INDEPENDENT VERIFICATION TEST SPECIFICATION FOR SURFACE COLLISION WARNING AND AVOIDANCE DEVICES (CxD): TRL4 STAGE GATE

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

REV 1

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Definitions and abbreviations

Table 1 defines terms and abbreviations used in this document.

Table 1: Abbreviations and their definitions appearing in this document

Abbreviation	Definition
CAN bus	Controller Area Network bus
CAN sniffer	A CAN sniffer is a tool (hardware or software) used to monitor and capture data traffic on a CAN bus.
CAN trace	A recording of all the messages/traffic on a CAN bus
CDI	CxD Interface
CLK	CxD Log keeping
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 Developer	The organisation selected for each CPS to act as the single entity to coordinate the development and testing of the specific CPS.
CPS Product Supplier	The organisation that provides one or more of the functional elements of either the CxD or the TMM CPS product.
CPS Stop	The state when the CxD intervenes with the intent of stopping or keeping the TMM stationary to avoid a collision or FTSWHI. This is the end state after a CPS intervention, reached by the CxD instructing the TMM to stop via the ISO/TS 21815-2:2021 CAN-bus interface, or by the TMM slowing and stopping due to FTSWHI.
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.
CSD	CxD Self-diagnostics
CxD	Collision Warning and Avoidance System device (CxD): 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
CxDI	CxD interface: A integration function between the CxD and the Machine Controller.
CLK	CxD Log keeping
DAQ	Real time computer with data acquisition and control capabilities. Has ISO21815 interface. Example: dSPACE MABX III.
DTS	Detection and Tracking System
EMC	Electromagnetic compatibility
EW	Effective Warning
F&TPR	Functional and Technical Performance Requirements
FTSWHI	Fail to Safe Without Human Intervention
HME	Heavy Mining Equipment
HP INSS	High Precision Inertial Navigation Satellite System, capable of measuring position, with an absolute accuracy of 0.1m and velocity to within 0.2km/h with an update rate of 100Hz. Example Racelogic VBOX 3i.
ID	Identifier.
Interface	A boundary across which two independent systems meet and act on or communicate with each other. Two examples are: 1. CxD-machine interface – The interface between a Collision Warning and Avoidance System Device (CxD) and the machine. This interface is described in ISO/DTS21815-2. 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. 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

Abbreviation	Definition
MBS	Machine Braking System: The physical components that makes an unintelligent TMM intelligent and enables the CPS auto slow-down and stop functionality.
MCI	Machine Control Interface: The interface between the Machine Controller and the CXD interface.
MHSAct	Mine Health and Safety Act No. 29 of 1996 and Regulations.
MOSH	Mining Industry Occupational Safety and Health Initiative
MSDS	Material Safety Data Sheet
OWS	Operator warning subsystem the device in the vehicle that warns the operator of potential collisions
Reasonably practicable measure	Reasonably practicable means practicable with regards to: (a) The severity and scope of the hazard, or risk concerned. (b) The state of knowledge reasonably available, concerning the hazard or risk, and of any means of removing or mitigating the hazard or risk. (c) The availability and suitability of means to remove or mitigate that hazard or risk, and (d) The costs and the benefits of removing or mitigating that hazard or risk.
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.
SAMI	South African Mining Industry.
SM	Surface Mining: Indicating that a specific aspect is applicable to surface mine TMMs/operations.
SP GNSS	Standard Precision Global Navigation Satellite System, capable of measuring position, with an absolute accuracy of 0.1m and velocity to within 0.2km/h with an update rate of 10Hz. Example Racelogic VBOX Sigma.
Stage gate	A step in the testing regime / process where the CPS product system is tested against acceptance criteria, the failure of which would limit the CPS product system from moving to the next step in the regime / process.
System	A combination of interacting elements organized to achieve one or more stated purposes (ISO/IEC/IEEE 2015).
TMM	Trackless Mobile Machine (Machine, vehicle, etc.) as defined in MHSAct
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 Emulator	A TMM emulator is system that behaves like a real TMM, enabling the TMM emulator to integrate with a CxD without compromising the performance of the CxD.
TMM OEM	Original Equipment Manufacturer of TMMs. Original Equipment Manufacturer of a TMM may be the organisation which originally supplied, or last rebuilt, or modified the TMM, or the supplier per section 21 of the Mine Health and Safety Act, 1996 (Act No. 29 of 1996).
TV	Test Vehicle: A vehicle used to conduct the verification scenarios specified in DTS, EW and CxDC test protocols

1 Introduction

This document is intended for Surface Collision Warning and Avoidance System Devices (CxD) to be used in the South African Mining Industry. The document is one of the documents in the Mining Industry Occupational Safety and Health Initiative (MOSH) Collision Prevention Systems (CPS) guideline. Whilst it is developed as a stand-alone document, it is advisable to view it in the context of the other MOSH CPS guideline documents[1]. This document must be read in conjunction with the CPS Requirements Verification Regime. Figure 1 depicts the CPS Requirements Verification Regime. The CPS Requirements Verification Regime document explains the end-to-end verification steps, including the Stage Gates.

This document covers the TRL4 Stage Gate for Surface CxDs, shown in purple in Figure 1.

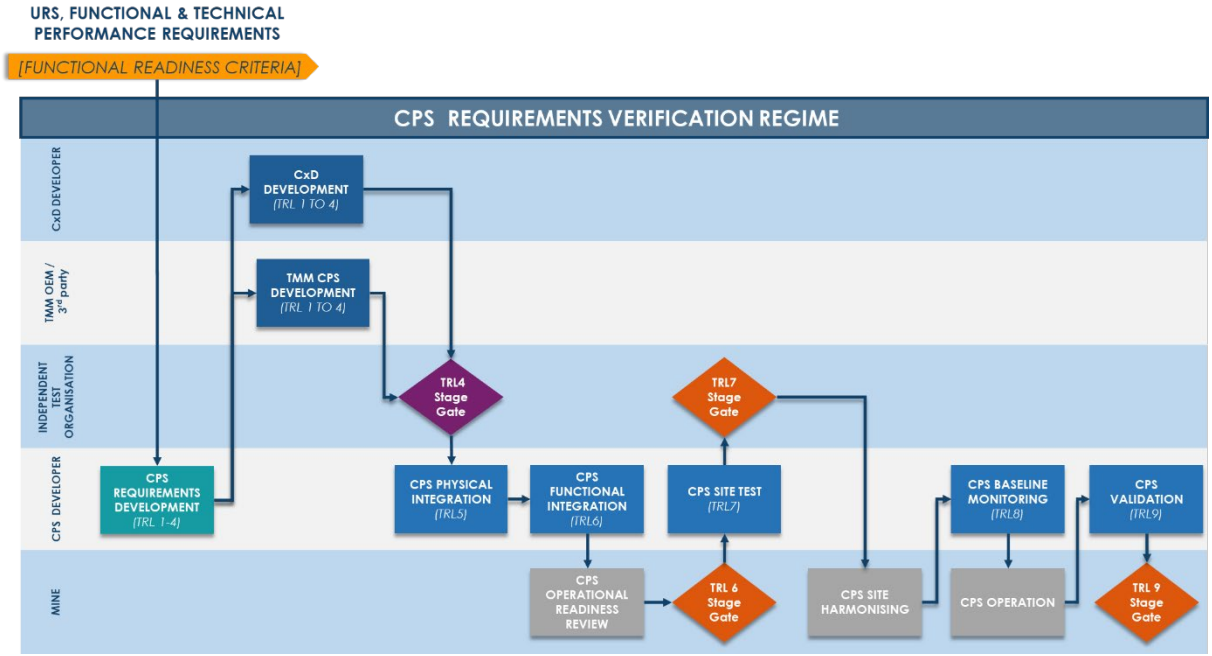

Figure 1: CPS requirements verification regime

This document is an update of the original CPS Test Specification published in November 2022. The original document contained all the Surface and Underground CPS tests. For user convenience, the independent verification test specifications are now structured as independent documents. Refer to the CPS Requirements Verification Regime for the CPS verification documentation tree for a detailed breakdown. The rationale and requirement for independent verification testing is also documented in the CPS Requirements Verification Regime.

Figure 2 shows the Surface CPS verification test regime. The Surface CPS product verification tests (Stage Gates) as shown in Figure 2 are:

1. CPS product independent verification Testing (CxD and TMM CPS) in a controlled environment (e.g., a laboratory or a proving ground), referred to as TRL4 tests.
2. CPS interaction testing in a representative, but controlled environment (e.g., in a test mine or a cordoned off section of an active mine), referred to as TRL7 tests.

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

3. CPS validation testing in the operational environment (e.g. monitoring the performance of a CPS over a period of time at an active mine), referred to as TRL9 tests.

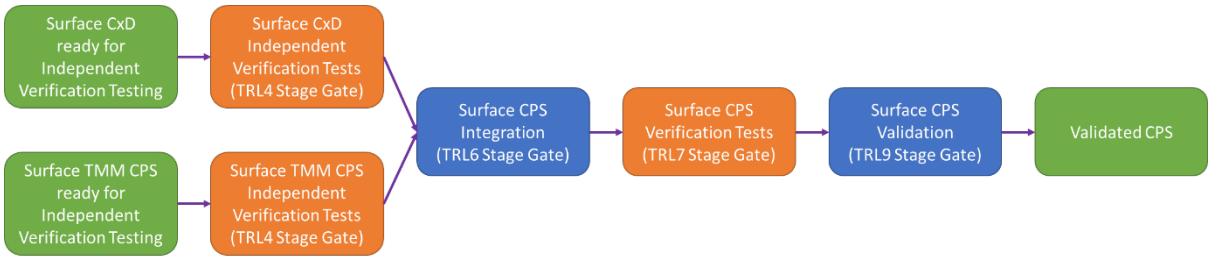

Figure 2: Surface CPS independent verification test regime (independent verification tests indicated in orange)

2 Context

Extensive documentation has been prepared to describe the user requirements, functional and technical performance requirements and test specifications of Surface CPS products. Figure 3 shows the document structure defining the MOSH blueprint towards compliant Surface CPS products.

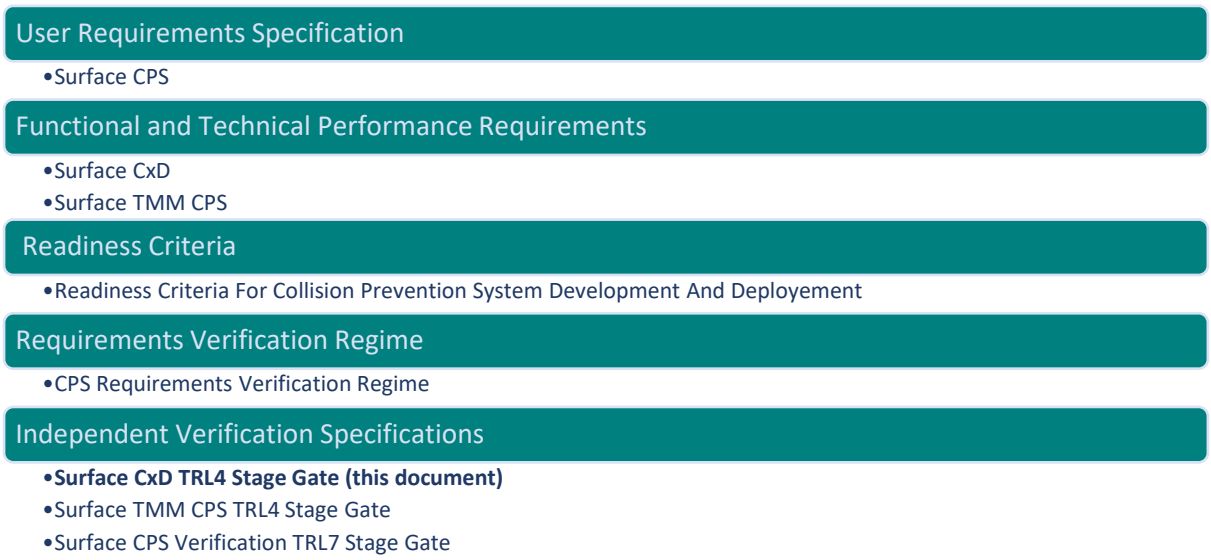

Figure 3: CPS functional testing related documentation

This document is the Surface CxD Independent Verification Test specification and builds on the User Requirement Specification (URS) for Surface CPS and the Functional and Technical Performance Requirements (F&TPRS) for Surface CxDs. The purpose of this document is to provide a single test specification to assess the functionality of Surface CxDs in accordance with the applicable URS and F&TPRS. Tests documented herein are independent verification tests and are intended for carefully controlled test environments, such as a laboratory or a proving ground (test track) since it must be repeatable and accurate so as not to unfairly reject any CxD submitted for verification.

Since the CxD is just one of the CPS products, this specification must be considered in conjunction with:

- The CPS F&TPR specification for Surface CxDs
- The CPS F&TPR specification for Surface TMM CPS
- The Independent Verification Test Specification for Surface TMM CPS.

Despite the importance of these tests, successful completion of the tests described in this document neither guarantees that a CxD will prevent all collisions under all circumstances, nor does it guarantee that a verified CxD will be deemed compliant with the Mine Health and Safety Act and Regulations. Successfully completing the tests in this document indicates that a CxD is ready for on-site CPS testing, once integrated with a Surface TMM CPS that has completed its TRL4 Stage Gate.

3 CxD Product Independent Verification Testing

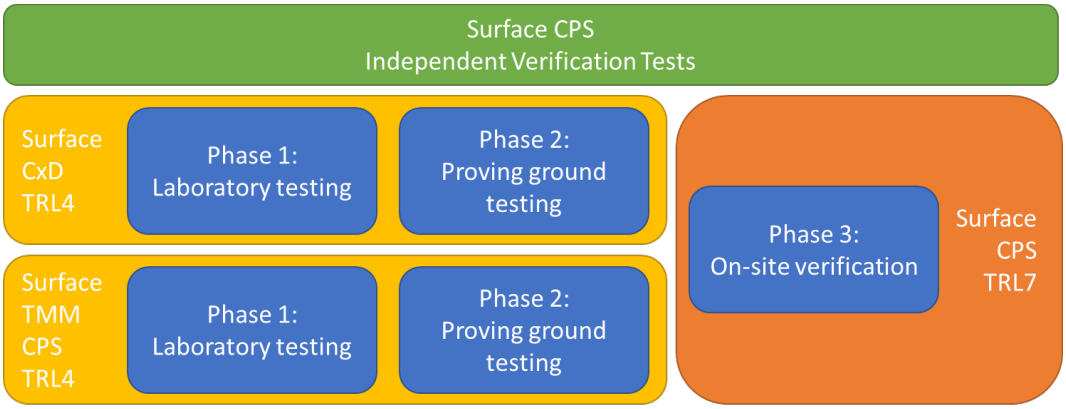

Figure 3: Surface CPS independent verification test regime

CxD product independent verification testing is done in three stages, **laboratory, proving ground** and **on-site**:

- **Phase 1:** Laboratory testing (independent 3rd Party laboratory) and
- **Phase 2:** Proving ground testing (independent 3rd party tests at a proving ground)
- **Phase 3:** On-site verification (independent 3rd party goes to a suitable area, such as a mine site, where the integrated CPS is ready for testing)

The following tests are done for **Phase 1: Laboratory CxD tests**

- Surface CxD Interface Test - the ISO/TS 21815-2: 2021 test
- Surface CxD Log Keeping Test
- Surface CxD Self-Diagnostic Test

Phase 1 tests are bench-top tests, typically conducted in a laboratory environment with a TMM CPS emulator.

The following tests are done for **Phase 2: Proving Ground CxD tests**

- ICASA Type Approval demonstration. The CxD supplier submits its ICASA certificate.
- EMC demonstration, as applicable (consult with an accredited EMC test laboratory). CxD supplier submits its EMC certificates.
- Surface CxD Detection and Tracking test
- Surface CxD Effective Warning test
- Surface CxD Controller test

Phase 2 tests are done at a proving ground, typically at Gerotek Test Facilities. The Phase 2 tests are done with light vehicles, allowing for safe and repeatable testing within a short timeframe.

