FUNCTIONAL AND TECHNICAL PERFORMANCE REQUIREMENTS SURFACE MINE TMM COLLISION PREVENTION SYSTEMS (TMM CPS)

INDUSTRY ALIGNMENT ON TMM REGULATIONS: SPECIAL PROJECT OF THE MINERALS COUNCIL SOUTH AFRICA

REV 1

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Executive Summary

This document is the functional and technical performance requirement for surface mine trackless mobile machinery collision prevention systems (TMM CPS) in the South African mining industry (SAMI). It aims to meet the User Requirement Specification (URS) for surface mine collision prevention systems (CPS).

Clear and unambiguous performance requirements are the cornerstone of successful product development. In the absence of clear requirements, the development process is, more often than not, a costly, iterative, trial-and-error endeavour. Every single stakeholder collaborating to meet the SAMI trackless mobile machinery (TMM) regulatory requirements will benefit greatly from this document, as it defines the requirements that developers need in order to develop a compliant and working CPS. Every requirement includes acceptance criteria that are, in the case of functional performance requirements, measurable or demonstratable.

The valuable contribution that the Minerals Council South Africa is making towards industry readiness for the TMM regulations, by facilitating the development of a single set of requirements on behalf of all stakeholders, cannot be over emphasised. Considering the enormity of the challenge as has been reported in the Collision Management Systems (CMS) Technical Requirements Guideline Review Report and other CPS Technical Reports developed by the Mining Industry Occupational Safety and Health Initiative Transport and Machinery (MOSH T&M) Adoption Team, this specification is the backbone of the entire accelerated development initiative.

Analysing user requirements, identifying functional and technical performance requirements (F&TPR) and synthesising it to represent a fit-for-purpose CPS product is a daunting task. If not for the work done since 2015, by individual mines and mining companies, the Earth Moving Equipment Safety Round Table (EMESRT), the University of Pretoria (UP) and others, the compilation of requirements as documented in this specification would have taken many years to develop. Being true pioneers in a challenging technical field, the SAMI is proving that some of the erstwhile technology development capability that South Africa had, can be re-established. However, this can only be achieved through industry-wide collaboration.

This document is a revised and updated version of the original set of CPS Functional and Technical Performance Requirements released in 2022. Key learnings of the last two to three years have now been incorporated in this document.

The document structure and specification approach are function based and therefore it leaves maximum flexibility for CxD and TMM CPS product developers to develop physical modules and components of their choice.

The conclusions that can be drawn directly and indirectly from the specification are:

- CPS products must have very specific functions as derived from the TMM regulations.
- CPS products are safety systems. This requires CPS products to also conform to a number of technical requirements such as safety integrity, robustness, reliability and others. To meet these requirements will also take development time as it is part of the functional readiness criteria in the early technology readiness levels.

The collaborative nature of the accelerated CPS development initiative requires a general agreement between collaborating parties.

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Definitions and abbreviations

The following definitions and abbreviations will be used to create a common approach for all deliverables.

Table 1: Abbreviations and their definitions appearing in this document

Term/Abbreviation	Definition
3rd Party	An entity appointed to execute work (testing, witnessing of testing and verifying portfolios of evidence) on behalf of SAMI. Note: The purpose of 3rd party execution is to establish independence and to eliminate duplication.
Accelerated Development	Development of CPS products in a coordinated and integrated way that will require less time (for the entire SAMI need), than the previous individual mine and supplier / OEM driven CPS product development approach.
Accuracy	The degree to which the result of a measurement, calculation, or estimate conforms to the correct value, i.e. the preciseness of the measurement.
CMS	Collision Management System: The overall combination of preventative controls, mitigation, recovery and supporting controls, implemented by a mine site to prevent TMM collisions.
CPS	Collision Prevention System: A Product System that comprises the functionality and characteristics that comply with the RSA TMM collision prevention regulations. (TMM Regulations 8.10.1 and 8.10.2 and user requirements.)
CPS Start-up	The operator has completed the pre-inspection checks as per the mine's standard operating procedure and removed the chocks or stop blocks from under the TMM's wheels. The operator has entered the cab and is preparing to start operating. During this state, the CPS is undergoing its start-up procedure, e.g. performing system health checks. The CPS is not ready to start normal operation.
CPS Slow	The state when the CxD limits the TMMs speed. The CxD instructs the TMM to slow by sending SLOW_DOWN or APPLY_PROPULSION_SETPOINTS via the ISO/TS 21815-2:2021 CAN-bus interface.
CPS Stop	The state when the CxD intervenes with the intent of stopping or keeping the TMM stationary to avoid a collision or FTSWHI. The CPS has detected a potential collision with a another TMM and is intervening or has intervened to bring the TMM to a safe stop. Once the TMM has stopped, it remains stationary. This state is reached by the CxD instructing the TMM to stop via the ISO/TS 21815-2:2021 CAN-bus interface.
Crawl speed	The maximum safe braking speed. The speed to which the TMM CPS will reduce (slow down) when the SLOW_DOWN command is received from the CxD.
CxD	Collision Warning and Avoidance System device: Device with sensors providing collision warning and avoidance functions, to detect objects in the vicinity of the machine, assess the collision risk level, effectively warn the operator of the presence of object(s) and/or provide signals to the machine control system, to initiate the appropriate interventional collision avoidance action on the machine, to prevent the collision. Note to entry: Proximity Detection System (PDS) is a colloquial industry term for a physical device, providing a warning or collision avoidance functionality.
CxDC	CxD Controller: A sub-system of the CxD, that is typically the computer that contains the decision-making logic.
CxDI	CxD interface: A integration function between the CxD and the Machine Controller.
CxDLK	CxD Log Keeping: The function that receives, and stores CxD data.
D&T	Detect and Track: A functional group of a CxD enabling detection and tracking of TMMs inside the detection area of a surface TMM.
Detection	Detection is sensing that an object has entered the detection area.
Driver or operator reaction time (also known as perception response time)	The time that elapses from the instant that the driver recognises the existence of a hazard in the road, to the instant that the driver takes appropriate action, for instance, applying the brakes. The response time can be broken down into four separate components: detection, identification, decision and response. When a person responds to something s/he hears, sees, or feels, the total reaction time can be broken down into a sequence of components namely: • Mental processing time (sensation, perception / recognition, situational awareness, response selection and programming). • Movement time, and • Driver response time. Driver reaction time is also affected by several issues such as visibility, operator state of mind (fatigue), and direction or position of perceived danger.

