Session and transport layer

The client system shall use a TCP/IP websocket secure (wss://) to connect to services defined in this document.

Once the connection is established, then the state of each data models shall be shared (not necessarily synchronized) between the client and the server.

Once the data models are shared, then each system shall update the other system through the wss:// connection as events and states change.

4.1.1 WebSocket client and service behaviour

The following should be behaviours of the WebSocket client and server:

— WebSocket clients should implement an automatic re-connection to the WebSocket server if the connection is lost.

— WebSocket servers (listeners) should implement a configurable Ping in accordance to RFC6455, Section 5.5.2.

— WebSocket clients may implement a configurable Ping in accordance to RFC6455, Section 5.5.2.

NOTE Some WebSocket implementations will close the connection if there is no frame transferred for a certain amount of time. RFC 6455, Section 5.5.2 provides a Ping-Pong function to prevent premature closure.

4.2 Presentation layer

The presentation layer is defined by OSI, presentation layer - ISO/IEC 7498-1 (basic model).

4.2.1 Container, serialization, and encoding

The following specifications shall apply to container, serialization, and encoding (see Table 1):

Table 1 — Container, serialization and encoding

Layer	Specifications
Container	JSON ECMA-404
Serialization	English text
Encoding	UTF-8

4.2.2 JSON container

The JSON notation shall be used in English human readable form to represent serialized object.

4.2.3 NULL attribute

If an attribute is required in a message (see 7.5) but is un-instrumented on the machine (i.e., it does not exist physically) from the sender, then the attribute shall be set to ‘null’.

NOTE Null has a different semantic than 0 and different from an empty array. NULL means it is absent. An empty array means that at the moment the list is empty, but the array may grow beyond empty in the future. Semantically, a zero value does not imply unknown, broken or invalid unless otherwise stated in the specification.

4.2.4 Units

The exchanged attributes shall use a common set of units for the different measurements. The following units shall be used for value transmission (see Table 2):

Table 2 — Measurement units

Measurement	Unit
UTC Date time stamp	ISO 8601 (all parts)
Time	seconds
Distance	meter
Speed	km/h
Angle	degree
Temperature	Celsius

Table 2 *(continued)*

Measurement	Unit
Pressure	kPa
Mass	kg
Heading	degree

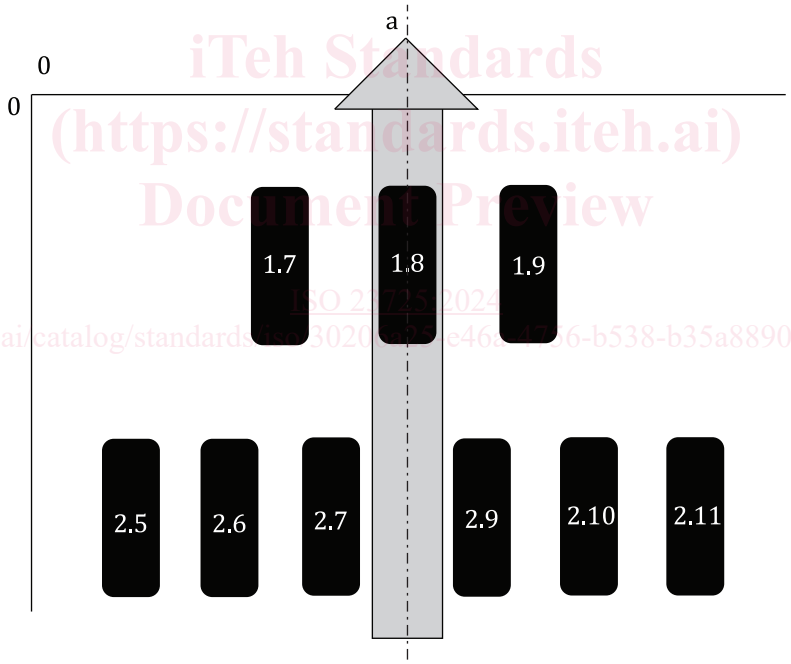
4.2.5 On machine component arrays

ISO 11992-2 shall be used to identify a particular tire/wheel and axle position. For consistency, the same numbering method shall be used to identify a particular machine component when there are multiple component instances on a machine.