The following tests are done for **Phase 3: On-site Surface CPS tests**

- Surface CPS integration
- Surface CPS interaction scenarios

Phase 3 tests are done with a fully integrated CPS in a representative environment, such as a cordoned-off area of a mine.

4 TRL4 Stage Gate

The Surface CxD verification testing (TRL4 Stage Gate) consists of six functional tests, each with a specific purpose, test prerequisites, test instrumentation, preparation, test method and acceptance criteria. Ideally, a CxD will be submitted for testing against all six the verification tests in one go with no alterations between tests. At the time of writing, this is unlikely. CxD technology is developing rapidly and some changes and alterations are often necessary between testing when not done at the same time. As such, the independent verification test process makes provision for **minor** alterations to CxD products between tests.

Figure 4 shows the verification test process. Each test (with the exception of the Surface CxD Interface test) is preceded by a pre-test check. The intent of the pre-test check is to quickly confirm if any significant changes to the CxD have affected previous test results. Here, the responsibility is placed on the CxD supplier to clearly indicate any changes made since the previous test. It is left to the discretion of the test engineer responsible for the verification test to decide if a CxD passes the pre-test check and that it may proceed with the subsequent verification test.

After completing a functional test, three recommendations may be made by the test engineer: Accept, Reject and Provisionally Accept.

- Accept: An Accept recommendation indicates that, on the day of testing, the CxD under test conformed to all the requirements of that specific test.
- Reject: A Reject recommendation indicates that there are significant shortcomings that need to be rectified before testing can proceed.
- Provisionally Accept: A Provisionally Accept recommendation indicates that the CxD under test does not conform to all of the requirements of that test, but, in the opinion of the test engineer, these deviations are easy to rectify and do not endanger the test team and/or test equipment of subsequent tests.

In the Provisionally Accept case, the CxD supplier will be given reasonable opportunity to address any shortcomings. Corrections and updates to such a CxD product will be allowed, and the pre-test check of the next verification test will be used to determine if corrections and/or updates have rectified the shortcomings. If the shortcomings have been rectified without compromising functionality already tested during prior verification tests, the CxD product will be allowed to proceed to the next verification test. However, if the modifications to the CxD product have not fully addressed the shortcomings, or if they have compromised the performance of functionalities tested earlier, the CxD under test will not be allowed to continue further verification testing. Shortcomings will have to be corrected and the CxD product submitted for retesting. The test engineer will recommend a suitable re-entry point for further testing.

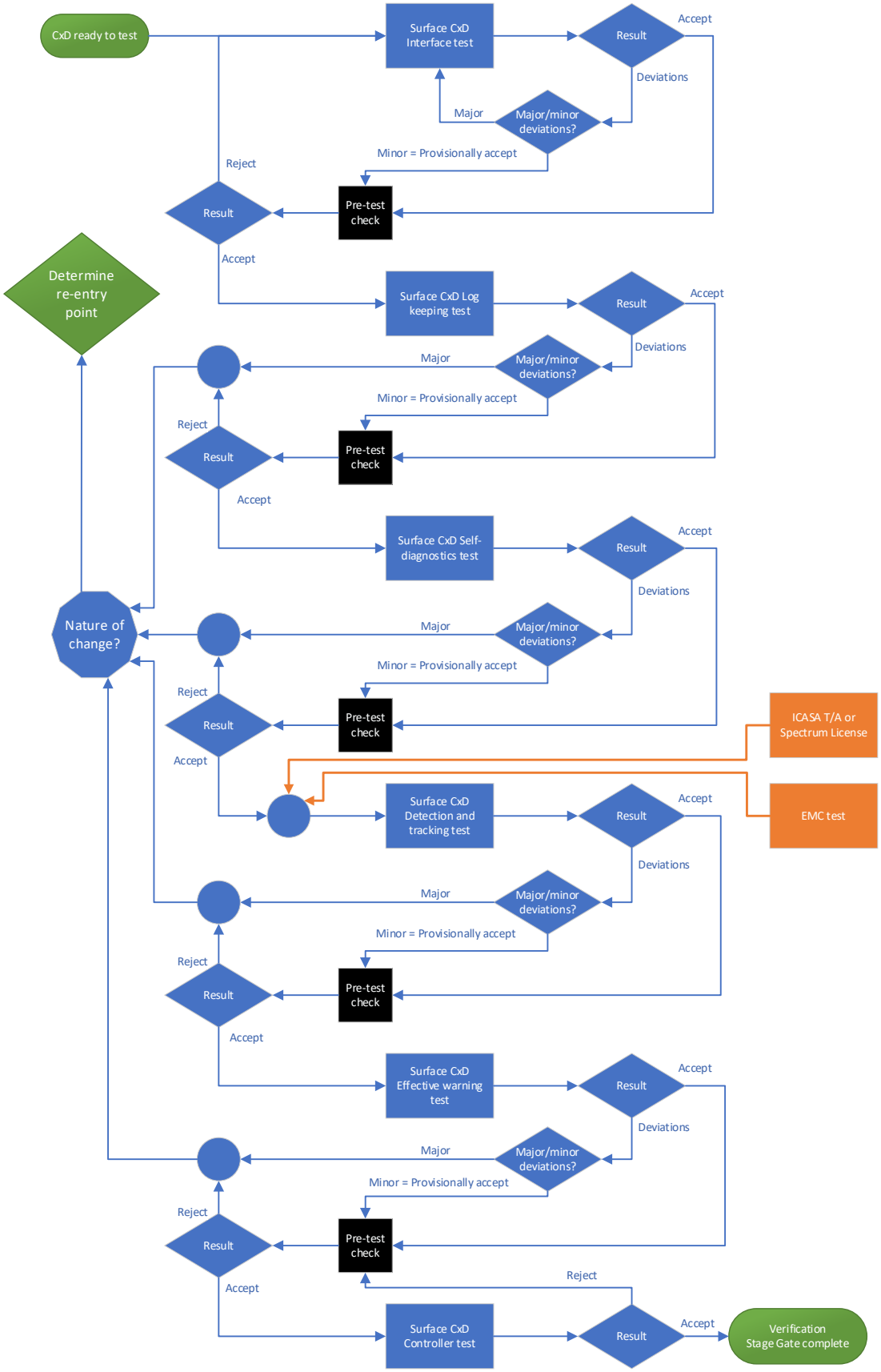

Figure 4: Surface CxD verification test process

5 Verification test report structure

Two categories of reports are prepared subsequent to verification tests:

1. Stage gate reports
2. Technical test reports

Stage gate reports indicate the high-level progress of a CxD product against the various CxD verification tests. The intent of stage gate reports is to give concise information to a non-technical audience of a CxD product's conformance to the FTPR for Surface CxDs. Stage gate reports summarize the findings and recommendations of the technical test reports for that specific stage. The stage gate report also highlights critical information that may affect later stage gate tests.

Technical test reports are detailed technical reports providing the specifics of CxD verification tests. The intent of technical test reports is to provide detailed feedback to the CxD product suppliers. Technical test reports are extensive and are intended for a technical audience.

Figure 5 shows the test report structure pertaining to Surface CxD verification testing

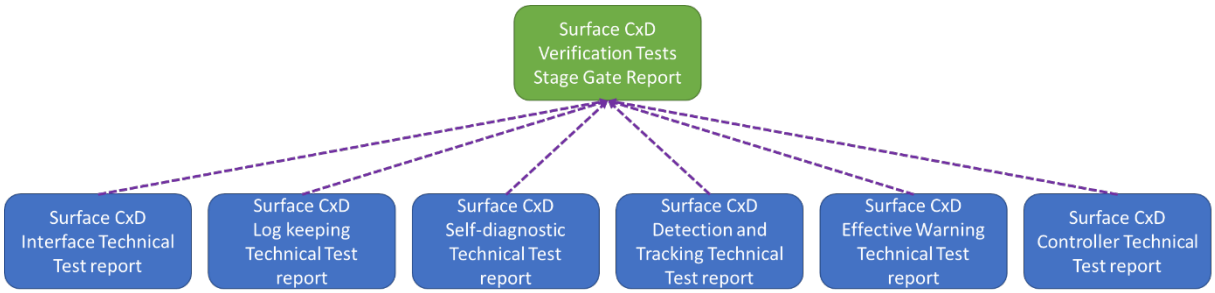

Figure 5: Surface CxD verification test report structure

6 Independent Verification test readiness

It is acknowledged that CxD developers / suppliers have performed functional tests over the past few years. CPS product suppliers are expected to do extensive in-house tests to verify conformance of its products. Independent verification testing is a reasonably practicable measure to ensure that mining employees are not injured as a result of TMM collisions. It is not the intention or a requirement of the project to have any CPS and/or element re-tested. The onus of such decision is entirely up to the CPS developer or product supplier to demonstrate conformance to the functional requirements. A CPS developer or any of its element providers can certify readiness at any given Stage Gate, together with all the information to demonstrate conformance. Such demonstration must include all the relevant functional readiness criteria as defined for all relevant Stage Gates.

Where a CPS developer or product supplier certifies its CPS product(s)for a specific Stage Gate, it must demonstrate conformance to the readiness criteria of all **prior** Stage Gates, as applicable.

7 Verification test instrumentation

Since the tests documented here are independent verification tests and are performed in carefully controlled test environments, such as a laboratory or a proving ground (test track), accurate and reliable instrumentation is a minimum requirement. Various measurements are collected during

testing. Table 2 documents the accuracy required of the instrumentation to be used when conducting the verification tests in this document. Independent 3rd party verifiers need to ensure that instruments are properly maintained and have valid calibration certificates, as directed by the instrument suppliers.

Table 2: Verification test instrumentation specification

Instrument	State	Accuracy (RMS)
High-precision INSS (HP INSS)	Velocity	0.1 km/h
	Update rate	100 Hz
	Position	0.3 m 95 % CEP
	Heading	0.1°
	Angle	0.1°
Standard-precision GNSS (SP GNSS)	Speed	0.1 km/h
	Update rate	10
	Position	1.5 m CEP
	Heading	0.3°
Camera	Resolution	720p
	Field of view	60°
	Frame rate	30 fps

8 Test Protocols

The Surface CxD Verification (TRL4 Stage Gate) test protocols are documented in Appendices 1 to 6.

In preparation for each test, the CxD supplier will be required to complete a product information sheet. The goal of the product information sheet is to:

1. Describe the product to ensure that the specifics are accurately reflected in the test reports.
2. Provide a formal sign-off to confirm that the product under test is fully functional and properly commissioned. The product is considered ready for testing.

The product information sheet is available in Appendix 7.

Appendix 8 documents a safety protocol to be followed prior to each test. The aim of the safety protocol is to ensure the safety of the test team and observers.

Appendix 1: Surface CxD Interface Test

Purpose

The CxD Interface (CxDI) subsystem must be able to communicate with the MCI using the standard as defined in ISO/TS21815-2:2021. The purpose of this test is to determine if the CxDI is compliant with the standard. It is expected that the CxDI can adapt to the capabilities of the MCI. The test evaluates the CxDI against acceptance criteria based on technical requirements in the Surface CxD F&TPR Specification.

Preceding tests

1. None

Test facility/site

Tests are static and can be done in a laboratory environment.

Instrumentation

1. 1x TMM Emulator
2. 1x CxDI
3. 1x CAN sniffer

Test preparation

1. The client will supply the CxDs in working order. An authorized person (technology provider representative) will submit the signed CxD test information sheet (Appendix 7). CxD has passed all preceding tests as stipulated in the Preceding tests section. No modifications to any aspect of the CxDs will be allowed once testing has commenced.
2. Connect TMM Emulator and sniffer to CxDI CAN-bus via the ISO21815 connector.
3. Power is to be supplied to the CxDI via the ISO21815 connector. Connect power supply to pins 2,3 and 4 in the ISO21815 connector.
4. The CxDI must be able to send commands to the TMM Emulator when requested by the test engineer. The CxDI must also be able to report which values and capabilities have been read on the TMM Emulator during testing (e.g. computer may be logged into CxDI to perform these tasks).
5. If any alterations are made to any aspect of the CxDI during testing (e.g. firmware, rewiring of connector, etc.), all previous tests become invalid, and this protocol has to be followed from the start.

Test method and acceptance criteria

1. Connector

1.1. Document if the Deutsch DT-Series 12-pin socket (male) part is used as in 6.2 of the ISO/TS 21815-2:2021 standard.

1.2. Verify pin assignment as specified in 6.2 of the ISO/TS 21815-2:2021.

1.3. If override is connected on CxD side of the connector, note logic as in 6.4 of the ISO/TS 21815-2:2021 standard.

Table 3: Connector acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.01	Deutsch DT-series 12 pin, part DT04-12PC-BE02 (Key C) is used for connection between CxD and TMM.	SM.CxDI.01

2. Negotiation sequence

2.1. Record a CAN trace while performing the following actions:

2.2. Have the CxDI attempt to perform negotiation without the use of trust mechanisms. If negotiation cannot be done without the use of trust mechanisms, document it as such and have the CxD developer provide information to enable negotiation between the CxDI and TMM Emulator.

2.3. After negotiation has been established between CxDI and TMM Emulator

2.4. Note:

2.4.1. Broadcast rate of CxD>>MachineStatus messages.

2.4.2. Broadcast rate of CxD>>MachineCommand messages.

Table 4: Negotiation sequence acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.02.1	For negotiation without authentication: Perform negotiation as described in ISO 21815-2.	SM.CxDI.02
SM.CxDI.AC.02.2	Negotiation with authentication (optional): Perform negotiation as described in ISO 21815-2. Mechanism to share credentials with interfacing party(ies).	SM.CxDI.02
SM.CxDI.AC.02.3	Send the PROTOCOL_NOP message periodically to maintain the connection.	SM.CxDI.03
SM.CxDI.AC.02.4	Send the command message every 100ms to ensure the TMM consistently receives instructions.	SM.CxDI.03

3. Communication loss

3.1. Record a CAN trace while performing the following actions:

3.2. Have the CxDI initiate the negotiation sequence and confirm communication is established between the two nodes.

3.3. Sever the connection between TMM Emulator and CxDI while maintaining connection between CAN sniffer and CxDI. Document CxDI behaviour to loss in communication.

3.4. Restore the connection between TMM Emulator and CxDI.

3.5. Note:

3.5.1. CxDI behaviour when connection is severed.

3.5.2. CxDI behaviour when connection is restored.

Table 5: Communication loss acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.03	The CxDI should detect a broken connection. Detection within 500ms of disconnection. Upon disconnection, CxD may opt to: Stay quiet, FTSWHI needed on TMM Attempt to negotiate again Send STAND_DOWN	SM.CxDI.04

4. Capability enquiry

4.1. Record a CAN trace while performing the following actions:

4.2. Pre-set capabilities on the TMM Emulator.

4.3. Record a CAN trace of the CxDI attempting to discover machine capabilities using the following methods:

4.3.1. Reading the MCAPS propulsion register with the CxD>>MachineStatus message.

4.3.2. Individual capability enquiries on the CxD>>MachineCommand message.

Table 6: Capability enquiry acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.04	The CxDI should determine machine capabilities using one or both of the following methods: Sending individual CxD>>MachineCommand messages. Reading the PROPULSION_MCAPS register.	SM.CxDI.05

5. Reading protocol registers

5.1. Record a CAN trace while performing the following actions:

5.2. Pre-set values for the following protocol registers:

5.2.1. PROTOCOL_REVISION

5.2.2. SUBSYSTEM_MCAPS

5.2.3. INTERFACE_STATE

5.2.4. MACHINE_SOFTWARE_REVISION

5.2.5. MACHINE_ID_0

5.2.6. MACHINE_ID_1

5.2.7. MACHINE_ID_2

5.2.8. MACHINE_ID_3

5.2.9. MACHINE_ID_4

5.2.10. INSTRUCTION_TIMEOUT

5.2.11. NEGOTIATION_TIMEOUT

5.2.12. RENEGOTIATION_TIMEOUT

5.3. Have the CxDI attempt to read protocol registers

Table 7: Reading protocol registers acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.05	The CxDI should attempt to read the following protocol registers: MACHINE_ID_0 to MACHINE_ID_4 MACHINE_SOFTWARE_REVISION	SM.CxDI.06.1

6. Reading propulsion registers

6.1. Pre-set values for the following propulsion registers:

6.1.1. PROPULSION_MCAPS

6.1.2. MIN_BRAKING
6.1.3. MAX_THROTTLE
6.1.4. MAX_SPEED
6.1.5. EMERGENCY_STOP_MAX_SPEED
6.1.6. CONTROLLED_STOP_MAX_SPEED
6.1.7. SLOW_DOWN_MAX_SPEED
6.1.8. MAX_FORWARD_GEAR
6.1.9. MAX_REVERSE_GEAR
6.2. Record a CAN trace of CxDI attempting to read propulsion registers.