Term/Abbreviation	Definition
EMC	Electromagnetic Compatibility
EMESRT	Earth Moving Equipment Safety Round Table
EMI	Electromagnetic Interference
Employee	Employee means any person who is employed or working at a mine.
EW	Effective Warning: For Surface TMMs: The expected outcome of the operator action is that the potential collision is prevented. Therefore, an effective warning must inform the operators of TMMs what the appropriate action(s) are to prevent the potential collision with TMMs in the vicinity.
F&TPR	Functional and Technical Performance Requirements
FMECA	Failure Mode Effect and Criticality Analysis
FTSWHI	Fail to Safe Without Human Intervention. The functionality that will bring a TMM to a controlled stop when there is a critical CPS failure.
Functional Specification	Specifications that define the function, duty, or role of the product/system. Functional specifications define the task or desired result, by focusing on what is to be achieved, rather than how it is to be done.
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ID	Identifier.
Independent	Separate from the CPS product developer. Note: Independent does not imply an accredited 3rd party, although where required by local or international standards, it includes accredited 3rd parties.
Interface	A boundary across which two independent systems meet and act on, or communicate with each other. Four highly relevant examples: 1. CxD-machine interface – The interface between a Collision Warning and Avoidance System Device (CxD) and the machine. This interface is described in ISO/TS21815-2. 2. The user interface – Also sometimes referred to as the Graphic User Interface (GUI) when an information display is used. This is the interface between the user (TMM operator or pedestrian) and the CxD or pedestrian warning system. 3. V2X interface – the interface between different CxD devices. V2X is a catch-all term for vehicle-to-everything. It may refer to vehicle-to-vehicle (V-V), vehicle-to-pedestrian (V-P), or vehicle-to-infrastructure (V-E). 4. CxD-peripheral interface – This is an interface between the CxD and other peripheral systems that may be present on the TMM. Examples include a fleet management system, machine condition monitoring system, or fatigue management system. Note: An interface implies that two separate parties (independent systems), are interacting with each other, which may present interoperability and/or EMI and EMC challenges.
LDV	Light Duty Vehicle
MBS	Machine Braking System
MC	Machine Controller.
MCI	Machine Control Interface: The interface between the Machine Controller and the CXD interface.
MHS Act	Mine Health and Safety Act No. 29 of 1996 and Regulations.
MHSC	Mine Health and Safety Council.
MI	MOTION_INHIBIT
Minerals Council	Minerals Council South Africa.
MLK	Machine Log Keeping: The function that receives, and stores TMM CPS data.
MOSH	Mining Industry Occupational Safety and Health Initiative.
MRAC	Mining Regulations Advisory Committee.
MS	Machine Sensing: Sensing functionality on a TMM that enable a fully functional CPS.
Off board components	Components not fitted inside or on the TMM
OWS	Operator Warning System: The system that provides the effective warning and other warnings to the operator of a TMM.
PDS	Proximity Detection System – see CxD.
Pedestrian	A person lying, sitting, or walking rather than travelling in a vehicle.
Project	Industry Alignment on TMM Collision Management Systems Project: CAS READINESS PHASE.
Quality Assurance	Verifying a process, product, or service; usually conducted by an experienced person in the specific field.

Term/Abbreviation	Definition
Reliability (sensor)	Sensor reliability refers to the consistency of a measure. Achieving the same result by using the same methods under the same circumstances, is considered a reliable measurement.
Robustness (sensor)	Sensor robustness is the ability of the sensing device (sensor), to remain functional in the presence of normal operating conditions of TMMs on a mine, such as electromagnetic interference, mechanical vibration, dust, adverse weather conditions, etc.
Safe Park	The TMM is safely parked as per the mine's standard operating procedure, e.g. the operator has engaged the park brake, switched the engine off and exited the cab. The operator has placed chocks or stop blocks under the TMM's wheel(s). This state is typically encountered at the start/end of shifts when the operators are prevented from moving. The TMM is not operational.
Safe speed	The speed that will ensure the controlled stopping of a TMM without any immediate negative impact on the operator or machine. Note: This is a conditional variable value, depending on multiple input variables.
SAMI	South African Mining Industry.
Significant risk (of collision)	The reasonable possibility of a TMM collision, given all the controls that a mine has put in place to prevent a TMM collision.
Slow down	ISO/TS 21815-2: 2021 defines slow down as: "The SLOW_DOWN action is sent by the CxD to reduce the speed of the machine in a controlled / conventional manner, as defined by the machine control system. The intent of this command is to slow down the machine when the CxD logic determines that a collision / interaction can be avoided by reducing speed".
Stop	ISO/TS 21815-2: 2021 provides for two definitions, an emergency stop, and a controlled stop, both of which are a 'Stop'. The definitions are: 1. "The EMERGENCY-STOP action is sent by CxD to instruct the machine to implement the emergency stop sequence defined by the machine control system. The intent of this command is to stop the machine motion as rapidly as possible, to reduce the consequence level, if the CxD logic determines that a collision is imminent. The equivalent of an emergency stop is the operator slamming on the brakes in an emergency." 2. "The CONTROLLED-STOP action is sent by CxD to instruct the machine to implement the controlled stop sequence, defined by the machine control system." The intent of this command is to stop the machine motion in a controlled / conventional manner, when the CxD logic determines that a collision / interaction can be avoided by slowing down and stopping. The equivalent of a controlled stop is slowing down and stopping when approaching a red traffic light.
System	A combination of interacting elements organized to achieve one or more stated purposes (ISO/IEC/IEEE 2015).
Technical specification	Specifications that define the technical and physical characteristics and/or measurements of a product, such as physical aspects (e.g. dimensions, colour, and surface finish), design details, material properties, energy requirements, processes, maintenance requirements and operational requirements.
Technician	Competent person with testing experience in the mining / vehicle environment, e.g. testing technician, TMM OEM technician, CxD technician, auto electrician, etc.
This document	FUNCTIONAL AND TECHNICAL PERFORMANCE REQUIREMENTS FOR SURFACE MINE COLLISION TRACKLESS MOBILE MACHIN COLLISION PREVENTION SYSTEMS
TMM	Trackless Mobile Machine as defined in MHSA Regulation 8.10
TMM CPS	The functional group comprising all TMM CPS related functions.
TMM CPS Product	The product that will make a non-intelligent TMM intelligent and CxD ready.
TMM OEM	Original Equipment Manufacturer of TMMs. Original Equipment Manufacturer of a TMM may be the organisation which originally supplied, or the supplier per section 21 of the Mine Health and Safety Act, 1996 (Act No. 29 of 1996).
Tracking	Tracking is the monitoring of the progress of the objects in the detection area over time.
V2X	Vehicle to anything.
Vicinity	The distance or time to the point of a potential collision, such that, if the operators receive an effective warning to prevent a potential collision, and one or both (or all) do not take action, the CPS will still be able to prevent the potential collision.
WP 9	Work Package 9: Testing protocols (including legacy equipment). One of the work packages of the Industry Alignment on TMM Collision Management Systems Project: CAS READINESS PHASE.

1 Purpose and Scope

The purpose of the TMM CPS Functional and Technical Performance Requirements (F&TPR) specification is to define the technical and functional performance requirements for a TMM CPS product that:

- Meets the Mine Health and Safety Act (MHSA) TMM collision prevention regulatory requirements in accordance with Regulation 8.10,
- Meets the needs of the SAMI mine types and mine working environments as defined in the Surface Mine User Requirement Specification (URS),
- Meets the needs of collision prevention for surface mines in South Africa.

The content of this TMM CPS F&TPR specification applies to:

- TMM CPS products to be used in the SAMI for surface mines,
- CPS User Requirements as defined in the URS for Surface Mine CPS.

This document is a deliverable of phase 2 of the INDUSTRY ALIGNMENT ON TMM REGULATIONS PROJECT.

2 Background

The SAMI is the only international jurisdiction (other than proximity detection systems (PDS) regulations in underground coal mines in the USA), that has regulated the installation of TMM safety products that can prevent collisions between TMMs in surface mining operations. Whilst the regulations make provision for managing collision risks with more effective controls that are higher on the hierarchy of risk controls, there is a need to ensure that CPS products are readily available to the SAMI.

Although the TMM regulations have been promulgated in 2015, the two clauses requiring automatic slow-down and stopping of TMMs had been suspended due to the unavailability of CPS products. Since 2015 the SAMI made efforts to develop CPS products that will comply with the TMM regulations. Some obstacles to overcome the challenge only became apparent during the initial years of the development effort.