Machine components shall be numbered according to their position on the machine. Represented as a 2D coordinate in the form {ROW, COLUMN}. Rows are starting from the front to the back of the machine in accordance to their position.

Row numbering shall start at 1.*x*, and increasing in increments of 1 (i.e. 1.*x*, 2.*x*, etc.). Objects to the left of the middle should count down from .7 and objects to the right of the middle should count up from .9. An odd cardinality of components (a middle component) shall be assigned ROW#.**8** (ROW# corresponding to the specific row number).

The following examples clarify when and how to use ROW#.8 for odd and even number of items; Figure 1 and Figure 2 a) and b) provide examples of component numberings.



[a] Forward driving direction.

Figure 1 — Example of tire number on 9-wheel rig (adapted from ISO 11992-2:2014)

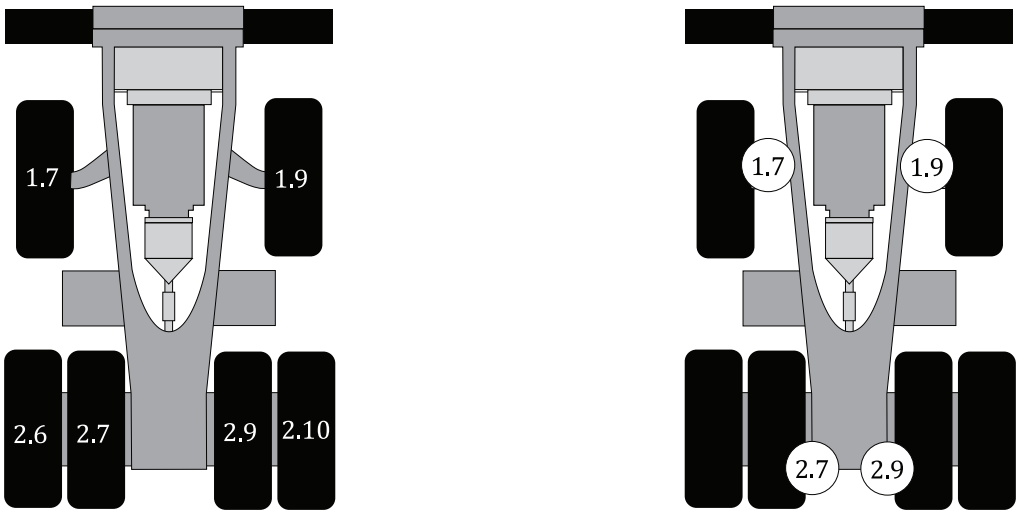


Figure 2 — Example of tire and strut numbering on a rigid dump truck

Figure 2 a) is numbering the tires of a rigid dump truck. The procedure is

— to orient the machine's front pointing upwards.

— All tires of the first row start with a "1.", the one to the left is "1.7" and the one on the right is "1.9". There is no "1.8" because there is no tire in the middle.

— All tires of the second row start with a "2.", the one to the most left is "2.6", then its right neighbour is "2.7". The 2 tires to the right of the middle are "2.9" and "2.10" is the right most.

Figure 2 b) is simpler as we're numbering the truck struts, use the same approach, the machine is oriented forward then follow the algorithm.

5 Messaging

5.1 Overview

The interface shall use asynchronous messaging and be compliant to the rule set in Clause 4, which defines the transport, container, encoding and behaviour.

Annex A contains a set of sequence diagram as examples of how the messages are expected to be used between the systems. Annex A should be consulted to understand how they are intended to be used under typical circumstances.

5.2 Event based messaging

— A message shall be sent when a state or measurement is changed within the monitored system. Continuously changing measurements shall be limited to a maximum message sending frequency.

— The maximum frequency shall be configurable on a per message type basis on the sending application during commissioning.

— Unchanged state messages shall not be sent periodically based on a timer.