Table 8: Reading propulsion registers acceptance criteria

AC No.	**Criteria**	**Func. Req. No.**
SM.CxDI.AC.06	The CxDI should read data from the propulsion registers if available.	SM.CxDI.06.3

7. Setting protocol registers

7.1. Record a CAN trace of CxDI attempting to set protocol registers.

Table 9: Setting protocol registers acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.07	The CxDI should attempt to write the following protocol registers: CxD_SOFTWARE_REVISION CxD_HARDWARE_REVISION CxD_HARDWARE_ID	SM.CxDI.06.2

8. Reset of registers

8.1. Record a CAN trace of CxDI attempting to reset propulsion and protocol registers.

Table 10: Reset of registers acceptance criteria

AC No.	**Criteria**	**Func. Req. No.**
SM.CxDI.AC.08.1	The CxDI may attempt to reset the data in the protocol registers to default values.	SM.MCI.06.4
SM.CxDI.AC.08.2	The CxDI may attempt to reset the data in the propulsion registers to default values.	SM.MCI.06.4

9. Propulsion commands

9.1. Record a CAN trace of CxDI attempting to execute the following action commands:
9.1.1. EMERGENCY_STOP
9.1.2. CONTROLLED_STOP
9.1.3. SLOW_DOWN
9.1.4. STAND_DOWN
9.1.5. BYPASS_PROPULSION
9.1.6. INHIBIT_COMMAND

Table 11: Propulsion commands acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.09.1	The CxDI must send NORMAL_OPERATION to allow the TMM to operate without restrictions on operator controls.	SM.CxDI.07 SM.CxDI.07.1
SM.CxDI.AC.09.2	If the CxD makes use of open-loop interventions, it must send: 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.CxDI.07.1
SM.CxDI.AC.09.3	The CxDI must send STAND_DOWN to slow down and stop the TMM in a controlled manner when the CxD experiences a fault (fail to safe without human intervention response).	SM.CxDI.07.3
SM.CxDI.AC.09.4	The CxDI must send BYPASS_PROPULSION to reduce the TMM's speed to a predefined crawl speed due to an override on the CxD side of the interface (limp mode).	SM.CxDI.07.4
SM.CxDI.AC.09.5	The CxDI must send INHIBIT_COMMAND must be used to ensure a stationary TMM remains stationary (e.g. during CPS start-up).	SM.CxDI.07.5

10. Apply propulsion set points

10.1. Record a CAN trace of CxDI attempting to set, load and apply the propulsion set points with the following methods:

10.1.1. UPDATE_AND_APPLY

10.1.2. APPLY_FROM_LIST

10.1.3. MATCH_TAG

Table 12: Apply propulsion set points acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.10	The TMM may be controlled by correctly loading and applying set points using one or more of the following methods: 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.CxDI.06.2 SM.CxDI.07.2

11. Error handling

11.1. Pre-set TMM Emulator to have a certain capability that the CxDI can discover (e.g. EMERGENCY_STOP), but replies with ACTION_ERROR when this command is sent from the CxDI.

11.2. Record a CAN trace while performing the following actions:

11.2.1. Restart negotiation and capability discovery between CxDI and TMM Emulator.

11.2.2. Have CxDI issue the command that was pre-set to reply with ACTION_ERROR.

Table 13: Error handling acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.11	If the CxD issues an unsupported command or one that cannot be applied at the current speed, the TMM may return an ACTION_ERROR. The CxDI should handle such errors safely.	SM.CxDI.09

12. Machine data

12.1. Modify measurements sent in Machine>>CxDdata message and document interpretation of:

12.1.1. SYSTEM_FAULT

12.1.2. OVERRIDE_FAULT

12.1.3. ROLLBACK_FAULT
12.1.4. TRACTION_FAULT
12.1.5. PAYLOAD_FAULT
12.1.6. SPEED
12.1.7. DIR
12.1.8. MOTION_INHIBIT
12.1.9. GEAR
12.1.10. OVERRIDE_STATUS
12.1.11. ROLLBACK_STATUS
12.1.12. TRACTION_STATUS
12.1.13. PAYLOAD_STATUS
12.1.14. PITCH
12.1.15. ROLL

Table 14: Machine data acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.12	The CxDI should correctly interpret information contained in the Machine>>CxDdata PGN. If only some parameters are used, the CxDI must correctly interpret all utilised parameters.	SM.CxDI.10

13. Delayed status responses

13.1. Record a CAN trace while performing the following actions:
13.1.1. While negotiated delay the response from the TMM Emulator on the Machine>>CxDreply message to 50ms.
13.1.2. Sever connection
13.1.3. Perform negotiation between TMM emulator and CxDI.

Table 15: Delayed status responses acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.13	The CxDI should be able to handle the case where the TMM delays its response to the CxD>>MachineStatus message by up to 50ms.	SM.CxDI.11

14. Override

14.1. CxD maintenance override
14.1.1. Document authentication method used to activate a maintenance override
14.1.2. Record a CAN trace and activate maintenance override.
14.2. Machine side override
14.2.1. Record a CAN trace and perform the following action:
14.2.2. Activate override on Machine side of the interface (either a physical switch or on the TMM emulator).

Table 16: Override acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.14.1	CxD sends BYPASS_PROPULSION to MCI.	SM.CxDI.07.4
SM.CxDI.AC.14.2	Document indication of machine side override activation on CxD when machine-side override is activated.	SM.CxDI.10

15. Time/Date

15.1. Record a CAN trace and perform the following actions:
15.1.1. Send SAE J1939 request for Time/Date from MCI to CxDI.

15.1.1.1. Note receipt of CxD Time/Date message response to message from MCI.

15.1.2. Send SAE J1939 request for Time/Date from CxDI to MCI.

15.1.2.1. Note receipt of Time/Date message request from CxDI.

15.1.2.2. Note CxDI time request period.

Table 17: Time/Date acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDI.AC.15.1	The CxDI should use the SAE J1939 Request PGN to request the SAE J1939 Date/Time PGN from the TMM.	SM.CxDI.12
SM.CxDI.AC.15.2	The CxDI should respond to any SAE J1939 Request for time addressed to it with the SAE J1939 Date/Time PGN.	SM.CxDI.12

Deviations from protocol during testing

If any deviation from the test protocol occurs for any reason, have all parties accept in writing:

1. The proposed deviation.
2. Reason for the proposed deviation.
3. Motivation why the proposed deviation will not affect the purpose of the test.

Appendix 2: Surface CxD Log Keeping Test

Purpose

The CLK subsystem must be able to store all data from CxD functions as well as data relevant to the Machine state. The purpose of this test is to determine if the CLK can perform its log keeping duties successfully to provide a permanent auditable record. The test evaluates the CLK against acceptance criteria based on technical requirements in Surface CxD F&TPR Specification.

Preceding tests

1. Surface CxD Interface Test

Test facility/site

Tests are static and can be done in a laboratory environment.

Instrumentation

1. 1x TMM Emulator
2. 1x CxDI
3. 1x CLK
4. 1x Device or other mechanism to induce intervention
5. 1x CAN sniffer

Test preparation

1. The client will supply the CxDs in working order. An authorized person (technology provider representative) will submit the signed CxD test information sheet (Appendix 7). CxD has passed all preceding tests as stipulated in the Preceding Tests section. No modifications to any aspect of the CxDs will be allowed once testing has commenced.
2. Connect CxD Emulator, TMM Emulator and to CxDI CAN-bus via the ISO21815 connector.
3. If any alterations are made to the firmware of the CLK or CxDI during testing, all previous testing becomes invalid and this protocol must be followed from the start.

Test method and acceptance criteria

1. Stored data and accuracy of log file

1.1. Ensure that CxDI and TMM Emulator are ready to negotiate when connected.

1.2. Connect the CxDI and TMM Emulator and ensure negotiation is complete and NORMAL_OPERATION has been reached.

1.3. Record a CAN trace and perform the following actions:

1.3.1. Note start time of test

1.3.2. Connect the CxDI and TMM Emulator and wait for negotiation to complete

1.3.3. NORMAL_OPERATION for 60 s

1.3.4. Effective warning for 10 s

1.3.5. Intervention for 10 s

1.3.6. NORMAL_OPERATION for 60 s

1.3.7. Maintenance Override for 10 s

1.3.8. NORMAL_OPERATION for 60 s
1.3.9. CxD fault for 10 s
1.3.10. NORMAL_OPERATION for 60 s
1.3.11. Note end time of test
1.4. Stop recording and transfer data from CLK to computer.

Table 18: Stored data and accuracy of log file acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CLK.AC.01.1	Synchronization can be done in post-processing (real-time synch not required). TMM time should be recorded at least once every hour of operation.	SM.CLK.01
SM.CLK.AC.01.2	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. Message ID changes are not considered to be 'on-change' events.	SM.CLK.02
SM.CLK.AC.01.3	The following information must be recorded at all times: Operator ID CxD firmware Machine ID and relevant information.	SM.CLK.03.1
SM.CLK.AC.01.4	All TMMs inside the detection area are recorded with a unique ID	SM.CLK.03.2
SM.CLK.AC.01.5	Information to be stored must at least include: CxD Time. TMM IDs and positions relative to the TMM. EW status. Minimum resolution of 10Hz required during interventions.	SM.CLK.04
SM.CLK.AC.01.6	Maintenance override status. Authorized person ID that activates the maintenance Override.	SM.CLK.05
SM.CLK.AC.01.7	The presence of any CxD faults must to be recorded .	SM.CLK.06

2. Data transfer

2.1. Note sufficient storage space as per CLK supplier product information sheet.
2.2. Initiate data transfer and note time required to transfer log file to computer.
2.3. Note:
2.3.1. Size of log file
2.3.2. Data transfer interface
2.3.3. Security measures to prevent log file from being deleted on CLK with a computer.
2.3.4. Security measures to prevent log file from being altered on CLK with a computer.
2.3.5. Measures in place to ensure that the integrity of the log file will not be compromised with physical damage, electrical discharge or magnetic exposure.

Table 19: Data transfer acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CLK.AC.02.1	Reasonable provision made to store up to and including 7 days' worth of data If storage capacity is full before 7 days has passed, fail-to-safe response is triggered.	SM.CLK.07.1
SM.CLK.AC.02.2	At least once per week using an easily accessible data transfer mechanism, such as: Wi-Fi, Local Area Network (e.g. Ethernet), Personal Area Network (e.g. Bluetooth), USB / serial, Removable storage;	SM.CLK.08
SM.CLK.AC.02.3	Reasonable steps taken to ensure that data containing sensitive information is protected.	SM.CLK.09
SM.CLK.AC.02.4	CLK to provide mechanism to prevent unauthorized data deletion. CLK to record ID of authorized person deleting data. Reasonably practicable measures must be taken.	SM.CLK.11
SM.CLK.AC.02.5	CLK to provide mechanism to prevent alteration of stored data. Reasonably practicable measures must be taken.	SM.CLK.12

3. Human-readable tracking data

The Surface Detection and Tracking test requires analysis of the CLK logs. This analysis aims to ensure that interactor positional tracking requirements are met during all interventions. To enable this analysis, the CxD OEM must provide a mechanism to extract the following data in a human-readable format: range, direction, interactor ID, and intervention state.

3.1. Request the CxD OEM to convert a regular CLK log file containing relevant position data into a human-readable format with only the required data present.

Table 20: Human-readable tracking data acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CLK.AC.03	A mechanism to extract range, direction, interactor ID, and intervention state in a human-readable format must be provided.	None (testing requirement)

Deviations from protocol during testing

If any deviation from the test protocol occurs for any reason, have all parties accept in writing:

1. The proposed deviation.
2. Reason for the proposed deviation.
3. Motivation why the proposed deviation will not affect the purpose of the test.

Appendix 3: Surface CxD Self-Diagnostic Test

Purpose

The CxDC, CxDI, CLK, DTS, OWS and PWS subsystems must be able to self-diagnose any reasonably foreseeable failure modes that it may experience. The purpose of this test is to determine how the CxD responds to imposed failure modes. The test evaluates the CxD subsystems against acceptance criteria based on technical requirements in Surface CxD F&TPR Specification.

Preceding tests

1. Surface CxD interface test
2. Surface CxD Log Keeping test

Test facility/site

Tests are static and can be done in a laboratory environment.

Instrumentation

1. 1x Fully commissioned CxD system
2. 1x TMM Emulator
3. 1x CAN sniffer

Test preparation

1. The client will supply the CxDs in working order. An authorized person (technology provider representative) will submit the signed CxD test information sheet (Appendix 7). CxD has passed all preceding tests as stipulated in the Preceding Tests section. No modifications to any aspect of the CxDs will be allowed once testing has commenced.
2. Connect TMM Emulator to the CxD CAN-harness via the ISO21815 connector.
3. Complete negotiation sequence between TMM Emulator and CxD and ensure that CxD is in Normal Operation.
4. If any alterations are made to the firmware of the CxDC, CxDI, CLK, DTS or EW during testing, all previous testing becomes invalid and this protocol has to be followed from the start.

Test method and acceptance criteria

1. Power interruption

Test the system response of the CxD to power interruption by performing the following actions. Treat subsystems as one if contained in a single unit that draws power from a single source.

1.1. Record a CAN trace.
1.2. Disconnect power supply from each of the following subsystems (if possible)
1.2.1. CxDC
1.2.2. CxDI
1.2.3. CLK
1.2.4. DTS
1.2.5. OWS

1.3. Document subsystem behaviour when disconnected from power.
1.4. Reconnect power to subsystem.
1.5. Document subsystem behaviour when reconnected to power.
1.6. Repeat 3 times.
1.7. Expected Behaviour:
1.7.1. *CxDI Active, Other Subsystem Unpowered:* If the CxDI remains powered while power is removed from *any other* component (CxDC, CLK, DTS, or OWS), the CxDI should send STAND_DOWN message to the TMM.
1.7.2. *CxDI Unpowered:* If the CxDI is *also* unpowered (along with or instead of another component), the CAN connection will be lost. In this case, the TMM would be expected to FTSWHI.

Table 21: Power interruption/failure acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CSD.AC.01.1	Be able to monitor the health of all DTS elements. As per supplier FMECA. Detection of critical failure leads to FTSWHI response.	SM.DT.4.1
SM.CSD.AC.01.2	Off-board elements (such as beacons) must fail to safe without human intervention when critical failure mode is detected. As per supplier FMECA.	SM.DT.4.2

2. CAN communication interruption

Test the system response when CxDI to CAN communication is interrupted by performing the following actions:

2.1. Record a CAN trace
2.2. Disconnect CAN communication between CxDI and TMM Emulator.
2.3. Document behaviour when communication is disconnected.
2.4. Reconnect CAN communication between CxDI and TMM Emulator.
2.5. Document behaviour when communication is restored.
2.6. Repeat 3 times
2.7. Expected Behaviour:
2.7.1. When CAN connection is lost, the TMM is expected to FTSWHI.
2.7.2. When CAN connection is restored the CxD may renegotiate and resume operation *or* remain in a non-negotiated state until a technician has located the source of the connection problem.

Table 22: CAN disconnection acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CSD.AC.02	Disconnection between the CxDI and MI should be detected and actioned. Detection within 500ms of disconnection. Upon disconnection, CxD may opt to: Stay quiet, FTSWHI needed on TMM. Attempt to negotiate again. Send STAND_DOWN.	SM.CxDI.04

3. CLK storage full

Test the system response when CLK storage full condition is detected by performing the following actions:

3.1. Record a CAN trace.

3.2. Induce a CLK full state.
3.3. Document behaviour when CLK storage full state is detected.
3.4. Clear storage to resolve the CLK full state.
3.5. Document behaviour when CLK storage full state is resolved.
3.6. Expected Behaviour:
3.6.1. When the storage full fault is detected the CxD should send STAND_DOWN to the TMM.
3.6.2. When the storage full fault is resolved the CxD may resume operation.