In 2019 the Mine Health and Safety Council's (MHSC's) Mining Regulation Advisory Committee (MRAC) convened a TMM Task team, consisting of experts, and members of mines, to advise them on the readiness of CPS products, with a view to recommend a date for uplifting the suspended regulations to the board of the MHSC. The task team had several deliberations and concluded that CPS technology was not at a level of maturity to uplift the regulation in the next few years.

The team identified several challenges that still needed to be addressed and resolved. The Minerals Council South Africa took heed of the report issued by the Task Team, and initiated a multi-million-rand project, namely: Industry Alignment On TMM Regulations: Special Project Of The Minerals Council South Africa, to facilitate the integrated development of, not only CPS products, but the required ecosystem that would enable the upliftment of the suspended clauses of the TMM regulations as soon as feasible.

The Technology Readiness Phase of the project consisted of several deliverables to enable the accelerated development of CPS products. The deliverables include, a review report, technology specific reports, and a CPS URS. All this work contributed to the development of a F&TPR specification.

This surface mine F&TPR specification forms the basis of the accelerated CPS development initiative as it provides the requirements for CPS product development that CPS developers must conform to.

On 21 December 2022, the Minister of Mineral Resources and Energy uplifted the suspended regulations with immediate effect. In the period since the Technology Readiness Phase to date, CPS products have undergone widespread testing by the UP. Additionally, extensive engagement with CPS stakeholders have been completed. The test and stakeholder engagements indicated the need to update the original F&TPRs, including the following:

- Separating the surface and underground CxD and TMM CPS requirements into distinct documents.
- Improving the consistency of the requirements and cross-referencing the FTPR to the URS.
- Updating the FTPR with the lessons learnt through testing and stakeholder engagement.

3 Requirements Structure

The approved structure for the development of CPS product requirements is shown in Figure 1.

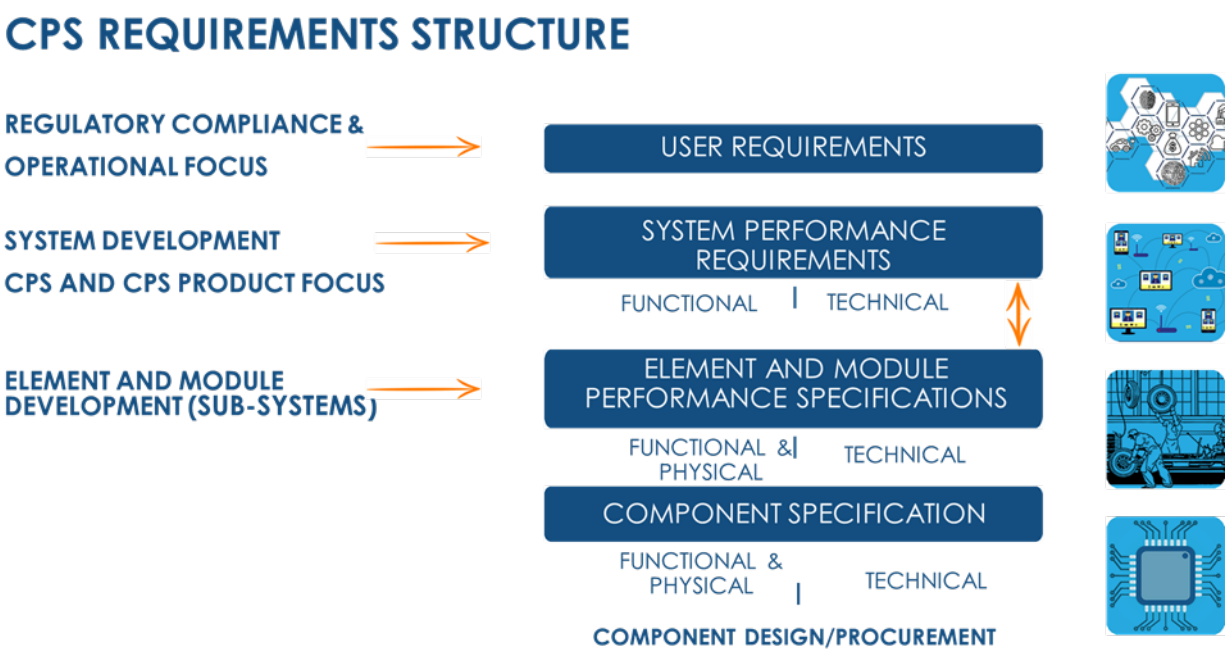

Figure 1: Requirements structure for CPS product development

4 Context

It is important to view this document in the context of the overall suite of MOSH CPS guideline documents. The document relationship with other documents provides that context.

USER REQUIREMENTS SPECIFICATION FOR SURFACE MINE COLLISION PREVENTION SYSTEMs is the higher-level document as defined in the above structure. It provides key regulatory requirements, both direct and derived for Surface CPS product suppliers as well as the surface mines using diesel powered TMMs. It is essential to read and understand the URS before studying this document. A key aspect addressed in the URS is **verification of requirements and independent verification** of requirements.

General Requirement SM.G04: Demonstrate conformance, states “CPS conformance to user functional and technical requirements must be demonstrated by formal supplier verification as well

as independent **verification,** as defined in the CPS Requirements Verification Regime, as well as the CPS Independent Verification Test Specification, as documented in the MOSH CPS guideline."

The overall CPS Requirements Verification Regime is documented in the document titled CPS Requirements Verification Regime. All requirements as stated in this document must be verified by the TMM CPS supplier, recorded and be referenced in the specific product Section 21 Technical File.

As per the Requirements Verification Regime all the requirements as defined herein are independently verified at TRL 4 and TRL 7 stage gates.

5 Development Approach

The TMM CPS F&TPR has been developed from the following inputs[1]:

- CPS User Requirements.
- Zone Functionality and Sensor Fusion Report.
- Electromagnetic interference (EMI) and electromagnetic compatibility (EMC) Report.
- CPS Interoperability Report.
- Readiness Criteria
- International Standards.
- National Standards.

The relationship between the mentioned document is shown in Figure 2 below:

