Kumba Iron Ore, Sishen Mine

MULTI DISCIPLINARY TASK TEAM MEETING
21 APRIL 2023

MINERALS COUNCIL
SOUTH AFRICA

Significant Risk of TMM Collisions

Where in the Law is Significant Risk?

The term "*significant risk*" is found in the following regulations:

- **Chapter 3**: 3.3.3; 3.3.5; 3.9; 3.16 and 3.28
- **Chapter 4**: 4.2 (b), (b) (ii), (2) (ii), (3) (iv); 4.3 (6); 4.7; 4.11; 4.12; 4.14 (1); 4.16 (2), (5), (5) (a) and (7)
- **Chapter 5**: 5.1 (2) and (4)
- **Chapter 8**: 8.6 (1); 8.6 (2); 8.8 (3) (a), (b), (c), (f), (g), (a) and (b), **8.10 (1), (2), (2.2)**; 8.11 (12); 8.12 (9) (c)
- **Chapter 9**: 9.1 (2)
- **Chapter 10**: 10 (1), (2) (i) (cc), (m), (o) (bb)
- **Chapter 14**: 14.1; 14.4; 14.5; 14.6
- **Chapter 16**: 16.2 (2)
- **Chapter 17**: 17.1 (definition of restricted area); 17.6 (a); 17.7 (a), (c); 7.14 (b) (iv)
- **Chapter 23**: 23.4 (b), (c), (e), (i), (o) (iii),

54 TIMES!

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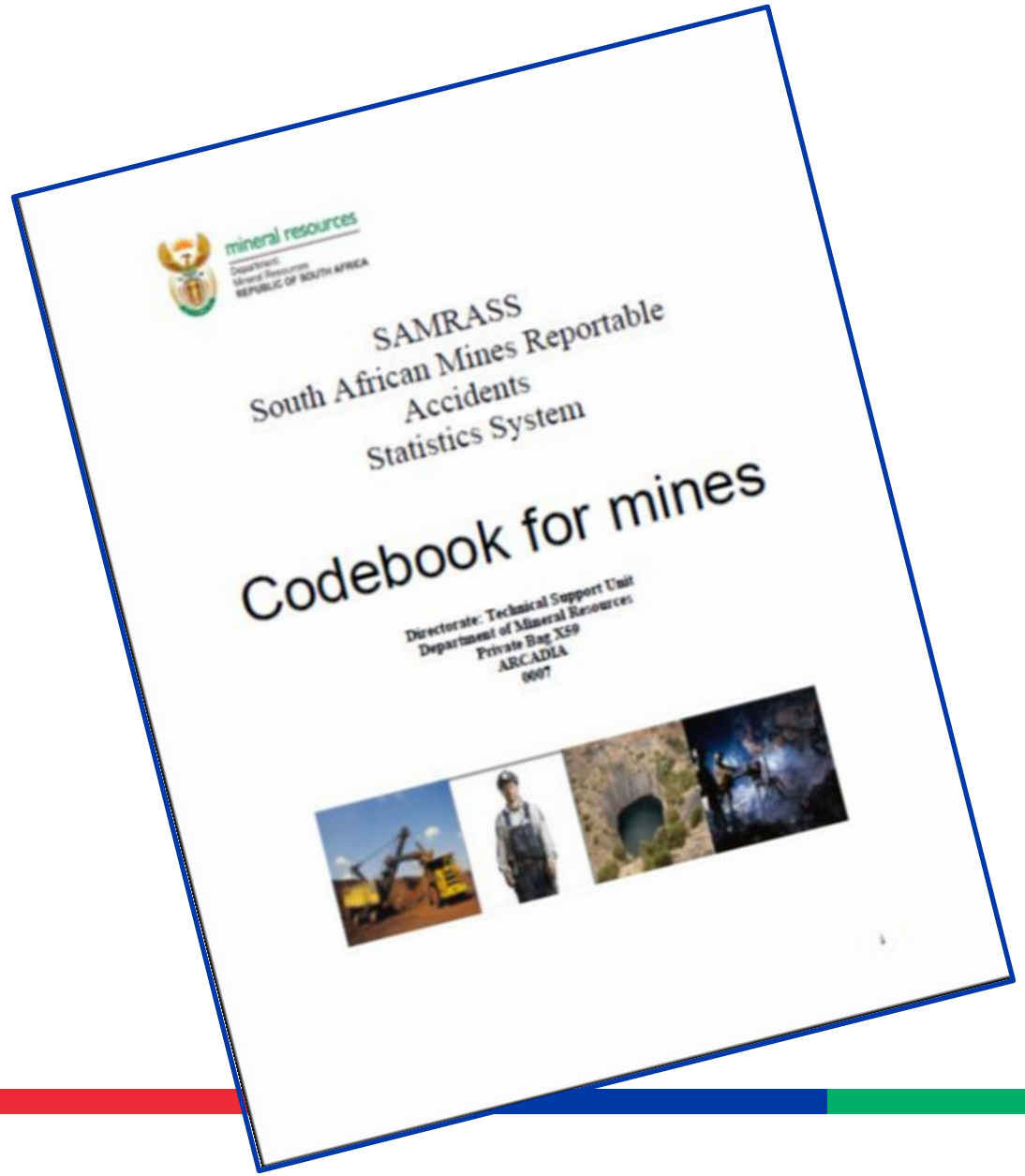
Has it Been Defined?


mineral resources
Department:
Mineral Resources
REPUBLIC OF SOUTH AFRICA

SAMRASS
South African Mines Reportable Accidents Statistics System

Codebook for mines

Directorate: Technical Support Unit
Department of Mineral Resources
Private Bag X59
ARCADIA
0007

SIGNIFICANT RISK

Section 11 of the Mine Health and Safety Act (MHSA) requires the *employer* to assess and respond to risk.