Table 23: CLK storage full acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CSD.AC.03	Fail to safe response is automatically triggered if CLK functionality is compromised (e.g. power failure, storage media unplugged). CLK error handling mechanisms (e.g. read/write errors) used to activate fail to safe response.	SM.CLK.10

4. CLK not recording

Test the system response when CLK not recording condition is detected by performing the following actions:

4.1. Record a CAN trace and perform the following:
4.2. Induce a fault which prevents the CLK from recording.
4.3. Document behaviour when CLK not recording is detected.
4.4. Remove the fault to allow the CLK to record.
4.5. Document behaviour when CLK not recording fault is resolved.
4.6. Expected Behaviour:
4.6.1. When the CLK not recording fault is detected the CxD should send STAND_DOWN to the TMM.
4.6.2. When the CLK not recording fault is resolved the CxD may resume operation.

Table 24: CLK not recording acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CSD.AC.04	Fail to safe response is automatically triggered if CLK functionality is compromised (e.g. power failure, storage media unplugged) CLK error handling mechanisms (e.g. read/write errors) used to activate fail to safe response.	SM.CLK.10

5. CxD elements disconnected

Test the system response when elements vital to safe CxD operation are disconnected by performing the following actions:

5.1. Record a CAN trace.
5.2. Disconnect each of the following CxD elements:
5.2.1. OWS Screen.
5.2.2. Sensors used for detection and tracking.
5.2.3. Maintenance Override switch and or elements.
5.2.4. Any other elements that can be disconnected.
5.3. Document behaviour when each CxD element is disconnected.
5.4. Reconnect element.
5.5. Document behaviour when each CxD element is reconnected.
5.6. Repeat 3 times.

5.7. Expected Behaviour:

5.7.1. When the element disconnection is detected the CxD should send STAND_DOWN to the TMM.

5.7.2. When the element connection is restored the CxD may resume operation.

Table 25: CxD elements disconnected acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CSD.AC.05.1	Be able to monitor the health of all DTS elements. As per supplier FMECA. Detection of critical failure leads to FTSWHI response.	SM.DT.4.1
SM.CSD.AC.05.2	Upon detection or reporting of any critical CxD failure, the CxD must initiate a fail to safe intervention. Within 500ms from critical failure detection.	SM.CxDC.22.2
SM.CSD.AC.05.3	STAND_DOWN to slow down and stop the TMM in a controlled manner when the CxD experiences a fault (fail to safe response)	SM.CxDI.07.3

6. Time/Date exchange fault

Test the system response when Time/Date cannot be exchanged with the Machine by performing the following actions:

6.1. Record a CAN trace.

6.2. Initiate Time/Date exchange procedure between CxD and TMM Emulator.

6.3. Initiate Time/Date exchange fault by setting the TMM Emulator to not respond to CxD time requests.

6.4. Document behaviour when time request is not replied to.

6.5. Restore fault by setting the MCI emulator to respond to CxD time requests.

6.6. Document behaviour when time request response is restored.

6.7. Repeat 3 times.

6.8. Expected Behaviour:

6.8.1. When the Time/Date request is ignored the CxD should send STAND_DOWN to the TMM.

6.8.2. When the Time/Date request is responded to the CxD may resume operation.

Table 26: Time/Date exchange fault acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CSD.AC.06	500 ms timeout on Time/Date requests. If no response within 500 ms, CxD FTSWHI.	SM.CxDI.12 SM.CxDC.22.2

7. Faults display

This test is used to verify whether the CxD communicates faults clearly and allows for a technician to diagnose faults based only on the screen information.

7.1. Document any message, icons, symbols on the screen communicate faults.

7.2. Expected Behaviour:

7.2.1. OWS is used to inform operator that a fault is present.

7.2.2. OWS can be used by a technician to diagnose faults.

7.2.3. Fault warnings use standardized fault codes and icons where appropriate.

Table 27: Fault display acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CSD.AC.07	Faults are communicated on the display. Presence of faults (including both CxD and TMM CPS faults) are clearly displayed Standardized fault codes and icons are used where appropriate. Sufficient information is provided to facilitate quick component replacement.	SM.EW.06.2

Deviations from protocol during testing

If any deviation from the test protocol occurs for any reason, have all parties accept in writing:

1. The proposed deviation.
2. Reason for the proposed deviation.
3. Motivation why the proposed deviation will not affect the purpose of the test.

Appendix 4: Surface CxD Detection and Tracking Test

Purpose

The Detection and Tracking subsystem (DTS) must be able to sense and differentiate between multiple objects at a distance in a harsh mining environment. The purpose of this test is to determine if the sensor suite implemented by the CxD is effective in detecting and tracking multiple objects in a controlled environment. The system will be evaluated using the CLK logs. The test evaluates the DTS against acceptance criteria based on technical requirements in Surface CxD F&TPR Specification.

Supplemental videos

Videos showing the test methods have been posted to the Minerals Council South Africa's YouTube channel and are available at the following link:

https://youtube.com/playlist?list=PLGYvaoV3Ba6JEjNSBDl7lo6j5OmjE2uDI&si=8XWtsOASsiR0k02j

Preceding test

1. ICASA Type Approval OR Spectrum License as applicable (consult with an accredited EMC test laboratory).
2. EMC tests as applicable (consult with an accredited EMC test laboratory)
3. Surface CxD Interface Test
4. Surface CxD Log Keeping Test
5. Surface CxD Self-Diagnostic Test

Test facility/site

The site must be appropriately sized for the test being conducted. Tests are highly dynamic and adequate space for run-up, interaction and run-off is required. The site should have a level, even, hard surface.

Instrumentation

1. 6x test vehicles with CxD installed (TV1-TV6)
2. 2x TMM Emulators
3. 2x HP INSSs
4. 6x DAQs with ISO/TS 21815-2 interface
5. 2x Video cameras, each synchronised with DAQ

Test preparation

1. The client will supply the CxDs in working order. An authorized person (technology provider representative) will submit the signed CxD test information sheet (Appendix 7). CxD has passed all preceding tests as stipulated in the Preceding Tests section. No modifications to any aspect of the CxDs will be allowed once testing has commenced.
2. Fence off test area. Ensure all aspects in Safety protocol is adhered to.
3. Install HP INSSs on both TVs and ensure good satellite reception is obtained.
4. Ensure all personnel, equipment and all obstacles are removed in front and behind the TVs.

Test method and acceptance criteria

For all of the following scenarios the following General CxDC acceptance criteria will apply. These criteria should be read in conjunction with any specific criteria in any of the test procedures in this test protocol.

Table 28: DTS acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.DTS.AC.00.1	Detection of 5 or more TMMs simultaneously. 200 m minimum detection range. ±1.5 m or ±10 % position accuracy, whichever is greater.	SM.DT.1.1
SM.DTS.AC.00.2	Track 5 TMMs simultaneously. No dropouts (max 1s intervals between log entries). May not identify one of the TMMs as a new object (must be the same objects maintained throughout).	SM.DT.2
SM.DTS.AC.00.3	CxD DTS must measure or estimate the distance to any TMM within the detection area. ±1.5m or ±10% position (range and direction) accuracy, whichever is greater.	SM.DT.3.1

1. Long Range Detection

This test verifies a moving DTS's ability to locate and track another vehicle that enters its detection range. During this test, no interventions from the CxD will be applied to any test vehicle.

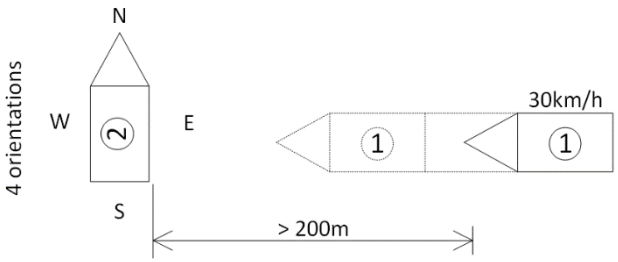

Figure 6: Long range detection test configuration

1.1. Set up test area as depicted in the figure above

1.2. Position TV2 at the centre of the test area, oriented to allow TV1 to approach from an easterly direction.

1.3. Start recording data on both TVs.

1.4. Instruct the driver of TV1 to approach TV2 from a distance of at least 200 m at a constant speed of 30 km/h. The driver shall then manually initiate deceleration and bring TV1 to a controlled stop, ensuring a safe separation distance from TV2 is maintained.

1.5. Stop recording data on both TVs.

1.6. Repeat 3 times.

1.7. Re-position TV2 and repeat test for each North-South-East-West orientation.

1.8. Downloads log from CLK.

1.9. Expected Behaviour:

1.9.1. CLK on TV1 records the position of TV2 relative to its own position.

1.9.2. No dropouts (max 1 s intervals between log entries).

1.9.3. TV2 is tracked constantly while TV1 approaches it.

1.9.4. OWS in TV1 displays the location of TV2 on a map.

1.9.5. EW and intervention will not be assessed.

2. Short Range Detection

This test verifies a moving DTS's ability to continuously detect and track another vehicle in close proximity. During this test, no interventions from the CxD will be applied to any test vehicle.

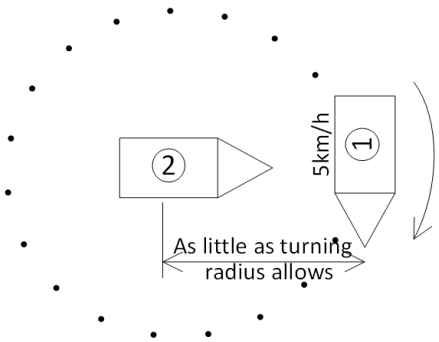

Figure 7: Short range detection test configuration

2.1. Set up test area as depicted in the right panel of the figure above.
2.2. Position TV2 in the centre of test area.
2.3. Start recording data on both TVs.
2.4. Have TV1 drive clockwise around TV2 in the smallest radius that the turning radius allows at a speed of 5km/h.
2.5. Stop recording when TV1 returns to its starting position.
2.6. Repeat 3 times.
2.7. Downloads log from CLK.
2.8. Expected Behaviour:
2.8.1. CLK on TV1 records the position of TV2 relative to its own position.
2.8.2. No dropouts (max 1 s intervals between log entries).
2.8.3. TV2 is tracked constantly while TV1 drives around it.
2.8.4. OWS on TV1 should display the location of *TV2* on a map.
2.8.5. EW and intervention will not be assessed.

3. Head-on high-speed test

This test verifies the DTS's ability to accurately track an interacting vehicle during high speed, head-on approach scenarios that may trigger a stop intervention at long range. During this test, no interventions from the CxD will be applied to any test vehicle.

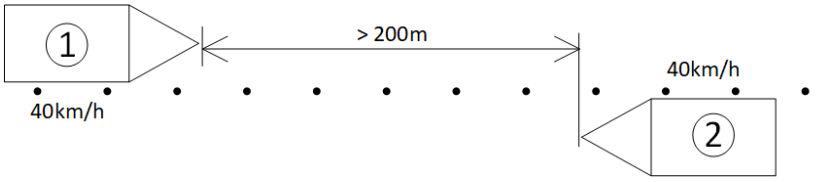

Figure 8: Head-on high-speed test configuration

3.1. Set up test area as depicted in the figure.
3.2. Position the two TVs facing each other (head-on) and offset with minimal lateral clearance. The starting distance between them should be far enough apart to allow both vehicles to accelerate to 40km/h before entering a 200m "detection zone."
3.3. Start recording data on both TVs.
3.4. Accelerate both TVs to 40km/h.
3.5. Maintain 40km/h on both TVs while in the 200-meter detection zone.

3.6. Drive the vehicles past one another and stop.
3.7. Stop recording data on both TVs once they have come to a complete stop.
3.8. Repeat 3 times at each speed.
3.9. Downloads log from CLK.
3.10. Expected Behaviour:
3.10.1. CLK on TV1 should record the position of TV2, relative to TV1's own position.
3.10.2. CLK on TV2 should record the position of TV1, relative to TV2's own position.
3.10.3. No dropouts (max 1 s intervals between log entries).
3.10.4. TV2 should be tracked continuously by TV1 as TV1 approaches.
3.10.5. TV1 should be tracked continuously by TV2 as TV2 approaches.
3.10.6. OWS on TV1 should display the location of TV2 on a map.
3.10.7. OWS on TV2 should display the location of TV1 on a map.
3.10.8. EW and intervention will not be assessed.

4. Near-Miss Multiple Interactors

The Near-miss Multiple Interactor Test evaluates the ability of the DTS to accurately detect and track multiple TMMs in the detection area. During this test, no interventions from the CxD will be applied to any test vehicle.

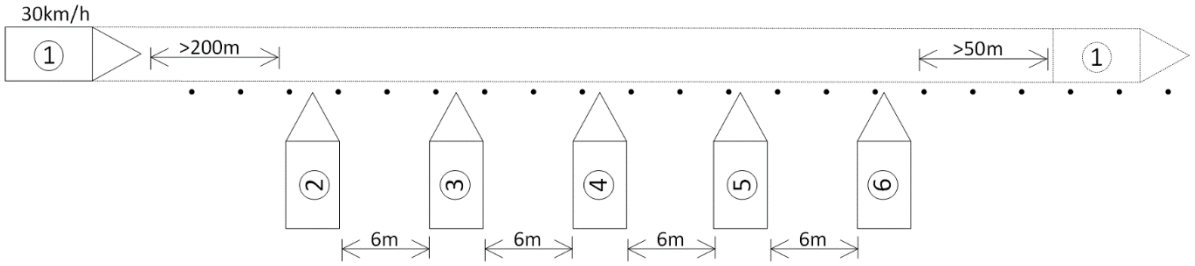

Figure 9: Near miss multiple interactor test configuration

4.1. Set up the test area as depicted in the figure with 5 TVs parked and spaced equally.
4.2. TV1 is positioned > 200 m away from the test area. The starting distance should be far enough to allow TV1 to accelerate to 30km/h before entering the test zone.
4.3. Start recording data on TV1.
4.4. Accelerate TV1 to 30km/h.
4.5. Maintain 30km/h while driving passing the 5 parked TVs.
4.6. Stop TV1 when > 50 m past last parked TV.
4.7. Stop recording data TV1.
4.8. Repeat 3 times.
4.9. Downloads log from CLK.
4.10. Expected Behaviour:
4.10.1. CLK on TV1 should record the position of all interacting TVs, relative to TV1's own position.
4.10.2. No dropouts (max 1 s intervals between log entries).
4.10.3. All interacting TVs should be tracked continuously by TV1 as TV1 approaches.
4.10.4. OWS on TV1 should display the location of all *TVs* on a map.
4.10.5. EW and intervention will not be assessed.

Deviations from protocol during testing

If any deviation from the test protocol occurs for any reason, have all parties accept in writing:

1. The proposed deviation.
2. Reason for the proposed deviation.
3. Motivation why the proposed deviation will not affect the purpose of the test.

Appendix 5: Surface CxD Effective Warning Test

Purpose

The Surface CxD Effective Warning Test focuses on verifying the effectiveness of the Operator Warning Subsystem (OWS). The test evaluates the OWS against acceptance criteria based on technical requirements in Surface CxD F&TPR Specification.

Supplemental videos

Videos showing the test methods have been posted to the Minerals Council South Africa's YouTube channel and are available at the following link:

https://youtube.com/playlist?list=PLGYvaoV3Ba6IZ4w_w9y-cIc4XWNIRNbwC&si=3a9euj3jHXvfr0ov

Preceding tests

1. ICASA Type Approval OR Spectrum License as applicable (consult with an accredited EMC test laboratory)
2. EMC tests as applicable (consult with an accredited EMC test laboratory)
3. Surface CxD Interface Test
4. Surface CxD Log Keeping Test
5. Surface CxD Self-Diagnostic Test
6. Surface CxD Detection and Tracking Test

Test facility/site

The site must be appropriately sized for the test being conducted. Tests are highly dynamic and adequate space for run-up, interaction and run-off is required. The site should have a level, even, hard surface.