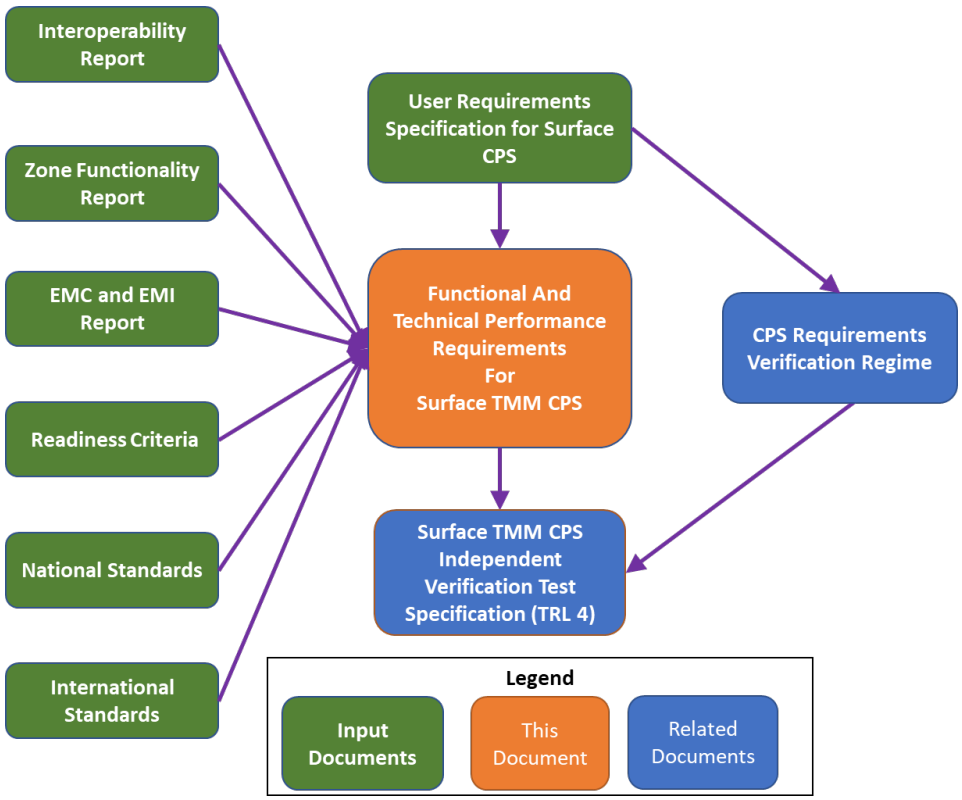

Figure 2: Relationship between various MOSH CPS guideline documents

[1] Available at https://www.mosh.co.za/transport-and-machinery/documents

6 CPS Functional Breakdown

The non-homogenous population of TMMs used in the SAMI necessitates a single set of CPS functions. For a fully functional CPS, all the performance requirements must be met. The extent to which a specific CPS product need to be developed will be determined by the extent to which a specific TMM (type, brand and model) is already intelligent.

The CPS Functional breakdown is shown in Figure 2.

The CPS comprises of two functional elements namely:

1. TMM CPS Functions (TMM CPS).
2. CxD Functions (CxD).

Each of the functional elements have a number of subgroups of functions. These groups are logically structured and do not imply that a CPS element must have a similar product breakdown structure.

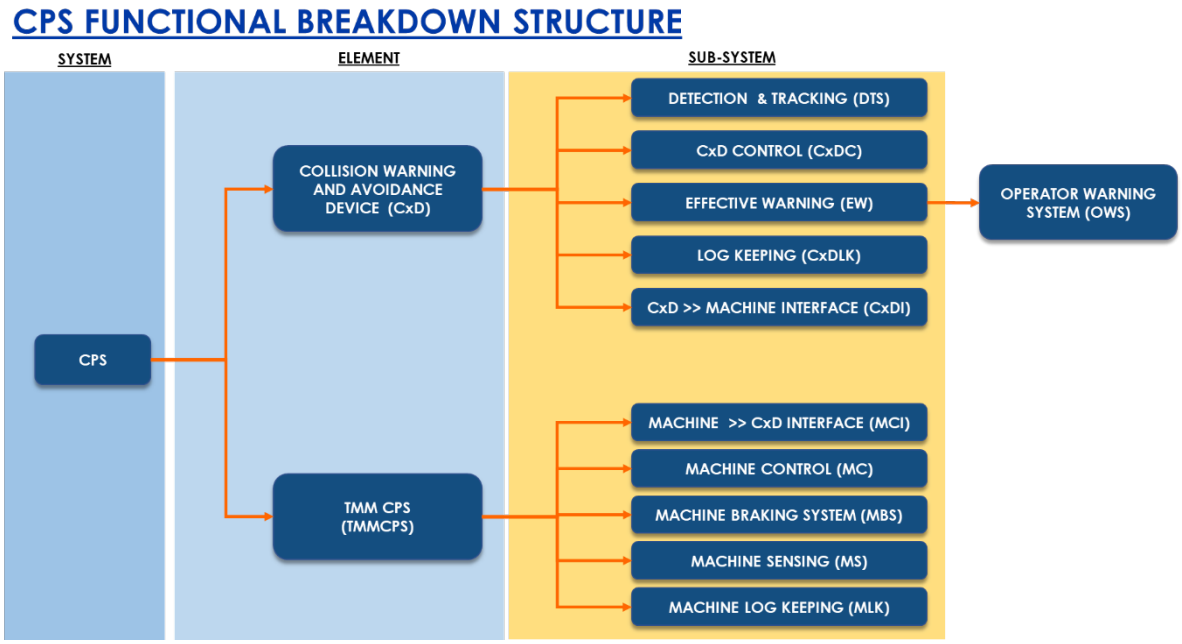

Figure 3: CPS functional breakdown structure.

The TMM CPS Functions are structured in five sub-groups, namely:

1. Machine CxD Interface functions (MCI).
2. Machine Controller functions (MC).
3. Machine Braking System functions (MBS).
4. Machine Sensing functions (MS).
5. Machine Log Keeping functions (MLK).

The CxD Functions are broken down into five sub-groups, namely:

1. Detection and Tracking functions (D&T).
2. CxD Control functions (CxD).
3. Effective Warning functions (EWS).
4. CxD Log Keeping functions (CxDLK).
5. CxD Machine Interface functions (CxDI).

7 F&TP Requirements

The functional and technical performance requirements of the Surface Mine TMM CPS are structured as per Figure 3 in the following functional groups:

- Machine CxD Interface functions (MCI).
- Machine Controller functions (MC).
- Machine Braking System functions (MBS).
- Machine Sensing functions (MS).
- Machine Log Keeping functions (MLK).
- General technical requirements

7.1 Machine>>CxD Interface functions (MCI)

Table 2 lists the Machine>>CxD interface functions of a surface mine TMM CPS. Functions are uniquely identified with a number and are cross-referenced to the URS requirement that informed them.

Table 2: Surface mine TMM CPS Machine>>CxD interface functions

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MCI.01	Physical Connection	The connection between the CxDI and the MCI uses the standardised connector.	Deutsch DT-series 12 pin, part DT06-12SC-EP06 (Key C) is used for connection between CxD and TMM Deutsch DT-series 12 pin, part DT06-12SC-EP06 (Key C)	SM.G08.1 (and sub-requirements)
SM.MCI.02	Perform Negotiation	The negotiation between the CxDI and the MCI is performed as per ISO21815-2:2021.	For negotiation without authentication: Perform negotiation as described in ISO 21815-2:2021 Negotiation with authentication (optional): Perform negotiation as described in ISO 21815-2:2021 Mechanism to share credentials with interfacing party(ies)	SM.G08.1 (and sub-requirements)
SM.MCI.03	Keep connection alive	The connection between the CxDI and the MCI should not disconnect and renegotiate under normal operating conditions.	Reply to the PROTOCOL_NOP message to indicate system health Maintain the connection Reply to the CxD>>MachineCommand message to indicate execution of instructions.	SM.G08.1 (and sub-requirements)
SM.MCI.04	Detect Disconnection	Disconnection between the CxDI and MCI should be detected and actioned.	The MCI should detect a broken connection Detection should occur within 500ms of disconnection MCI disconnection should trigger the TMM to FTSWHI	SM.G08.1 (and sub-requirements) SM.G10 (and sub-requirements)
SM.MCI.05	Discover Capabilities	The MCI should allow discovery of TMM capabilities.	The MCI should allow machine capabilities to be discovered by using one or both of the following methods: - Replying to individual CxD>>MachineCommand messages - Replying to reads of the PROPULSION_MCAPS register.	SM.G08.1 (and sub-requirements)
SM.MCI.06.1	Read Protocol Registers	The MCI should allow the CxDI to read TMM identification information from the TMM registers.	The MCI should populate and allow reading of the following protocol registers: - MACHINE_ID_0 to MACHINE_ID_4 - MACHINE_SOFTWARE_REVISION	SM.G08.1 (and sub-requirements) SM.G11.1
SM.MCI.06.2	Write Protocol Registers	The MCI write CxD information sent into the appropriate TMM registers.	The MCI should accept write instructions to the following protocol registers: - CxD_SOFTWARE_REVISION - CxD_HARDWARE_REVISION - CxD_HARDWARE_ID	SM.G08.1 (and sub-requirements) SM.G11.1