Instrumentation

1. 2x Test vehicles with all CxD installed (TV1 and TV2)
2. 2x TMM Emulators
3. 2x HP INSS
4. 2x DAQs
5. 2x Video cameras, each synchronised with DAQ

Test preparation

1. The client will supply the CxDs in working order. An authorized person (technology provider representative) will submit the signed CxD test information sheet (Appendix 7). CxD has passed all preceding tests as stipulated in the Preceding Tests section. No modifications to any aspect of the CxDs will be allowed once testing has commenced.
2. Fence off test area. Ensure all aspects in Safety protocol are adhered to.
3. Ensure all personnel, equipment and obstacles are removed in front and behind the TVs.
4. Install HP INSSs on both TVs and ensure good satellite reception is obtained.
5. Synchronise cameras so that footage can be used to evaluate warning timing.

Test method and acceptance criteria

1. Warning timing and effectiveness

This test is used to quantify the timing of warnings triggered on the OWS by simulating head-on and reverse-on collisions. It also assesses the overall warning effectiveness against the acceptance criteria. During this test, no interventions from the CxD will be applied to any test vehicle.

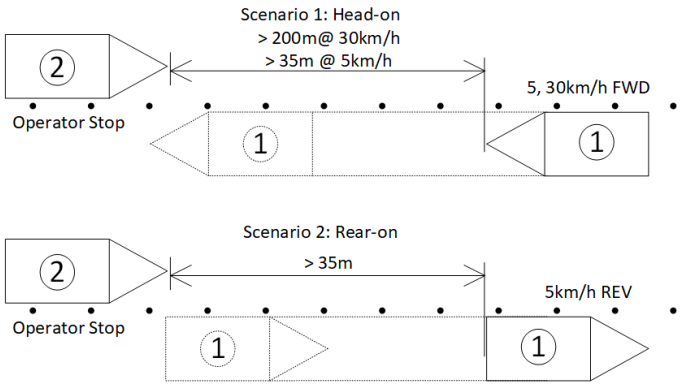

Figure 10: Warning timing and effectiveness test configuration

1.1. Set up test area with a minimal pass gap as depicted in the figure.
1.2. In both scenarios TV2 is stationary with Operator Stop active.
1.3. **Scenario 1: Head-on**
1.3.1. TV1 is starting position is:
1.3.1.1. > 200m from TV2 in forward motion at 30 km/h.
1.3.1.2. > 35m from TV2 in forward motion at 5 km/h.
1.3.2. Ensure that both OWSs are in Normal Operation with no EW.
1.3.3. Start recording data on both TVs.
1.3.4. Drive TV1 straight towards TV2 at 5km/h and 30 km/h to simulate a head-on collision.
1.3.5. Repeat 3 times for each speed.
1.4. **Scenario 2: Reverse-on**
1.4.1. TV1 is > 35m away from TV2 in reverse motion.
1.4.2. Ensure that both OWSs are in Normal Operation with no EW.
1.4.3. Start recording data on both TVs.
1.4.4. Drive TV1 straight towards TV2 at 5km/h in reverse to simulate a rear-on collision.
1.4.5. Repeat 3 times.
1.5. Expected Behaviour for both scenarios:
1.5.1. OWS on TV1 gives EW 2.5 – 3.0s before entering CPS Stop.
1.5.2. OWS on TV1 uses audible and visual cues to indicate a warning is active.
1.5.3. OWS on TV1 indicates interactor causing CPS Stop.
1.5.4. OWS on TV1 should display the location of TV2 on a map.
1.5.5. OWS on TV2 should display the location of TV1 on a map.

Table 29: CxD Effective Warning acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.EW.AC.01.1	EW Timing: Provides 2.5s - 3.0s EW time before automatic slow down and stop intervention.	SM.EW.06 SM.CxDC.08.1 SM.CxDC.08.2
SM.EW.AC.01.2	OWS Audible Warning: A maximum of three audible alarms will be generated per incident. The warning will provide clear verbal instructions, such as "STOP" or "SLOW DOWN". The warning will use programmable language sets, as specified in the mine specifications.	SM.EW.01 SM.EW.04 SM.EW.05 SM.EW.07
SM.EW.AC.01.3	OWS Visual Warning: A clear warning will be displayed to the operator for the duration of a CPS incident, including any automatic machine slowdown or stop initiated by the system.	SM.EW.01 SM.EW.05
SM.EW.AC.01.4	OWS TMM Information The display will indicate the TMM with the highest collision priority. The display will show the position of all detected TMMs' relative to the machine. The display will maintain full functionality with up to 5 TMMs within the detection area. The display will only highlight currently relevant information. Information will be communicated using appropriate icons.	SM.EW.02 SM.EW.05 SM.EW.06 SM.EW.06.3 SM.EW.07 SM.CxDC.04
SM.EW.AC.01.5	OWS Display Characteristics All CPS display requirements will be integrated into a single display The display will be backlit. The display will have automatic brightness adjustment, bright enough for sunlight viewing and dimmable for low-light conditions.	SM.EW.06 SM.EW.06.1

2. Speed limit zone warning

The speed limit zone warning test evaluates the effective warning on the OWS when a TMM approaches and enters a speed limited zone. During this test, no interventions from the CxD will be applied to any test vehicle.

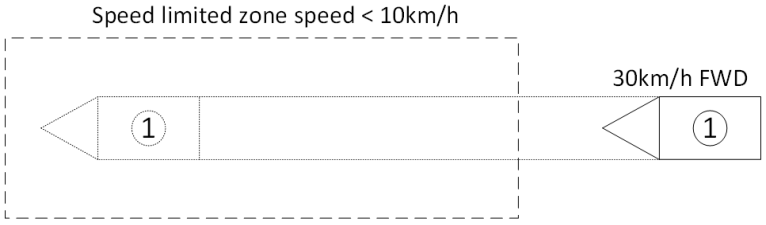

Figure 11: Warning timing and effectiveness test configuration

2.1. Set up test area as depicted in the figure.

2.2. Set up a speed-limited zone.

2.3. Record the GPS position of the zone border.

2.4. TV1 is positioned well outside the speed zone so that a stable 30km/h can be reached before speed warning occurs.

2.5. **Stage 1: Vehicle entering speed limit zone**

2.5.1. Drive TV1 towards the edge of the speed-limited zone at 15km/h and 30km/h.

2.5.2. Expected behaviour:

2.5.2.1. TV1 has EW before CPS Slow is actioned.

2.6. **Stage 2: Vehicle below speed limit**

2.6.1. Drive TV1 into the speed-limited zone at or below the speed limit.

2.6.2. Expected behaviour:

2.6.2.1. TV1 has speed limit indicated on OWS while in the speed-limited zone.

2.7. **Stage 3: Vehicle above speed limit**

2.7.1. While inside the speed-limited zone increase speed and attempt to exceed the speed limit with TV1.

2.7.2. Expected behaviour:

2.7.2.1. TV1 has speed limit indicated on OWS while in the speed-limited zone.

2.8. Repeat all stages in sequence, 3 times for each speed

Table 30: Speed limit EW acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.EW.AC.02	Operator warned when speed is within 2 km/h of the speed limit. Operator to be instructed to slow down if she/he exceeds the speed limit.	SM.EW.08

Deviations from protocol during testing

If any deviation from the test protocol occurs for any reason, have all parties accept in writing:

1. The proposed deviation.
2. Reason for the proposed deviation.
3. Motivation why the proposed deviation will not affect the purpose of the test.

Appendix 6: Surface CxD Controller Test

Purpose

The CxD Controller (CxDC) subsystem is at the heart of the CxD and must be able to decide on the correct action in complex scenarios to prevent collisions in a surface mine. The purpose of this test is to determine if the logic of the CxDC is able to provide effective collision prevention in the 12 defined surface scenarios. The test evaluates the CxDC against acceptance criteria based on technical requirements in the Surface CxD F&TPR Specification.

Supplemental videos

Videos showing the test methods have been posted to the Minerals Council South Africa's YouTube channel and are available at the following link:

https://youtube.com/playlist?list=PLGYvaoV3Ba6LfF8_YYe-eC6_G0QyLGWhG&si=fOPhUvSPjkn9UXtd

Preceding test

1. ICASA Type Approval OR Spectrum License as applicable (consult with an accredited EMC test laboratory)
2. EMC tests as applicable (consult with an accredited EMC test laboratory)
3. Surface CxD Interface Test
4. Surface CxD Log Keeping Test
5. Surface CxD Self-Diagnostic Test
6. Surface CxD Effective Warning Test
7. Surface CxD Detection and Tracking Test

Test facility/site

The site must be appropriately sized for the test being conducted. Tests are highly dynamic and adequate space for run-up, interaction and run-off is required. The site should have a level, even, hard surface.

Instrumentation

1. 6x test vehicles with CxD installed (TV1-TV6)
2. 3x brake robots
3. 3x HP INSSs
4. 3x SP GNSSs
5. 6x DAQs with ISO/TS 21815-2 interface

Test preparation

1. The client will supply the CxDs in working order. An authorized person (technology provider representative) will submit the signed CxD test information sheet (Appendix 7). CxD has passed all preceding tests as stipulated in the Preceding Tests section. No modifications to any aspect of the CxDs will be allowed once testing has commenced.
2. Fence off test area. Ensure all aspects in Safety protocol is adhered to.
3. Install HP INSSs on both TVs and ensure good satellite reception is obtained.

4. Connect DAQ to the CxD CAN-harness via the ISO21815 connector.
5. Complete negotiation sequence between CxD and TMM Emulator.
6. Set slowdown and stop decelerations on brake robot to 0.1g and 0.2g respectively.
7. Ensure all personnel, equipment and all obstacles are removed in front and behind the TVs.

Test method and acceptance criteria

For all of the following scenarios the following General CxDC acceptance criteria will apply. These criteria should be read in conjunction with any specific criteria in any of the test procedures in this test protocol.

Table 31: General CxDC acceptance criteria, to be read in conjunction with any test specific criteria in this test protocol

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.00.1	2.5s - 3.0s EW time before automatic slow down and stop intervention.	SM.CxDC.08.1 SM.CxDC.08.2
SM.CxDC.AC.00.2	If speed limit is > 10 km/h: 15 ±5 m stop gap (shortest distance between nearest TMMs). If speed limit is ≤10 km/h: 1.0-4.0 m stop gap (shortest distance between nearest TMMs).	SM.CxDC.02 SM.CxDC.03 SM.CxDC.05 SM.CxDC.07
SM.CxDC.AC.00.3	No false interventions and false warnings.	SM.CxDC.09
SM.CxDC.AC.00.4	EW and automatic intervention successfully initiated in all cases. Intervention strategy must use TMM capability as reported by TMM during ISO21815-2:2021 capability discovery. Intervention strategy to be consistent and repeatable.	SM.CxDC.10
SM.CxDC.AC.00.5	CxDC must allow TMM to return to Normal Operation if there is no significant risk of collision as per the mine's standard operating procedure.	SM.CxDC.20

1. Speed limits

The speed limits test evaluates the CxDC when a TMM approaches and enters a speed limited zone. It also evaluates the CxDC when the TMM exceeds the CxD design speed limit.

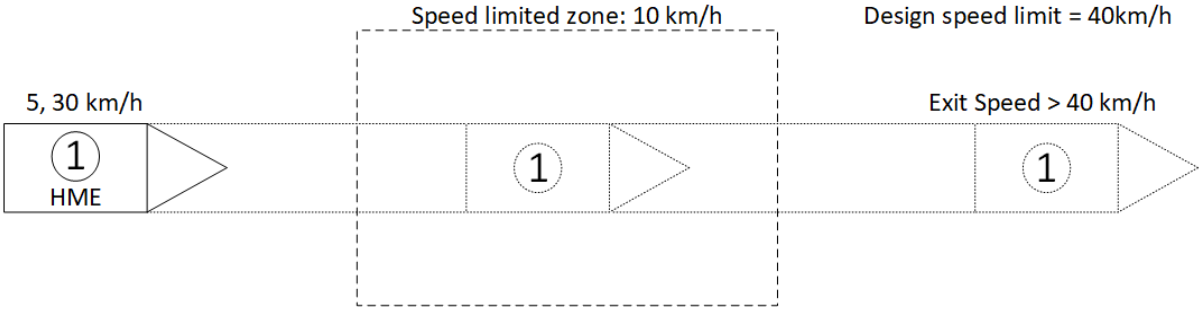

Figure 12: Speed limited zone test configuration

1.1. Set up a speed limited zone of 10 km/h as depicted in the figure.
1.1.1. Note GPS coordinates of edge of speed limited zone.
1.2. Set up design speed limit of 40km/h.
1.3. TV1 is HME and outside vicinity of speed limited zone.

1.4. **Stage 1: Vehicle entering speed limit zone**
1.4.1. Drive TV1 towards the edge of the speed-limited zone at 30 km/h
1.4.2. Expected behaviour:
1.4.2.1. TV1 has EW before CPS Slow is actioned
1.4.2.2. TV1 has CPS Slow active before entering the speed-limited zone

1.4.2.3. TV1 reaches speed limit before entering the speed-limited zone

1.5. **Stage 2: Vehicle driving in zone**

1.5.1. Drive TV1 through the speed-limited zone at 5 km/h

1.5.2. Expected behaviour:

1.5.2.1. TV1 has speed limit indicated on OWS while in the speed-limited zone

1.5.2.2. Operator cannot exceed speed limit while in the speed-limited zone

1.6. **Stage 3: Exceed design speed limit**

1.6.1. Drive TV1 away from the speed-limited zone and try to exceed the design speed limit

1.6.2. Expected behaviour:

1.6.2.1. TV1 has EW

1.6.2.2. TV1 has CPS Slow active when operator attempts to exceed design speed limit

1.7. Repeat all stages in sequence, 3 times

Table 32: Speed limit CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.01.1	Conforms to requirements of Table 31.	See Table 31
SM.CxDC.AC.01.2	CxDC must ensure that TMM stays below speed limit inside speed limited zone.	SM.CxDC.12
SM.CxDC.AC.01.3	CxDC must ensure the TMM stays at or below the CPS Design Speed Limit.	SM.CxDC.19

2. No-go zone

The No-Go Zone Test evaluates the ability of the CxDC to prevent unauthorized TMMs from entering demarcated areas.

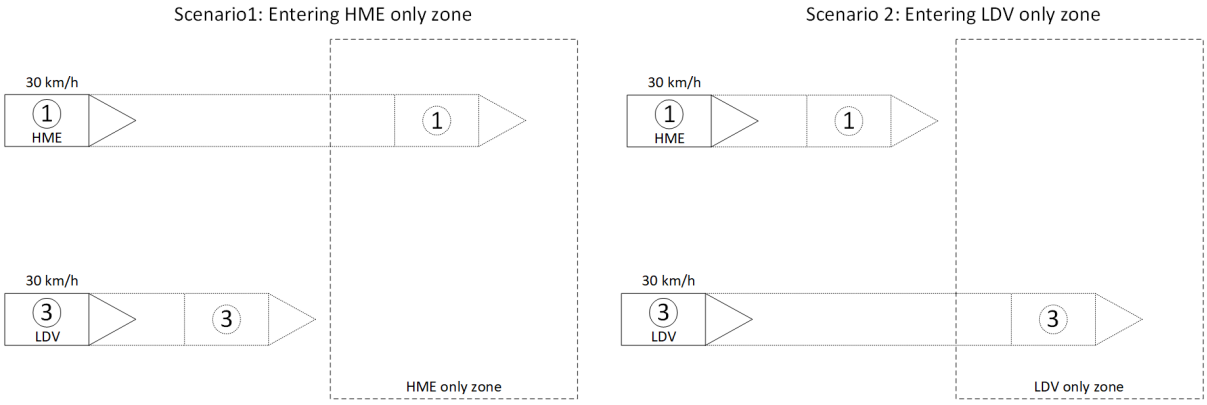

Figure 13: Speed limited zone test configuration

2.1. **Scenario 1: HME only zone**

2.1.1. Set up an HME only zone as depicted in the figure.

2.1.2. Note GPS coordinates of edge of HME only zone.

2.1.3. Set speed limit in test area to at least 40 km/h.

2.1.4. TV1 is HME and outside vicinity of HME only zone.

2.1.5. TV3 is LDV and outside vicinity of HME only zone.

2.1.6. Have each TV approach HME only zone at speed 30 km/h.

2.1.7. Repeat 3 times for each TV.

2.1.8. Expected behaviour:

2.1.8.1. HME has no EW.
2.1.8.2. HME can continue with Normal Operation.
2.1.8.3. LDV has EW.
2.1.8.4. LDV has CPS Stop before entering the HME only zone.
2.1.8.5. Stop gap of 15 ±5 m between LDV and HME only zone.