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MCI.06.3	Read Propulsion Registers	If propulsion registers are implemented, the MCI must allow the CxDI to read control parameters from the TMM propulsion registers.	The MCI should allow the CxD to read propulsion information from the propulsion registers.	SM.G08.1 (and sub-requirements) SM.G11.1
SM.MCI.06.4	Reset Protocol and Propulsion Registers	If resetting of registers is implemented, the MCI must allow the CxD to reset the registers to default values.	The MCI should allow resetting of the protocol registers to default values The MCI should allow resetting of the propulsion registers to default values	SM.G08.1 (and sub-requirements) SM.G11.1
SM.MCI.07	Use CxD commands	The MCI must reply correctly to CxD>>MachineCommand messages.	Must conform to either or both SM.MCI.07.1 and SM.MCI.07.2 Must conform to SM.MCI.07.3, SM.MCI.07.4 and SM.MCI.07.5	SM.G08.1 (and sub-requirements)
SM.MCI.07.1	Use open loop commands	The MCI replies to commands used to control TMM operation in an open loop manner.	The MCI must implement the following commands to control the TMM and achieve appropriate responses: - NORMAL_OPERATION to allow the TMM to operate without restrictions on operator controls - EMERGENCY_STOP to apply all available measures to stop the TMM as quickly as possible. Reserved for use when the collision cannot be avoided and the consequences of the collision must be mitigated by reducing TMM speed - CONTROLLED_STOP to slow down and stop the TMM in a controlled manner - SLOW_DOWN to reduce the TMM's speed to a predefined crawl speed and not exceeding the crawl speed while active	SM.G08.1 (and sub-requirements) SM.R14.5 SM.Sxx (all interaction scenarios)
SM.MCI.07.2	Use closed loop set points	The CxDI uses set point functionality to control the TMM in a closed loop manner.	The MCI must correctly implement one or more of the following methods to correctly load and apply set points: - UPDATE_AND_APPLY to apply only a single set point at a time - MATCH_TAG to apply multiple retagged set points - APPLY_FROM_LIST to apply all set points in a list	SM.G08.1 (and sub-requirements) SM.R14.5 SM.Sxx (all interaction scenarios)
SM.MCI.07.3	Use STAND_DOWN for FTSWHI	The MCI must accept the STAND_DOWN command if a critical CxD failure is detected.	STAND_DOWN to slow down and stop the TMM in a controlled manner when the CxD experiences a fault (fail to safe response)	SM.G08.1 (and sub-requirements) SM.R14.7

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MCI.07.4	Use BYPASS_PROPULSION for override	The MCI must accept BYPASS_PROPULSION when an override is triggered on the CxD.	BYPASS_PROPULSION to reduce the TMM's speed to a predefined crawl speed due to an override on the CxD (limp mode)	SM.G08.1 (and sub-requirements) SM.R14.8 SM.R14.9
SM.MCI.07.5	Inhibit motion	The MCI must implement INHIBIT_COMMAND.	INHIBIT_COMMAND must be used to ensure a stationary TMM remains stationary (e.g. during CPS start-up)	SM.G08.1 (and sub-requirements) SM.R14.2
SM.MCI.08	Message Timing	The MCI must respond to all CxD>>MachineStatus and Cxd>>MachineCommand messages in a timely manner.	The time between a CxD>>MachineStatus/Command message and a Machine>>CxDreply message should not be longer than 50ms to ensure all instructions are executed promptly	SM.G08.1 (and sub-requirements)
SM.MCI.09	Send Data message	MCI should send a correctly populated Machine>>CxDdata message containing measurements of the current machine state.	The MCI should correctly populate all fields contained in the Machine>>CxDdata Parameter Group Number (PGN). If some parameters are not available they should be correctly indicated as not available as per ISO21815-2:2021. The PGN should be sent at the ISO21815-2:2021 specified 100ms rate.	SM.G08.1 (and sub-requirements)
SM.MCI.10	Allow time exchange in both directions	MCI can exchange time/date information.	The MCI should use the SAE J1939 Request PGN to request the SAE J1939 Date/Time PGN from the CxD The MCI should respond to any SAE J1939 Request for time addressed to it with the SAE J1939 Date/Time PGN.	SM.G08.1 (and sub-requirements) SM.G11.1.1.1
SM.MCI.11	Communicate TMM CPS override to CxD	The TMM is expected to have an override functionality for emergency and maintenance situations. TMM CPS to share override status with CxD via MCI.	MCI communicates the status and fault state of the TMM side override to the CxD. Note: Override status in Machine>>CxDdata message is used to indicate the TMM's override functionality status MCI must not use override status in Machine>>CxDdata message to indicate BYPASS_PROPULSION command sent from CxD.	SM.G08.1 (and sub-requirements) SM.G11.1.1.1

7.2 Machine Controller Functions (MC)

Table 3 lists the controller functions of a surface mine TMM CPS. Functions are uniquely identified with a number and are cross-referenced to the URS requirement that informed them.

Table 3: Surface mine TMM CPS Controller functions

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MC.1	Execute CxD commands	The TMM machine control function must be such that it can execute the CxDC commands.	Intervention strategies as informed by ISO 21815 – 2:2021	SM.G08.1
SM.MC.2	Retain Control	TMM must not veer to the left or right from direction of travel when executing CxDC commands.	0.5x Width of TMM from centreline of travel No wheel lock (sliding)	SM.G07.1 SM.G07.1.1
SM.MC.3	Prevent movement	Prevent TMM from swivelling, articulation, boom or scoop activation after CPS Stop (while CPS Stop is active).	Cannot engage any gear while in CPS Stop No movement of articulation, boom, attachment etc. when speed = 0 km/h after a CPS stop	SM.R11
SM.MC.4	Auto slow and stop	Stop TMM without operator action.	MC must be able to slow down and stop the TMM with either open loop or closed loop (or both) interventions. Either (or both) SM.MC.4.1 or SM.MC.4.2 must be implemented	SM.G01 SM.R14.5
SM.MC.4.1	Open loop slow and stop	Slow and Stop TMM (CPS Stop) with open loop CxD intervention.	TMM must automatically slow down and stop with the following Machine>>CxDcommands: - EMERGENCY_STOP - CONTROLLED_STOP - SLOW_DOWN	SM.G01 SM.R14.5

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MC.4.1.1	Controlled stop max stopping distance	Stop TMM within reasonable stopping distance.	TMM will come to a complete stop when instructed with CONTROLLED_STOP command For CONTROLLED_STOP and APPLY_PROPULSION_SETPOINTS with set point appropriate to stop the TMM, the maximum stopping distance is determined by the following equation: $$S = \frac{vt}{3.6} + \frac{v^2}{13 \times 2a}$$ Where S *is stopping distance, in metres* (m) v *is the test speed, in kilometres per hour* (km/h) $t = 0.35\ s$ And $a = 1.0\, m/s^2$ for TMMs with top speed > 20 km/h $a = 0.5\, m/s^2$ for all other TMMs Test conditions described in ISO 3450:2011 Par 5.3 (with gradient ≤ 1%)	SM.G01 SM.R14.5
SM.MC.4.1.2	Emergency stop max stopping distance	Shorter stopping distance than CONTROLLED_STOP stopping distance.	TMM will come to a complete stop when instructed with CONTROLLED_STOP command For EMERGENCY_STOP, the maximum stopping distance is determined by the following equation: $$S = \frac{vt}{3.6} + \frac{v^2}{13 \times 2a}$$ Where S *is stopping distance, in metres* (m) v *is the test speed, in kilometres per hour* (km/h) $t = 0.35\ s$ And $a = 1.9\, m/s^2$ for TMMs with top speed > 20 km/h $a = 1.0\, m/s^2$ for all other TMMs Test conditions described in ISO 3450:2011 Par 5.3 (with gradient ≤ 1%)	SM.G01 SM.R14.5