2.2. **Scenario 2: LDV only zone**
2.2.1. Set up an LDV only zone as depicted in the figure.
2.2.2. Note GPS coordinates of edge of LDV only zone.
2.2.3. TV1 is HME and outside vicinity of LDV only zone.
2.2.4. TV3 is LDV and outside vicinity of LDV only zone.
2.2.5. Have each TV approach LDV only zone at speed 30 km/h.
2.2.6. Repeat 3 times for each TV.
2.2.7. Expected behaviour:
2.2.7.1. LDV has no EW.
2.2.7.2. LDV can continue with Normal Operation.
2.2.7.3. HME has EW.
2.2.7.4. HME has CPS Stop before entering the HME only zone.
2.2.7.5. Stop gap of 15 ±5 m between HME and LDV only zone.

Table 33: No-go zone CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.02.1	Conforms to requirements of Table 31.	See Table 31
SM.CxDC.AC.02.2	CxDC must prevent TMMs from entering areas that are not permitted to.	SM.CxDC.16.2 SM.CxDC.16.4

3. LDV approach

The LDV approach test evaluates the ability of the CxDC to prevent collisions when an LDV approaches an HME.

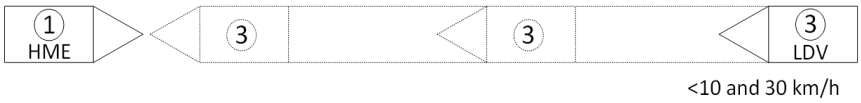

Figure 14: LDV approach test configuration

3.1. Position HME and LDV in a straight line, LDV at least 200 m away.
3.2. Set test area speed limit to at least 40 km/h.

3.3. **Scenario 1: LDV approach with HME in Operator Stop**
3.3.1. LDV in Normal Operation.
3.3.2. Engage Operator Stop on HME.
3.3.3. Drive LDV at <10 km/h towards HME.
3.3.4. Once LDV has stopped, engage NOP on HME.
3.3.5. Attempt to drive HME towards LDV.
3.3.6. Repeat 3 times
3.3.7. Expected behaviour
3.3.7.1. HME has CPS Stop when attempting to move when LDV is in vicinity.
3.3.7.2. LDV slows and stops with 15 ±5 m gap to HME.

3.4. **Scenario 2: LDV approach with HME in Normal Operation**

3.4.1. HME and LDV in Normal Operation.

3.4.2. Drive LDV at 30 km/h towards HME.

3.4.3. Once LDV has stopped, attempt to drive HME towards LDV.

3.4.4. Repeat 3 times.

3.4.5. Expected behaviour:

3.4.5.1. HME has CPS Stop when attempting to move when LDV is in vicinity.

3.4.5.2. LDV slows and stops with 15 ±5 m gap to HME.

Table 34: LDV approach CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.03.1	Conforms to requirements of Table 31.	See Table 31
SM.CxDC.AC.03.2	The CPS shall prevent potential collisions between HMEs (including FELs, excavators, etc.) and LDVs in all operational areas. The CPS shall allow the LDV to approach the HME if the HME is in Safe Park or Operator Stop. The CPS shall only allow the HME to move once the LDV is out of the vicinity.	SM.CxDC.11

4. Straight dovetail and overtaking

The straight dovetail and overtaking test evaluates the ability of the CxDC to prevent rear-end collisions and near-misses while allowing overtaking on straight roads.

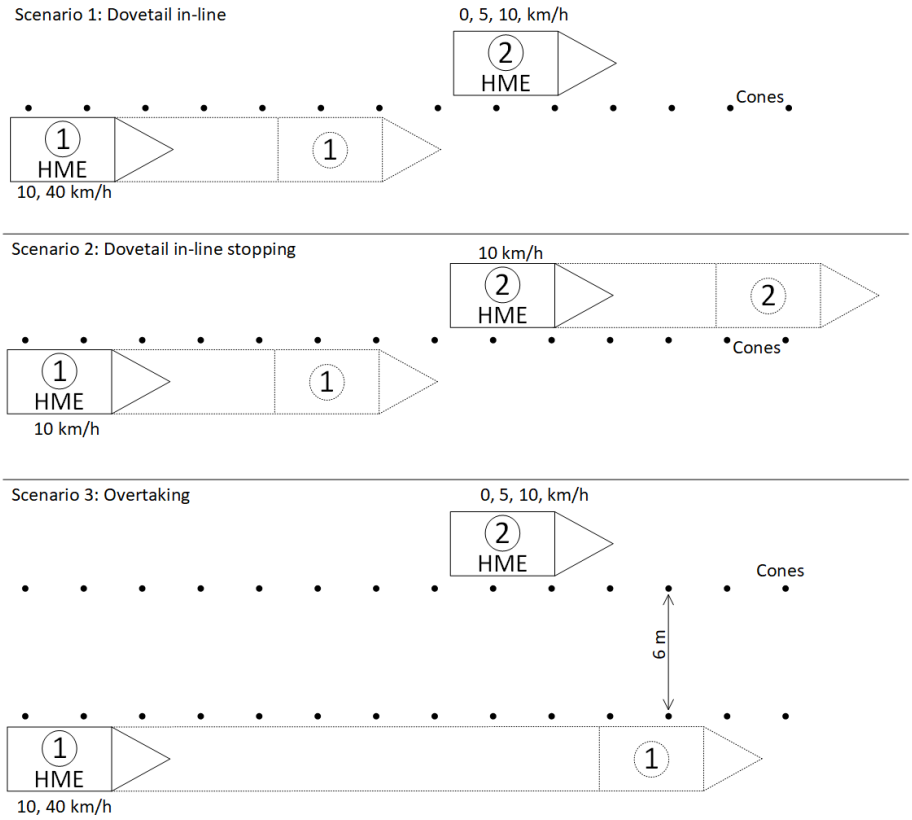

Figure 15: Straight dovetail and overtake test layout

4.1. Set up test area with pass gap of 6 m as depicted in the figure.

4.2. Speed limit in the test area is at least 40 km/h.

4.3. TV1 is HME, outside vicinity of TV2 and can travel at 10 and 40 km/h.

4.4. TV2 is HME, outside vicinity of TV1 and can travel at 0, 5 and 10 km/h.

4.5. **Scenario 1: Dovetail in-line**

4.5.1. Have TV1 approach TV2 at combinations of 10-0, 10-5, 40-0, 40-5, 40-10 km/h respectively in dove-tail fashion directly in-line.

4.5.2. Repeat 3 times.

4.5.3. Expected behaviour:

4.5.3.1. EW on TV1.

4.5.3.2. No automatic intervention on TV2 (the lead vehicle).

4.5.3.3. TV1 receives CPS Slow and reduces speed until its speed matches or falls below TV2's speed.

4.5.3.4. Following distance > 10 m.

4.6. **Scenario 2: Dovetail in-line and stopping**

4.6.1. Have TV1 follow TV2, both driving at 10 km/h.

4.6.2. Ensure that following distance is > 50 m at the start of the test

4.6.3. Have TV2 stop.

4.6.4. Repeat 3 times.

4.6.5. Expected behaviour:

4.6.5.1. EW on TV1 .

4.6.5.2. TV1 receives CPS Stop and automatically slows and stops behind TV2.

4.6.5.3. No automatic intervention on TV2 (the lead vehicle).

4.6.5.4. Stop gap 15 ±5 m.

4.7. **Scenario 3: Overtaking**

4.7.1. Have TV1 approach TV2 at combinations of 10-0, 10-5, 40-0, 40-5, 40-10km/h respectively in overtaking fashion (i.e. in outside lane).

4.7.2. Repeat 3 times

4.7.3. Expected behaviour:

4.7.3.1. No EW on TV1.

4.7.3.2. No EW on TV2.

4.7.3.3. No CSP Slow on TV1.

4.7.3.4. No CPS slow on TV2.

Table 35: Straight dovetail and overtaking CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.04.1	Conforms to requirements of Table 31.	See Table 31
SM.CxDC.AC.04.2	The CPS must prevent collisions when TMMs are following each other. The CPS must prevent collisions between slow moving TMMs and faster TMMs approaching from the rear. CPS must allow faster moving TMM to overtake. CPS must prevent collisions with on-coming traffic. CPS must prevent near misses. The CPS must prevent collisions between TMMs passing broken-down TMMs.	SM.CxDC.13.1 SM.CxDC.14.1 SM.CxDC.14.2 SM.CxDC.17.4

5. Curved dovetail

The curved dovetail test evaluates the ability of the CxDC to prevent rear-end collisions on curved roads.

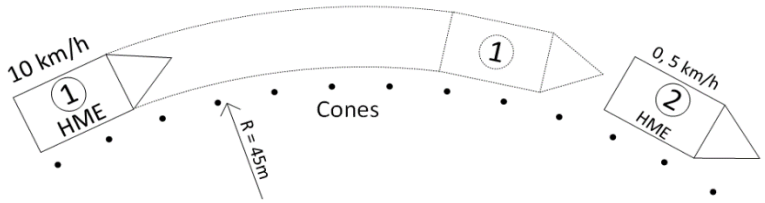

Figure 16: Curved dovetail test layout

5.1. Set up test area as depicted in the figure.
5.2. Speed limit in the test area is at least 20 km/h.
5.3. Have TV1 approach TV2 at combinations of 10-5 and 10-0 km/h respectively in dove-tail fashion (in-line).
5.4. Repeat three times for each speed combination.
5.5. Expected behaviour:
5.5.1. EW on TV1.
5.5.2. No automatic intervention on TV2 (the lead vehicle).
5.5.3. TV1 receives CPS Slow and reduces speed until its speed matches or falls below TV2's speed.
5.5.4. Following distance > 10 m.

Table 36: Curved dovetail CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.05.1	Conforms to requirements of Table 31	See Table 31
SM.CxDC.AC.05.2	The CPS must prevent collisions when TMMs are following each other around curves. The CPS must prevent collisions between slow moving TMMs and faster TMMs approaching from the rear around curves.	SM.CxDC.13.2

6. Straight Head-on and passing

The straight head-on test evaluates the ability of the CxDC to prevent head-on collisions and near-misses while allowing passing on straight roads.

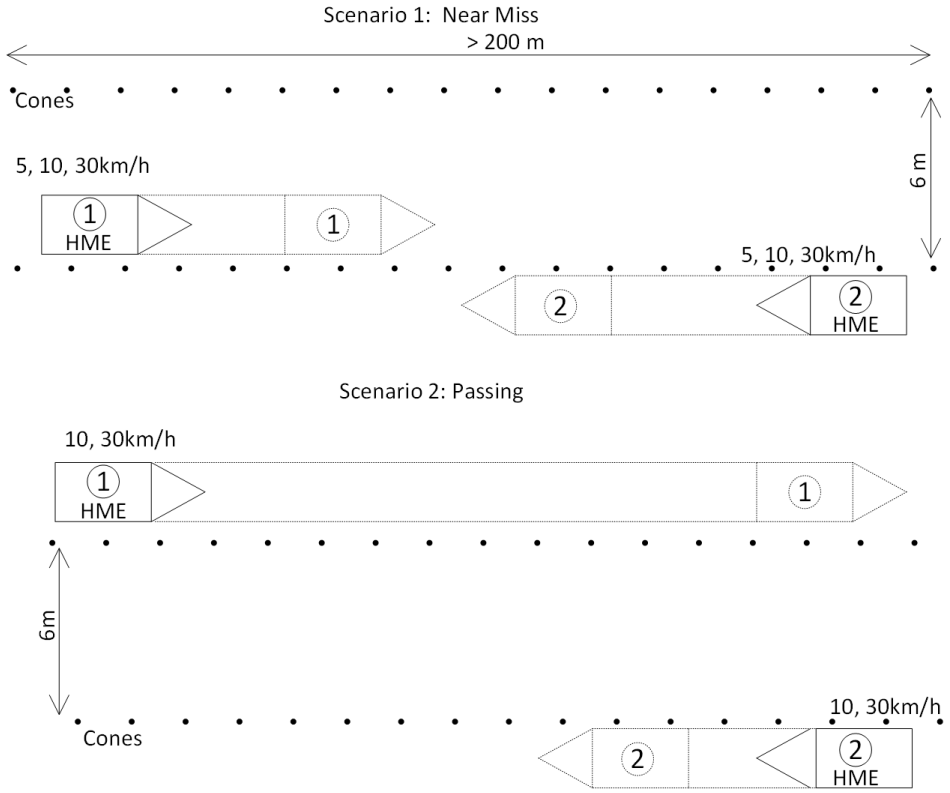

Figure 17: Head-on and passing test layout

6.1. Set up test area as depicted in figure.

6.2. Speed limit in the test area is at least 40 km/h.

6.3. **Scenario 1: Near miss**

6.3.1. Position TV 1 and TV2 so that the TVs will attempt to pass each other with a very small offset (near miss).

6.3.2. Have TV1 approach TV2 at speed combinations of 5-5, 10-5, 10-10, 30-10, 30-30km/h.

6.3.3. Repeat three times for each speed combination.

6.3.4. Expected behaviour

6.3.4.1. EW on TV1.

6.3.4.2. EW on TV2.

6.3.4.3. TV1 receives CPS Stop and automatically stops.

6.3.4.4. TV2 receives CPS Stop and automatically stops.

6.3.4.5. Stop gap is 15 ±5 m.

6.4. **Scenario 2: Passing**

6.4.1. Position TV1 and TV2 so that the vehicles will pass each other with a gap of 6 m.

6.4.2. Have TV1 approach and pass TV2 head-on at speed combinations of 10-10, 30-10, 30-30km/h.

6.4.3. Repeat three times for each speed combination.

6.4.4. Expected behaviour:

6.4.4.1. No EW on TV1.
6.4.4.2. No EW on TV2.
6.4.4.3. No automatic intervention on TV1.
6.4.4.4. No automatic intervention on TV2.

Table 37: Straight head-on and passing CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.06.1	Conforms to requirements of Table 31.	See Table 31
SM.CxDC.AC.06.2	The CPS must prevent head-on collisions between TMMs. The CPS must allow TMMs to pass safely. CPS must prevent near misses.	SM.CxDC.15.1

7. Curved head-on and passing

The curved head-on test evaluates the ability of the CxDC to prevent head-on collisions and near-misses while allowing passing on curved roads.

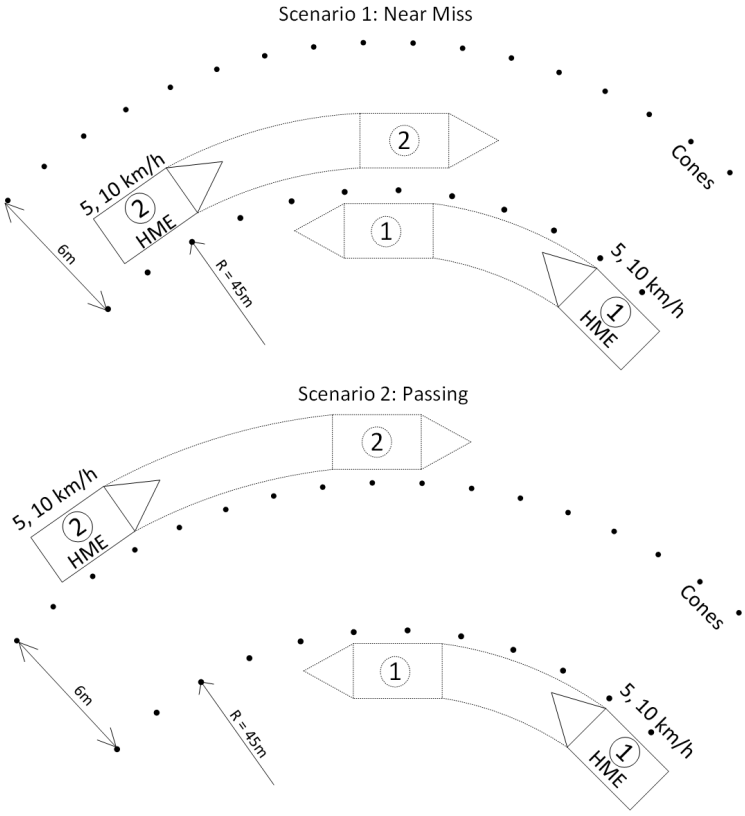

Figure 18: Curved head-on and passing test layout

7.1. Set up test area as depicted in figure.
7.2. Speed limit in the test area is at least 20 km/h.

7.3. **Scenario 1: Near Miss**
7.3.1. Place TV 1 and TV2 such that vehicles will attempt to pass each other with a very small offset (near miss).
7.3.2. Have TV1 approach TV2 head-on at speed combinations of 5-5, 10-5, 10-10km/h.
7.3.3. Repeat 3 times for each speed combination.
7.3.4. Expected behaviour:

7.3.4.1. EW on TV1.
7.3.4.2. EW on TV2.
7.3.4.3. Automatic intervention on TV1.
7.3.4.4. Automatic intervention on TV2.
7.3.4.5. Stop gap 15 ±5 m.