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MC.4.1.3	SLOW_DOWN	TMM to slow down (CPS Slow) to crawl speed (maximum safe braking speed) when SLOW_DOWN command is received.	TMM speed limited to < 10km/h in forward and reverse Deceleration 1.0m/s^2 Test conditions described in ISO 3450:2011 Par 5.3 (with gradient ≤ 1%) Operator retains use of the service braking system during SLOW_DOWN	SM.G01 SM.R14.5 SM.R14.9
SM.MC.4.2	Closed loop slow and stop	Slow and Stop TMM with closed loop CxD intervention.	TMM must automatically slow down and stop with the following Machine>>CxDcommands: - APPLY_PROPULSION_SETPOINT MAX_SPEED Operator retains use of the service braking system during APPLY_PROPULSION_SETPOINT MAX SPEED	SM.G01 SM.R14.5
SM.MC.4.2.1	Closed loop stop	Stop TMM (CPS Stop) with closed loop CxD intervention.	TMM will come to a complete stop when instructed with APPLY_PROPULSION_SETPOINT (ramp rate of 2.8m/s/s) within the stopping distance described in ISO 3450:2011 Table 3 Test conditions described in ISO 3450:2011 Par 5.3 (with gradient ≤ 1%) TMM tested without load	SM.G01 SM.R14.5
SM.MC.4.2.2	Closed loop slow down	TMM to slow down (CPS Slow) to MAX_SPEED setpoint.	TMM will slow to MAX_SPEED setpoint when instructed Ramp rate of 1.4m/s/s Steady-state speed does not exceed MAX_SPEED setpoint Test conditions described in ISO 3450:2011 Par 5.3 (with gradient ≤ 1%) TMM tested without load	SM.G01 SM.R14.5 SM.R14.9
SM.MC.5	STAND_DOWN	Stop the TMM when STAND_DOWN command is received.	TMM to come to a gradual stop when STAND_DOWN command is received. TMM held stationary once stopped	SM.G110.2.1 SM.G10.2.2 SM.R14.7
SM.MC.6	BYPASS_PROPULSION	MC will limit TMM speed to crawl speed when BYPASS_PROPULSION command is received.	Maximum speed limited to <10km/h	SM.R14.8
SM.MC.7	MOTION_INHIBIT	TMM will remain stationary	No significant movement of TMM that may lead to a collision between TMMs resulting in injury	SM.R14.2 SM.R14.5
SM.MC.8	NORMAL_OPERATION	TMM CPS to allow normal operation when no intervention is received.	TMM allowed to operate normally	SM.G07.3 SM.R14.3

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MC.9	Emergency Override	Machine control to provide an Emergency Override that can be configured to the mine's requirements. Emergency Override to be prevented from accidental activation. Emergency Override to be prevented from abuse. Emergency Override use to be monitored. Emergency Override to be activated for a limited time at a crawl speed (configurable to mine's specifications).	Measures implemented to prevent accidental activation of Emergency Override Emergency Override duration is limited to <5 min Emergency Override duration is configurable Emergency Override must limit the TMM speed Speed limit to be configurable < 10km/h Return to NORMAL_OPERATION as required by ISO 21815-1:2022	SM.G07.4.2.6 SM.G10.3 SM.R14.6
SM.MC.10	Maintenance Override	Machine control to provide a Maintenance Override that can be configured to the mine's requirements. Authorized Override must require credentials from duly authorized person. Authorized Override to be prevented from abuse. Authorized Override use to be monitored.	Credentials required to limit Maintenance Override activation to duly authorized personnel only Maintenance Override must limit the TMM speed to < 10km/h Return to NORMAL_OPERATION as required by ISO 21815-1:2022	SM.10.3 SM.G12.2 (and sub-requirements) SM.R14.8
SM.MC.11	Auto slow down and stop safely	Auto slow down and stop without negatively affecting operator health and safety	Prevent excessive jerk by using proportional braking during: - CONTROLLED_STOP - SLOW_DOWN - APPLY_PROPULSION_SETPOINT MAX_SPEED - STAND_DOWN	SM.G07.1 SM.G10.2.2.2 SM.G10.2.2.2.2
SM.MC.12	Retain operator control	Machine control function must allow operator action during automatic slow down and stop.	During CxD initiated automatic slow down and stop, operator must be able to maintain directional control of the TMM. No swerving under braking No rollover No sliding No spinning (excessive yaw)	SM.G07.1.1
SM.MC.13	Fail to safe	If there is a critical TMM CPS fault, TMM to come to a gradual stop and be held stationary until the fault is cleared.	TMM to come to a gradual stop when critical fault detected TMM held stationary once stopped Critical faults to be based on OEM Failure Mode, Effects and Criticality Analysis (FMECA)	SM.G10.1 SM.G10.2 (and sub-requirements)
SM.MC.14	Unexpected CxD behaviour	TMM to fail to safe when CxD exhibits unexpected behaviour (e.g. incorrect messages, unsupported commands, communication time out).	TMM has fail to safe response	SM.G10.1 SM.G10.2 (and sub-requirements)

7.3 Machine Braking System Functions (MBS)

Table 4 lists the Machine Braking System functions of a surface mine TMM CPS. Functions are uniquely identified with a number and are cross-referenced to the URS requirement that informed them.

Table 4: Surface mine TMM CPS Machine Braking System functions

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MBS.1	Provide ability to slow down and stop	The TMM must have the physical elements and components to slow down and stop the TMM without operator action.	Application of CxD>>MachineCommands must not lead to locked (skidding) wheels under ISO 3450:2011 Par 5.3 test conditions (gradient ≤ 1%) Brake disc wear must not exceed OEM brake wear limits per hours of operation (MTBF must remain as per original design intent)	SM.G07.1.1
SM.MBS.2	Use service braking system	The TMM must use the service braking system to slow and stop when instructed by the CxD under normal circumstances.	Service braking system as defined in ISO 3450:2011 used for all CxD>>MachineCommand commands Note: When EMERGENCY_STOP command is received, this function is not required (i.e. TMM may use additional braking systems when EMERGENCY_STOP command is received)	SM.G07.1.2
SM.MBS.3	Fail to safe braking	The TMM must have fail to safe brakes	Critical failure of MBS to result in fail-to-safe braking Critical faults to be based on OEM Failure Mode, Effects and Criticality Analysis (FMECA)	SM.G10.1 SM.G10.2 (and sub-requirements)

7.4 Machine Sensing Functions (MS)

Table 5 lists the Machine Sensing functions of a surface mine TMM CPS. Functions are uniquely identified with a number and are cross-referenced to the URS requirement that informed them.