7.4. **Scenario 2: Passing**

7.4.1. Position TV1 and TV2 such that vehicles will pass each other with a gap of 6 m.
7.4.2. Have TV1 approach and pass TV2 head-on at speed combinations of 5-5, 10-5 and 10-10 km/h.
7.4.3. Repeat 3 times for each speed combination
7.4.4. Expected behaviour:
7.4.4.1. No EW on TV1.
7.4.4.2. No EW on TV2.
7.4.4.3. No automatic intervention on TV1.
7.4.4.4. No automatic intervention on TV2.

Table 38: Curved head-on and passing CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.07.1	Conforms to requirements of Table 31.	See Table 31
SM.CxDC.AC.07.2	The CPS must prevent head-on collisions between TMMs. The CPS must allow TMMs to pass safely. CPS must prevent near misses.	SM.CxDC.15.2

8. T-junction

The T-junction test evaluates the ability of the CxDC to prevent collisions at T-junctions.

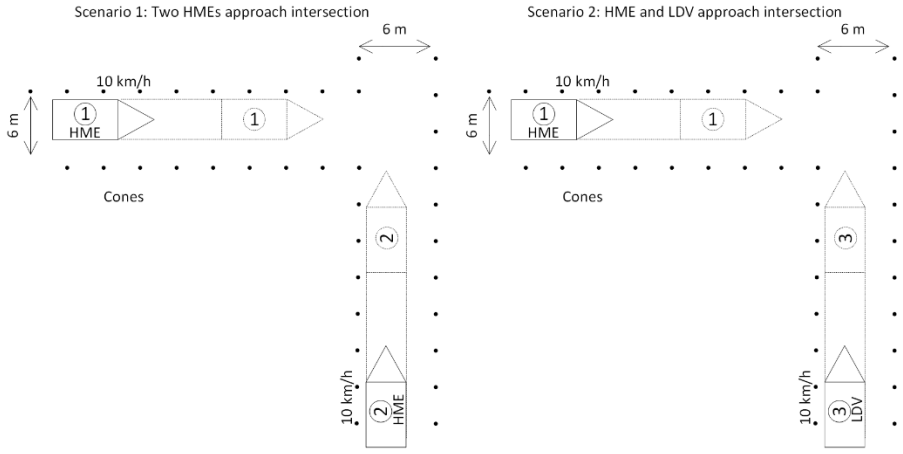

Figure 19: T-junction test layout

8.1. Set up a T-intersection in test area as depicted in the figure.
8.2. Set test area speed limit to at least 20 km/h.
8.3. TV1 is HME, outside the vicinity of all other vehicles, and the intersection.
8.4. TV2 is HME, outside the vicinity of all other vehicles, and the intersection.
8.5. TV3 is an LDV, outside the vicinity of all other vehicles, and the intersection .

8.6. **Scenario 1: Two HMEs approach intersection**

8.6.1. TV3 does not participate in this scenario.

8.6.2. Have TV1 and TV2 approach one another at a speed of 10 km/h such that the collision point will be inside the intersection.
8.6.3. Repeat 3 times.
8.6.4. Expected behaviour:
8.6.4.1. At least one of the TVs must have CPS Stop response.
8.6.4.2. CPS Stop must be preceded by EW.
8.6.4.3. Minimum distance between TV1 and TV2 must be > 6 m.

8.7. **Scenario 2: HME and LDV approach intersection**
8.7.1. TV2 does not participate in this scenario.
8.7.2. Have TV1 and TV3 approach one another at a speed of 10 km/h such that the collision point will be inside the intersection.
8.7.3. Repeat 3 times.
8.7.4. Expected behaviour:
8.7.4.1. At least one of the TVs must have CPS Stop response.
8.7.4.2. CPS Stop must be preceded by EW.
8.7.4.3. Minimum distance between TV1 and TV3 must be > 6 m.

Table 39: T-junction CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.08.1	Conforms to requirements of Table 31.	See Table 31
SM.CxDC.AC.08.2	The CPS must prevent potential collisions at intersections.	SM.CxDC.16.1

9. Multiple interactor intersection

The multiple interactor intersection test evaluates the ability of the CxDC to prevent collisions at intersections with multiple TMMs.

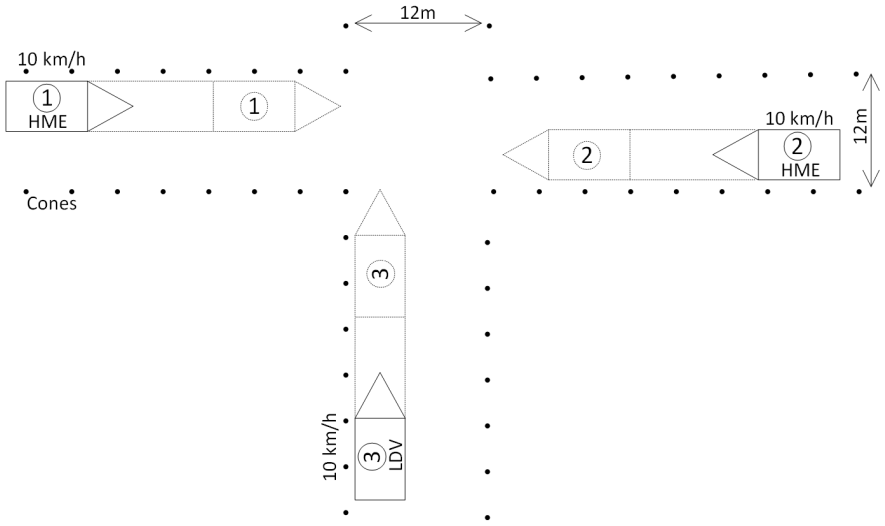

Figure 20: Multiple interactor intersection test layout

9.1. Set up the test area as depicted in the figure.
9.2. Set test area speed limit to at least 20 km/h.
9.3. TV1 is HME, outside the vicinity of all other vehicles, and the intersection.
9.4. TV2 is HME, outside the vicinity of all other vehicles, and the intersection.
9.5. TV3 is an LDV, outside the vicinity of all other vehicles, and the intersection.

9.6. Have countdown or trigger event to have TV1, TV2 and TV3 approach one another at 10 km/h such that the collision point will be in the intersection.

9.7. Repeat 3 times.

9.8. Expected behaviour:

9.8.1. At least two TVs must have CPS Stop response.

9.8.2. CPS Stop must always be preceded by EW.

9.8.3. Minimum distance between any TVs must be > 6 m.

Table 40: Multiple interactor intersection CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.09.1	Conforms to requirements of Table 31.	See Table 31
SM.CxDC.AC.09.2	The CPS must prevent potential collisions at intersections, including crossings where multiple TMMs from different directions may interact.	SM.CxDC.16.3 SM.CxDC.17.5

10. Dump area

The dump area test evaluates the ability of the CxDC to prevent collisions in areas designated for dumping.

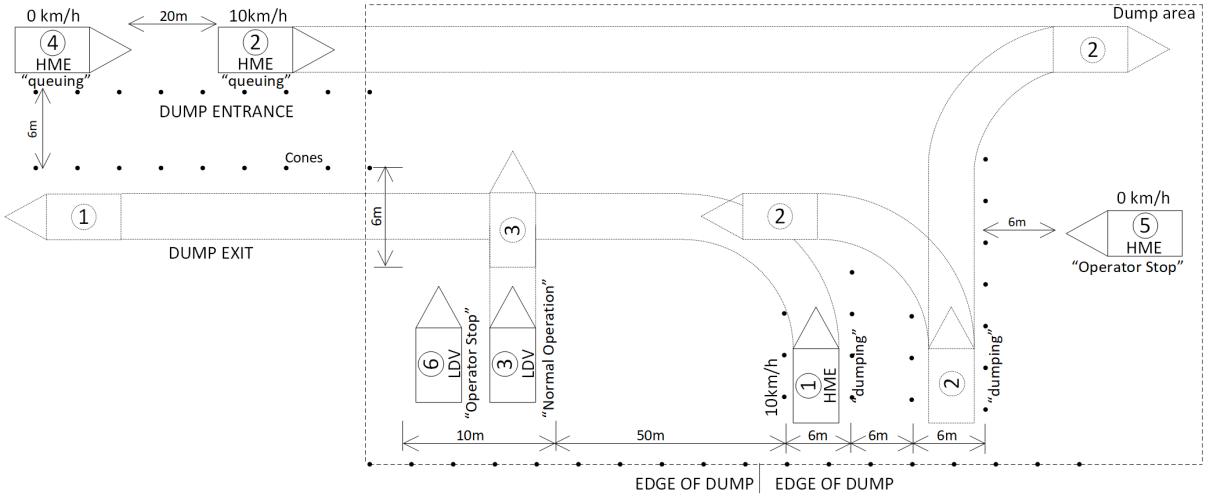

Figure 21: Dump area test layout

10.1. Set up test area as depicted in the figure.

10.2. Set test area speed limit to 10 km/h.

10.3. TV1, TV2, TV4 and TV5 are HMEs, outside vicinity of all other vehicles.

10.4. TV3 and TV6 are LDVs, outside vicinity of all other vehicles.

10.5. **Movement 1:** Perform the following 2 instructions simultaneously:

10.5.1. Have TV1 drive FWD at a speed < 10 km/h to simulate an HME leaving the dump area after dumping its load. TV1 must exit the test area.

10.5.2. Have TV2 enter the dump by driving FWD to at a speed < 10 km/h to such a point that it is in position to REV into its dumping spot. REV into the dumping position.

10.5.3. Expected behaviour:

10.5.3.1. No EW on any TVs.

10.5.3.2. No CPS Stop on any TVs.

10.5.3.3. No use of OVERRIDE, BYPASS_PROPULSION, ACKNOWLEDGE or similar features to allow Normal Operation. Note: Speed Limit zone permitted.

10.6. **Movement 2:** Perform the following 2 instructions simultaneously:

10.6.1. Have TV2 leave its dumping spot in a FWD direction driving < 10 km/h.

10.6.2. Have TV3 simulate an LDV leaving its parking bay when it is unsafe to do so. TV3 blocks TV2's exit route.

10.6.3. Expected behaviour:

10.6.3.1. EW on TV2.

10.6.3.2. No EW on TV1, TV4, TV5, TV6.

10.6.3.3. CPS Stop on TV2.

10.6.3.4. EW and CPS Stop on TV3 not assessed.

10.6.3.5. No use of OVERRIDE, BYPASS_PROPULSION, ACKNOWLEDGE or similar features to allow Normal Operation.

10.6.3.6. Minimum gap of 1-4 m between TV2 and TV3.

10.7. Repeat movements 1 and 2 three times, sequentially.

Table 41: Dump area CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.10.1	Conforms to requirements of Table 31	See Table 31
SM.CxDC.AC.10.2	Dump area speed limit is not exceeded. Minimum stop gap of 2.5m (±1.5m) if speed limit is ≤ 10km/h. Stop gap maintained between all types of TMMs in the dump area. Stop gap is the shortest distance between TMMs. No use of operator override/bypass/acknowledge when performing normal mining operations and procedures.	SM.CxDC.17.1 SM.CxDC.17.5

11. Loading area

The load area test evaluates the ability of the CxDC to prevent collisions in areas designated for loading.

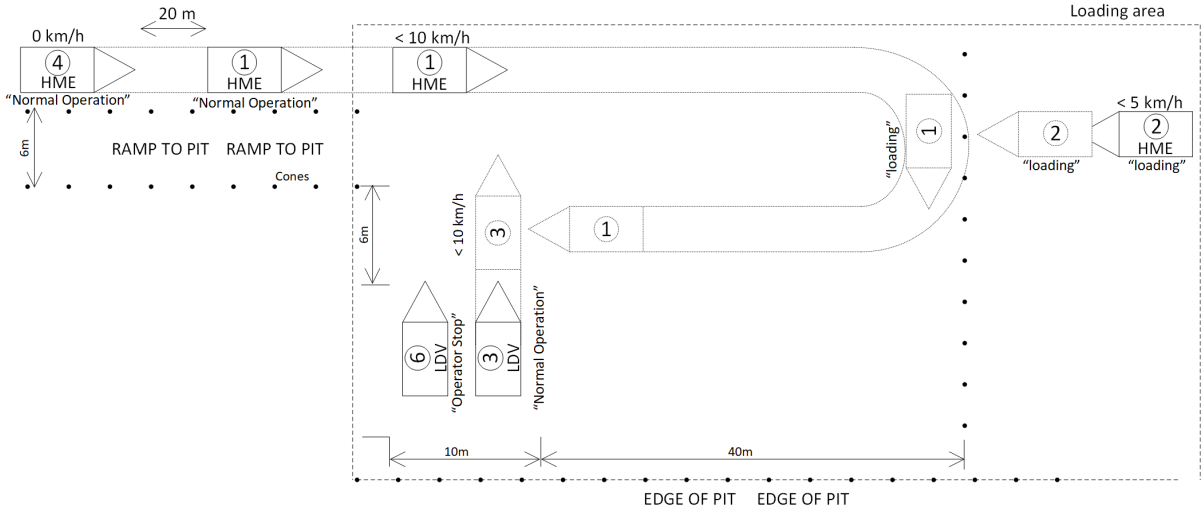

Figure 22: Loading area test layout

11.1. Set up test area as depicted in the figure.

11.2. Set speed limit to 10 km/h in test area.

11.3. TV1, TV2 and TV4 are HMEs, outside vicinity of all other vehicles.

11.4. TV3 and TV6 are LDVs, outside vicinity of all other vehicles.

11.5. **Movement 1:**

11.5.1. Have TV1 drive FWD at a speed < 10 km/h to simulate an HME entering the loading area. TV1 must reach the loading position in front of TV2 and come to Operator Stop.

11.5.2. Expected behaviour:

11.5.2.1. No EW on any TV.

11.5.2.2. Normal operation on all TVs.

11.5.2.3. No use of OVERRIDE, BYPASS_PROPULSION, ACKNOWLEDGE or similar features to allow Normal Operation. Note: Speed Limit zone permitted.

11.6. **Movement 2:**

11.6.1. Have TV2 approach TV1 to simulate a loading action, TV2 to move FWD, stop for a few seconds, and then move in REV to its original position.

11.6.2. TV2's speed should not exceed 5 km/h.

11.6.3. TV2 must stay at least 1 m away from TV1.

11.6.4. Expected behaviour:

11.6.4.1. No EW on any TV.

11.6.4.2. No CPS Stop on any TV.

11.6.4.3. No use of OVERRIDE, BYPASS_PROPULSION, ACKNOWLEDGE or similar features to allow Normal Operation; Note: Speed Limit zone permitted.

11.7. **Movement 3:** Perform the following 2 manoeuvres simultaneously.

11.7.1. Have TV1 leave its loading position in a FWD direction driving at < 10 km/h.

11.7.2. Have TV3 simulate an LDV leaving its parking bay when it is unsafe to do so. TV3 blocks TV1's exit route.

11.7.3. Expected behaviour:

11.7.3.1. EW on TV1.

11.7.3.2. No EW on TV2, TV4, TV5, TV6.

11.7.3.3. CPS Stop on TV1.

11.7.3.4. EW and CPS Stop on TV3 not assessed.

11.7.3.5. Stop gap of 1-4 m between TV1 and TV3.

11.7.3.6. No use of OVERRIDE, BYPASS_PROPULSION, ACKNOWLEDGE or similar features to allow Normal Operation. Note: Speed Limit zone permitted.

11.7.3.7. Repeat movements 1, 2 and 3 three times, sequentially.

Table 42: Loading area CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.11.1	Conforms to requirements of Table 31.	See Table 31
SM.CxDC.AC.11.2	Loading area speed limit is not exceeded. Minimum stop gap of 2.5m (±1.5m) if speed limit is ≤ 10km/h. Stop gap maintained between all types of TMMs in the dump area. Stop gap is the shortest distance between TMMs. No use of operator override/bypass/acknowledge when performing normal mining operations and procedures.	SM.CxDC.17.2 SM.CxDC.17.5

12. Parking area

The parking area test evaluates the ability of the CxDC to prevent collisions in hard parks.

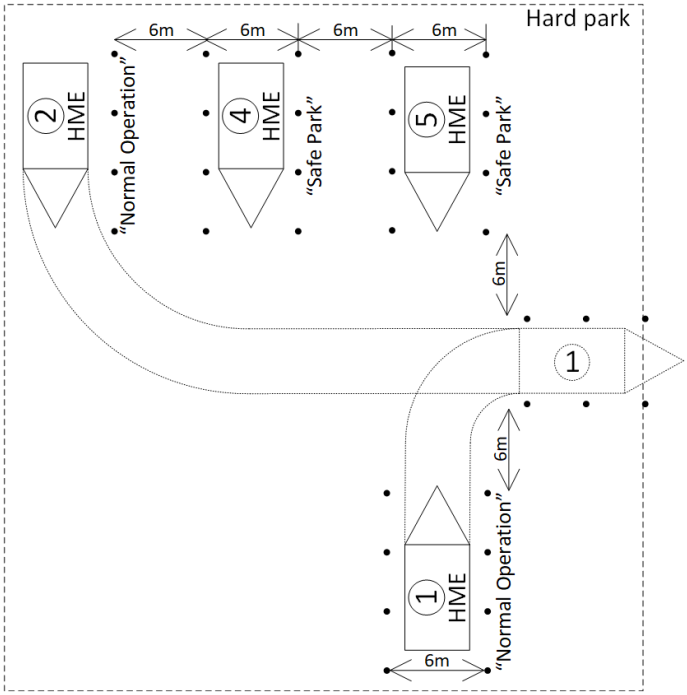

Figure 23: Parking area test layout

12.1. Set up test area as depicted in the figure.
12.2. Set speed limit in test area to 10 km/h.
12.3. TV1, TV2, TV4 and TV5 are HMEs, outside vicinity of all other vehicles.
12.4. All four TVs are in Operator Stop.
12.5. Performing the following two movements simultaneously:
12.6. TV1 enters Normal Operation and departs the parking area as indicated.
12.7. TV2 enters Normal Operation and departs the parking area as indicated.
12.8. Note: TV speeds to remain below 10 km/h.
12.9. Repeat 3 times
12.10. Expected behaviour:
12.10.1. No EW on any TV.
12.10.2. No CPS Stop on any TV.
12.10.3. No use of OVERRIDE, BYPASS_PROPULSION, ACKNOWLEDGE or similar features to allow Normal Operation. Note: Speed Limit zone permitted.

Table 43: Multiple interactor intersection CxDC acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.12.1	Conforms to requirements of Table 31.	See Table 31
SM.CxDC.AC.12.2	Hard park speed limit is not exceeded. Minimum stop gap of 2.5m (±1.5m) if speed limit is ≤ 10km/h. Stop gap maintained between all types of TMMs in the dump area. Stop gap is the shortest distance between TMMs. No use of operator override/bypass/acknowledge when performing normal mining operations and procedures.	SM.CxDC.17.3 SM.CxDC.17.5

13. CxD Maintenance Override

This test is used to verify the correct functioning of the CxDC before and after CxD maintenance override is activated.

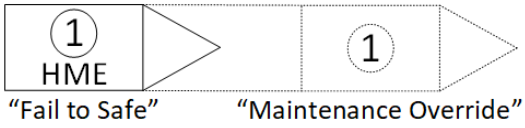

Figure 24: Maintenance override test configuration

13.1. TV1 with paired operator is stationary with Normal Operation active.

13.2. **Stage 1: Override inactive**

13.2.1. Induce a failure that will result in FTSWHI on the CxD and STAND_DOWN active.

13.2.2. Expected behaviour:

13.2.2.1. OWS inside TV1 has EW and STAND_DOWN active.

13.3. **Stage 2: Maintenance override active**

13.3.1. Activate CxD maintenance override on TV1.

13.3.2. Expected behaviour:

13.3.2.1. OWS requires authentication to activate override.

13.3.2.2. OWS inside TV1 clearly indicates override active.

13.3.2.3. CxDC uses BYPASS_PROPULSION to indicate override.

13.4. Repeat 3 times.

Table 44: Override acceptance criteria

AC No.	Criteria	Func. Req. No.
SM.CxDC.AC.13.1	Conforms to requirements of Table 31.	See Table 31
SM.CxDC.AC.13.2	Credentials required to activate maintenance override. Maintenance override implemented as specified in ISO 21815-1:2022.	SM.CxDC.21
SM.CxDC.AC.13.3	BYPASS_PROPULSION is used to indicate override.	SM.CxDI.07.4

Deviations from protocol during testing

If any deviation from the test protocol occurs for any reason, have all parties accept in writing:

1. The proposed deviation.
2. Reason for the proposed deviation.
3. Motivation why the proposed deviation will not affect the purpose of the test.

Appendix 7: CxD test information sheet

Table 45: CxD product information sheet

Test details	
Surface CxD test(s) performed	
Test location	
Test date	
TMM Emulator	
TMM Emulator Hardware	
TMM Emulator Firmware	
Name of test engineer	
Signature	
Signing this test information sheet confirms that the TMM Emulator and all test instrumentation used during the test were properly calibrated and commissioned and integration with the CxD product was checked prior to commencing with the test.	
CxD Details	
CxD Developer / Vendor	
CxD model	
Serial number	
ICASA T/A or Spectrum License? Provide details	
EMC tests passed? Provide details	
CxDC Details	
CxDC Hardware	
CxDC Firmware	
CxDC Other information	
CxDI Details	
Interface Hardware	
Interface Firmware	
ISO21815-2 Version	
ISO21815-2 Negotiation sequence specifics	
CLK Details	
CLK firmware	
Specifics recorded in log file	
CLK storage capacity	
Estimated storage period	
Mechanism to obtain log files	
Security measures to prevent log file deletion and alteration	
EW Details	
OWS Specifics	
DTS Details	
RF operating frequencies	
DTS sensing technologies	

CxD Developer / Vendor Sign-off	
Name of duly authorized CxD developer / vendor representative	
Date	
Signature	
Signing this test information sheet confirms that the CxD product under test was commissioned and tested as per the CxD specification prior to the commencement of the test. Reasonable steps were taken to ensure integration with the TMM Emulator was successful.	
Safety sign-off	
Name of test safety officer	
Date	
Signature	
Signing this test information sheet confirms that the test safety officer has taken reasonably practicable measures to ensure the safety of those present at the CPS test, including but not limited to: ● A site risk assessment ● Ensuring adequate emergency medical supplies are available ● Test safety briefing prior to the commencement of testing ● Ensuring steps set out in Appendix 8: Test safety protocol have been followed and will be adhered to	

Appendix 8: Test safety protocol

1. Purpose

The purpose of this document is to prescribe the safety management and controls required to ensure that safety and health risks are minimised due to interactions between TMMs and pedestrians during testing at the identified test sites.

Note: this document does not take the place of the pre-test risk assessment which may identify risks that are local or local environment induced. A pre-test risk assessment is always required, which includes a test site safe declaration, prior to the commencement of the tests each day or after a significant event.

2. Scope

The scope of this document applies to the safety management for all CPS testing performed at any test site where the MHSA is not in force. The scope of this document defines the following safety controls at the CPS test sites:

1. Access control and safety management during testing,
2. Emergency management of the test site during CPS testing,
3. Risk assessment completed for the testing,
4. Test area layout including signage for the test area,
5. Evacuation plan,
6. Test plan for each test.

3. Risk assessment

A CPS testing site risk assessment must be compiled for the test site and tests to be carried out. This risk assessment must be filed in a separate document and kept in the site office on the test site for easy access and reference by all on site.

A separate risk assessment will be conducted with all contractors on site and be available on the test site for ease of access and reference by all.

Each CxD and TMM CPS provider or contractor shall have completed an issue-based risk assessment for the fitting to and removal of their CPS systems from the TMMs.

Each TMM OEM provider or contractor shall have completed an issue-based risk assessment for the fitting to and removal of their CPS systems from the TMMs.

All controls defined in the risk assessments must be implemented.

4. Pre-test risk assessment

Prior to testing each day, a pre-test risk assessment must be conducted to ensure that any specific environmental or other risks specific to that day or tests are identified and controls put into place. Note: no tests may be conducted without the pre-test risk assessment being completed and signed off by both the legal appointees and all those involved in the test on that day.

5. Site entry register

Site entry to any person either included in the testing or invited is limited. All persons entering the site are required to sign a test site entry register and sign out before leaving the site.

6. Safety management

In accordance with the MHSA and the OHSA as well as the site safety policy, safety is the top priority on the test site. All persons or TMMs entering the test site must have authorisation to do so and shall comply with all site safety procedures and the test site specific safety requirements contained in this document.

The overarching safety management approach is the safety approach that would normally be followed in accordance with the MHSA and the OHSA. The safety approach is expanded below:

7. Before work begins

The site safety officer shall assess whether the site, task and issue-based risk assessment controls are still valid and address all the risks in the risk assessment,

The site safety officer shall conduct the pre-test risk assessment and sign it off with the test engineer,

- Safety talk led by the site safety officer – all people performing test site work must attend and sign the safety talk attendance register.
- Each TMM operator shall have a pre-start check performed by the operator. The completed pre-start check sheet shall be filed in the filing system and kept in the test site office.
- Each TMM operator shall perform a functional brake test on each TMM prior to the start of testing each day (see Annexure 3 for pre-start checklist),
- The test site responsible engineer shall verify that the test site is safe and that the roads are in an acceptable and safe condition (see Annexure 4 for road audit methodology) and declare the site safe for testing to resume every day.
- The test site safety officer shall check that all people on site are wearing the appropriate PPE and that any tools being used are in a safe working condition and being used safely.
- Both the test site safety officer and site test engineer shall declare the site safe for testing and sign the safe declaration form.

Note 1: No tests shall commence unless all the above has been completed and signed off.

Note 2: While not derogating from employees' rights in terms of Section 22 and 23 of the MHSA, the test site safety officer and/or the test site engineer may stop the test at any time when they deem any situation to be unsafe.

Note 3: Any unsafe condition must be reported and can be reported by anyone on the test site (see Annexure 6 for unsafe condition reporting document and log).

8. Changes in risk during the day

Any changes that may increase the risk to safety and render current controls insufficient, will result in the test being placed on hold or suspended pending further risk assessment. The site safety officer and or the site test engineer will perform a pre-test risk assessment and make the final decision on whether the controls specified in the revised risk assessment are adequate to control the changes in risk. This revised pre-work risk assessment shall be filed in the risk assessment file in the site office.

Note: Changes in risk can emanate from (this list is not exhaustive):

- Heavy rainstorms, high wind where visibility is reduced due to dust,
- Dark cloud that impinges visibility,
- Tyre change,
- Hydrocarbon spills that need to be cleaned,

- Pedestrians or vehicles inadvertently wandering on to the test site,
- Severe road damage that requires repair,
- Lightning,
- Illness of someone who requires immediate treatment on site,
- Injury on site,
- High environmental temperature that has a high risk of inducing heat stroke,
- TMM accident where persons are injured,
- Near misses where a high potential of interaction between TMM and TMM or TMM and pedestrian occurs.

9. Emergencies

For all emergencies, the number below shall be contacted, and the test site emergency plans enacted.

Emergency number

In the case of an emergency being declared, the following persons will take charge:

- Test site safety officer, and if not available then
- Test site responsible engineer, and if not available then
- The next highest-ranking test site employee on the test site.

All emergencies, as listed below, shall be reported to the site safety officer as incidents as per the test site incident management procedure. The safety officer shall ensure that the incident is reported and follows the above procedure. A copy of the procedure must be available at the test area.

Should an emergency be declared, the process below shall be followed:

- The person in charge shall immediately identify themselves and contact the number above and follow the test site emergency procedures and plans,
- All persons on site, shall listen to the instructions given by the person in charge,
- If possible, the operators of the TMMs shall drive the TMMs to the test site parking area, safe-park the TMMs, exit the TMM, hand keys to the person in charge (if TMM has keys) and follow instruction given by that person,
- Before doing all of this, all movement/operations on site must be stopped.

10. Personal protective equipment (PPE)

There are four different PPE requirements for the test site:

- Visitors who remain behind the safety barrier in front of the site office: no PPE is required,
- Test site personnel who are not working on the vehicles: safety shoes, reflective vests, or other acceptable high-visibility apparel, and hat (cap or similar sunshade system is recommended),
- Persons working on the TMMs: overall (with reflective bands), safety shoes, hard hat, gloves (if applicable for the task being performed), dust goggles may be required if wind is blowing,
- TMM operators: overalls, safety shoes, safety hats.

- Access to the test site shall be limited to those involved in performing the test, invited visitors, CxD technology providers, CPS interface provider, OEMs and various test functions required to support the test. No person other than those designated to perform the test are allowed on the test site without the permission of either the site safety officer or the site test engineer.

11. Communication

Communication during testing will be via the following means:

- Two-way handheld radios on a channel specifically for the test,
- Mobile communication via mobile phones,

12. TMM fitment and work area

All CxD technology, CPS interface technology and any OEM fitments will be done in the TMM parking area referred to as the test vehicle parking bay. A 220V power point must be provided for tool energy.

Note: All employees (test site, CxD, OEMs and contractors) shall adhere to the test site tool safety standard. The site safety officer will audit the tools being used and the way in which they are being used on an ad hoc basis. Note: the test site has zero tolerance for any unsafe power tool or other tool used and any deviation from this will not be tolerated on the test site. It is the contractor supervisor that must ensure all fitment and tools used for the fitment are carried out in a safe manner and in accordance with the test site safety standards. The power tool safety and use thereof procedure shall be available in the site office.

CxD technology providers shall ensure that they have consulted with the OEM and have approved drawings for installation on the OEM TMMs. These drawings are to include the location of each component on the TMM (with any accompanying instructions) and electrical connections etc and included in the Section 21 files.

13. Environmental management

All chemicals brought onto site and used must have an accompanying Material Safety Data Sheet (MSDS). The MSDS must be lodged with the site safety officer and filed in the MSDS file in the site office. No chemicals are permitted on the test site without an MSDS. (this is for both health, fire risks and controls and environmental risks and management),

Hydrocarbon spills: All hydrocarbon (fuel and oil) spills will be treated in accordance with the test site environmental management procedure, a copy of which must be available in the site office. All spills must be reported to the site safety officer,

Waste and rubbish: Rubbish bins must be provided for the different types of waste. These bins must be located close to the test site office.

Smoking area: Smoking is only allowed in the area demarcated. No smoking is allowed in any other area on the test site.

14. At the conclusion of testing

1. The site test engineer shall declare work ended for the day,
2. All TMMs will go to the test vehicle parking bay, where they will safely park, lock the vehicles and insert wheel chocks,
3. The TMM keys (if TMM has keys) will be handed to the site safety officer who will lock them in the site office key cabinet,

4. If contractors wish to leave their vehicles on site, then the vehicles must be safely parked in the LDV parking area and keys handed to the site safety officer who will lock them in the site office key cabinet,
5. The site safety officer shall check the attendance register and ensure that all employees have signed out for the day,
6. The site safety officer shall check the site and declare it safe to be locked for the night and ensure that all employees are off site and shall lock the pedestrian gate.