Table 5: Surface mine TMM CPS Machine Sensing functions

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MS.1	Sense parameters	The TMM must have the physical elements and components to sense the states required by ISO/TS 21815-2:2021.	The following states must be provided in the ISO/TS 21815-2:2021 Machine>>CxDdata message: - TMM speed - TMM pitch angle - TMM Gear - TMM Direction - TMM Override Status - TMM Motion Inhibit Status - TMM Subsystem Fault If design payload is > 40% of GVM: - TMM Payload status	SM.G07.4.2 (and sub-requirements) SM.G08 (and sub-requirements)
SM.MS.1.1	Provide accurate speed	TMM must measure and provide accurate speed.	±3km/h or 5% accuracy, whichever is greater Time delay of < 1s	SM.G07.4.2 (and sub-requirements) SM.G08 (and sub-requirements)
SM.MS.1.2	Provide accurate pitch angle	TMM must measure and provide accurate pitch angle.	±5° accuracy Time delay of < 5s	SM.G07.4.2 (and sub-requirements) SM.G08 (and sub-requirements)
SM.MS.1.3	Provide correct gear selection	TMM must measure and provide correct gear selection.	Correct gear	SM.G07.4.2 (and sub-requirements) SM.G08 (and sub-requirements)
SM.MS.1.4	Provide correct direction selection	TMM must measure and provide correct direction selection.	Correct direction	SM.G07.4.2 (and sub-requirements) SM.G08 (and sub-requirements)

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MS.1.5	Provide correct Override status	TMM must measure and provide correct override status.	Correct override status	SM.G07.4.2 (and sub-requirements) SM.G08 (and sub-requirements)
SM.MS.1.6	Provide correct Motion Inhibit status	TMM must measure and provide correct motion inhibit status.	Correct Motion Inhibit Status	SM.G07.4.2 (and sub-requirements) SM.G08 (and sub-requirements)
SM.MS.1.7	MS faults communicated	MS faults communicated as required by ISO/TS 21815-2:2021.	ISO/TS 21815-2:2021 MCI Subsystem Header correctly indicates presence of at least the following faults: - Subsystem fault (SF) - Override fault (OF) - Motion inhibit (MI) - Gear - Direction If design payload is > 40% of GVM - Payload fault (PF)	SM.G07.4.2 (and sub-requirements) SM.G08 (and sub-requirements)
SM.MS.2	Fail to safe sensing	MS functions not available to be detected and communicated as per ISO/TS 21815-2:2021	The TMM must fail to safe if the ISO/TS 21815-2:2021 Machine>>CxDdata states defined in SM.MS.1 are not available	SM.G07.4.2 (and sub-requirements) SM.G08 (and sub-requirements) SM.G10.1 (and sub-requirements)

7.5 Machine Log Keeping Functions (MLK)

Table 6 lists the Machine Log Keeping functions of a surface mine TMM CPS. Functions are uniquely identified with a number and are cross-referenced to the URS requirement that informed them.

Table 6: Surface mine TMM CPS Machine Log Keeping functions

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MLK.01	Synchronise	It must be possible to synchronize TMM CPS and CxD logs based on time.	Synchronisation can be done in post-processing (real-time synch not required) TMM time should be recorded at least once every hour of operation	SM.G11.1 SM.G11.1.1.1 SM.G11.1.2
SM.MLK.02	Record all CxDI and MCI data	Record all data shared between CxDI and MCI via the ISO 21815-2:2021 interface.	Record all messages shared via the CxDI and MCI: - CxD>>MachineStatus - CxD>>MachineCommand - Machine>>CxDReply - Machine>>CxDData - Time/Date requests and responses Data should at least be stored on change events MessageID changes are not considered to be on-change events	SM.G11.1.1.2 SM.G11.1.1.3
SM.MLK.03	Record information	Record information describing the operator and CPS (including TMM CPS, CxD and any relevant CPS peripherals)	The following information must be recorded at all times - CxD information (obtained in MCI Protocol Registers) - TMM ID - TMM firmware information	SM.G11.1 SM.G11.1.2
SM.MLK.04	Record all relevant data during an intervention	During interventions, all information needed to recreate interaction scenarios to be stored at a minimum resolution of 10Hz.	Information to be stored must at least include: - TMM Time - TMM speed - TMM pitch angle - TMM override status - Any TMM CPS faults if present If TMM design payload is > 40% of TMM GVM - Payload status Minimum resolution of 10Hz required during interventions	SM.G11.1.1 (and sub-requirements)
SM.MLK.05.1	Record maintenance override	Maintenance override data must be stored.	Maintenance override status Authorized person ID (e.g. employee number) that activates the Maintenance Override	SM.G11.1 SM.G11.1.1.4

Func. Req. No.	Function Name	Function Description	Performance Criteria	URS No.
SM.MLK.05.2	Record emergency override	Emergency override data must be stored.	Emergency override status as per ISO/TS 21815-2:2021 must be recorded	SM.G11.1 SM.G11.1.1.4
SM.MLK.06	Record any TMM CPS faults	Record TMM CPS system health information.	The presence of any TMM CPS faults must be recorded - Fault event - Fault time - Any other information needed to identify the fault, fault find	SM.G11.1.5
SM.MLK.07.1	On Machine Data storage capacity	Data must be stored for at least 7 days on the TMM.	Reasonable provision made to store up to and including 7 days' worth of data on the MLK? If storage capacity is full before 7 days has passed, fail-to-safe response must be triggered and storage full fault indicated	SM.G11.1.4
SM.MLK.08	Data Transfer	Provide for periodic data transfer to mine data infrastructure.	Make provision for a data transfer mechanism to access machine logs periodically, as needed according to the **mine's specification**. The data transfer mechanism may be wireless or require a physical connection or make use of removable storage. Reasonable considerations must be taken to grant authorized persons access to the logs after an incident has occurred.	SM.G11.1.1.4 SM.G11.1.4
SM.MLK.09	Data Security	Provide data security for stored and transfer of data.	Reasonable steps taken to ensure that data containing sensitive information is protected	SM.G11.1
SM.MLK.10	FTS log keeping	CPS must fail to safe when log keeping system does not work.	Fail to safe response is automatically triggered if MLK functionality is compromised (e.g. power failure, storage media unplugged, storage full) MLK error handling mechanisms (e.g. read/write errors) used to activate fail to safe response	SM.G11.1.3
SM.MLK.11	Data deletion	MLK must prevent data from being deleted without authorization.	MLK to provide mechanism to prevent unauthorized data deletion MLK to record ID of authorized person deleting data Reasonably practicable measures must be taken	SM.G11.1
SM.MLK.12	Data alteration	MLK must prevent data from being altered.	MLK to provide mechanism to prevent alteration of stored data. Reasonably practicable measures must be taken	SM.G11.1

8 TMM CPS General Technical Requirements

Table 7 lists the general technical requirements of a surface mine TMM CPS. Functions are uniquely identified with a number and are cross-referenced to the URS requirement that informed them.

Table 7: Surface mine TMM CPS General Technical requirements

Func. Req. No	Function Name	Function Description	Performance criteria	URS No.
SM.T01	Risk informed	The TMM CPS and all its individual modules must be informed by formal design risk assessment.	Functional safety Mineral Composition Health Safety Environment Operator	SM.G02 SM.G03 SM.G07.4.3 SM.G07.5.2.3 SM.G07.5.2.4 SM.G07.5.2.5 SM.G10.2.2.1 SM.G10.2.2.2 SM.G.14.1 (and sub-requirements)
SM.T02	Be EMC	The CPS must be electromagnetically compatible with other electronic systems on the mine (including detonation systems and aftermarket products installed on the TMM). The complete integrated CPS, comprising the TMM CPS, CxD, other peripheral CPS components, and other aftermarket installed items. It must not have any negative health impact on operators or pedestrians and no negative functional impact on any other sensing device used on the TMM.	Must consider other systems on the mine that may affect the CPS performance Must consider the effect of CPS on performance of other systems due to possible EMI Conform to the requirements of: • CISPR 12 • CISPR 25 • IEC 61000-4-2 • IEC 61000-4-3 • IEC 61000-4-4 • IEC 61000-4-5 • IEC 61000-4-6 • IEC 61000-4-8 • IEC 61000-4-11 Comply with Electronic Communications Act 36 of 2005 ICNIRP Guidelines for limiting exposure to electromagnetic fields	SM.G09.1 (and sub-requirements)
SM.T03	Robustness	TMM CPS must remain functional in the harsh mining environment.	See lower level functions	SM.G07.4.3 (and sub-requirements)

Func. Req. No	Function Name	Function Description	Performance criteria	URS No.
SM.T03.1	Prevent dust and water ingress	TMM CPS and related sub-systems must prevent ingress of dust and water.	IP56 for internal components (e.g. inside the cab) IP66 rating for external components on the TMM (or off-board)	SM.G13.1.2 SM.G13.1.5 SM.G13.1.6
SM.T03.2	Survive exposure to shock	TMM CPS components must be able to withstand typical vibration, shocks, etc. as normally experienced by TMMs.	Mil-STD-810G shock (or similar)	SM.G13.1.4
SM.T03.3	Survive exposure to vibration	Must be able to withstand exposure to vibration.	Mil-STD-810G vibration (or similar)	SM.G13.1.4
SM.T03.4	Operate at high and low temperatures	TMM CPS components able to withstand elevated internal temperatures and external temperatures (high and low) as typically encountered on the mine	Mil-STD-810G temperatures (or similar)	SM.G13.1.5
SM.T05.1	Out of cab components	Failure of off-board components/units must result in a FTSWHI response	Formal FMECA informed Consider mine operations in terms of Installation, Maintenance and Repair (IMR) and reliability	SM.G10 (and sub-requirements)
SM.T05.2	Off board components	Failure of off-board components/units must result in a FTSWHI response	Formal FMECA informed Failure of off-board components (e.g. sensors) must result in FTSWHI	SM.G10 (and sub-requirements)
SM.T06	Be self-diagnostic	All TMM CPS functional elements to be self-diagnostic and continuously monitor function availability.	Be informed by formal FMECA Critical failures to be detected within 500ms of failure Critical faults to be based on OEM Failure Mode, Effects and Criticality Analysis (FMECA)	SM.G02 SM.G03 SM.G10 (and sub-requirements)
SM.T07	Data Logging function)	The TMM CPS must have its own separate data logging capabilities.	See MLK functional requirements	SM.G11.1 (and sub-requirements)
SM.T08.1	Installation (Buildability)	All TMM CPS physical components and elements to be designed for effective installation.	Retrofittable to existing TMMs with minimal modification of the TMM. See lower level requirements	SM.G02 SM.G12.1 SM.G12.4 SM.G12.5
SM.T08.2	Mounting	Mountings not to deteriorate TMM integrity.	Positioned as per TMM OEM specification, drawings and procedures Provision to be made for operational hazards - falling material, TMM articulation Not affect structural safety i.e. mountings, drilling and welding. Not to cause operator injury - bumping, nipping, cutting. To be quickly removable once fitted. Not require special tools to remove after fitting.	SM.G02 SM.G12.1 SM.G12.4 SM.G12.5

Func. Req. No	Function Name	Function Description	Performance criteria	URS No.
SM.T08.3	Cable routing	All cable routing to support TMM maintainability.	Positioned as per TMM CPS specification, drawings and instructions. Be protected from normal operating damage Ease of securing and removal of all modules and components Positive locking of cable connectors. No negatively impact on maintainability of other in-cab systems	SM.G02 SM.G12.1 SM.G12.4 SM.G12.5
SM.T08.4	Availability	All TMM CPS modules must be designed for availability.	98% TMM CPS availability 95% machine availability maintained	SM.G13.1
SM.T08.5	Maintainability	The TMM CPS to be designed for optimal maintainability.	FMECA informed. RCM informed. Formal TMM CPS reliability model. Formal maintenance and repair strategy. Fault codes displayed to operator screen Quick removal and mounting of modules and/or components. Modular design to facilitate quick swop out. fault finding and lower replacement unit cost MTTR < 90min (Time of FTSWHI until authorised override) Critical spares identified	SM.G12.1 SM.G12.3 SM.G.12.4 SM.G12.5 SM.G13.1 (and sub-requirements)
SM.T08.6	Operability	All TMM CPS modules to be operable/configured/tested after maintenance or unit/component replacement.	Quick reconfigurable/commissioning Formal documentation Formal training material	SM.G12.1 SM.G12.3 SM.G.12.4 SM.G12.5 SM.G13.1 (and sub-requirements)
SM.T08.7	Reliability	All TMM CPS modules designed for reliability.	Formal FMECA informed TMM CPS MTBF > 2000 operating hours TMM CPS and key function failure analysis program	SM.G13.1
SM.T09	Identification and marking	All TMM CPS modules and components to be uniquely identified and marked.	Item number Item name Serial number Hardware, firmware and software versions Physically marked Data stored in MLK Data displayed on OWS on request	SM.G12.1 SM.G14.1 SM.G14.1.1

Func. Req. No	Function Name	Function Description	Performance criteria	URS No.
SM.T10	Firmware requirements	Version controlled and electronically updatable.	Unique identifier Version Date installed or last updated Firmware version to be updated when changed Recommissioned after update Data logged in specific firmware log file. Stage Gate report number and date.	SM.G12.1 SM.G14.1 SM.G14.1.1
SM.T11	Reporting	The TMM CPS must have a reporting, trending and business intelligence function that is configurable by the mine.	TMM CPS performance to be monitored and used for continuous business improvement. Integrated TMM CPS and CxD report(s) for CPS performance monitoring. Standard report templates, customisable	SM.G11.1
SM.T12	Safety integrity	The TMM CPS must be designed for safety integrity.	Comply with GMG Guideline for Applying Functional Safety to Autonomous Systems in Mining	SM.G05 SM.G10 (and sub-requirements)
SM.T13	System Conformance	Demonstrate conformance.	TMM CPS products must demonstrate conformance to this F&TPR through inhouse verification, independent verification and record keeping. (Sec 21 Technical File) Tested according to MOSH Surface TMM CPS Independent verification Test Specifications	SM.G04
SM.T14	Legal Liability	Unambiguous legal boundaries.	TMM CPS must formally define its legal boundary.	Legal boundary informed by functional breakdown structure shown in Figure 2

7. References

The following documents are referenced in this document:

1. ISO/TS 21815-2:2021: Earth-moving machinery — Collision warning and avoidance — Part 2: On-board J1939 communication interface.
2. ISO/TS 21815-1:2022: Earth-moving machinery – Collision warning and avoidance – Part 1: General Requirements.
3. MIL-STD-810G: 31October 2008: Environmental engineering considerations and laboratory tests.
4. ICNIRP Guidelines for limiting exposure to electromagnetic fields (100 KHZ TO 300 GHZ).
5. The Global Mining Guidelines Group (GMG) 18 Aug 2020 Publication: GMG Guideline for Applying Functional Safety to Autonomous Systems in Mining.
6. SANS 60079-1:2015: Edition 5: IEC 60079-1:2014: Edition 7: Explosive atmospheres Part 1: Equipment protection by flameproof enclosures “d”.
7. BS EN 13921:2007: Personal protective equipment. Ergonomic principles.