11 (1) Every *employer* must-

a) identify the *hazards* to *health* or *safety* to which employees may be exposed while they are at work;
b) assess the *risk* to *health* and *safety* to which employees may be exposed while they are at work;
c) *record* the significant *hazards* identified and *risks* assessed; and
d) make these records available for inspection by employees.

Section 102 of the MHSA defines the terms *hazard* and *risk* as follows:

"hazard" means a source of or exposure to danger

"risk" means the likelihood that occupational injury or harm to persons will occur

The term "significant" is defined in the Oxford Dictionary as being "noteworthy, of considerable amount or considerable effect or considerable importance".

Several of the dangerous occurrences refer to an incident occurring "which may pose significant risk to the safety of persons at a mine".

It is not possible to legislate the definition of significant risk, as this will invariably differ from mine to mine, commodity to commodity or even operation to operation. It is therefore the duty of every *employer* to conduct a risk assessment as required in terms of Section 11 of the MHSA to determine the significant risks to the safety of persons at that particular mine.

For example, a runaway vehicle may pose a significant risk to a large opencast mine, but will in all likelihood be an insignificant risk at a small salt mine. Similarly, a diamond mine may be exposed to the significant risk of an inrush of water while a small quarry would not be faced with that particular problem. It is often possible that an incident could occur where no persons are present, thereby not posing any risk at all. Under slightly different circumstances such as at a later time, or when persons are nearby, the same incident could occur and persons are injured or exposed to significant risk.

It is therefore the duty of the *employer* to ensure that he has identify all the hazards on that mine which may pose a significant risk to the health and/or safety of persons at that mine, and to ensure that any dangerous occurrences that occur are reported in terms of this regulation.

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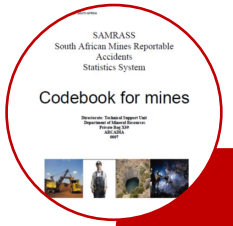
Significant Risk According to SAMRASS & MHSA

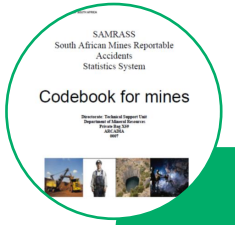


SAMRASS

The term "**significant**" is defined in the Oxford Dictionary as being "noteworthy, of considerable amount or considerable effect or considerable importance".

MHSA SEC. 102

"**risk**" means the likelihood that occupational injury or harm to persons will occur



SAMRASS

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TMM Collision Risk: Why is it an issue?

- Mines don't want to install CPS on all TMMs?
- Mines want to leverage the EMESRT approach to justify their CPS strategy?
- Mines don't want to introduce other controls to reduce significant risk of TMM collisions?

What is the reality?

- Since 2015 the TMM Regulations state:
- 8.10.1 The employer must take 1) **reasonably practicable measures** to 2) **ensure** that 3) pedestrians are 4) **prevented from being 5) injured** as a result of 6) **collisions** between 7) trackless mobile machines and **pedestrians**.
- 8.10.2 The employer must take **1) reasonably practicable measures** to 2) **ensure** that 3) **persons** are 4) **prevented from being 5) injured** as a result of 6) **collisions** between 7) **diesel** powered trackless mobile machines.

How do we prevent injuries

We must prevent TMM collisions

This is not anything new

- Most if not all mines consider TMM collisions with pedestrians as **Priority or Material Unwanted Events** (PUE or MUE) that must be prevented. As far as TMM collisions with pedestrians are concerned most mines consider such collisions as **Fatal Risks**. It is clear that all such collisions are considered significant risk. **No other Fatal Risk is considered insignificant**.
- As for TMM-to-TMM collisions, most if not all mines consider any Heavy Mining Equipment (HME) collision as a **Priority or Material Unwanted** Event and hence significant risk and in particular HME to LDV collisions. **No other PUE is considered insignificant**

Why then must TMMs only have CPS when there is a significant risk of collision?

- There are **other** Controls (Reasonably Practicable Measures) to prevent TMM collisions and in doing so reduce the risk of TMM collisions to be **insignificant**.

Sec 11 states the order in which the TMM collision hazard must be dealt with

1. **substituting** a hazard with something, or a number of things, that gives rise to a lesser risk.
2. **isolating** the hazard from any person exposed to it.
3. implementing **engineering** controls
4. minimizing the risk as far as is reasonably practicable by implementing **administrativ**e controls,

- A mine cannot use Collision Prevention Systems (CPS) as the **only** measure to fulfil his/her duty in terms of Section 11. (CPS is not a silver bullet for collision prevention)
- It could be argued that a mine will have to still take other measures than only CPS. A practical example is the use of centre berms on bi-directional haul roads to prevent head on collisions of two TMMs.

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Significant Risks of TMM Collisions

- The worst case consequence of any vehicle to vehicle (V-V) and vehicle to pedestrian (V-P) interaction is a fatality irrespective of the speed of the vehicle(s).

CONSEQUENCE ≥ **HIGH**

- Unless prevented, it can be agreed that there will be a "noteworthy" likelihood that occupational injury or harm to persons will occur as a result of V-V or V-P collision.

SIGNIFICANT RISK OF TMM COLLISIONS

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What are the implications if the mine don’t want to introduce other reasonably practicable measures to prevent TMM

- **All** the TMMs operating where there is a significant risk of collision must be fitted with:

1. Auto detection **and**
2. effective warning to both operators/operator and pedestrian when a collision is imminent **and**
3. provide the operator with time to take appropriate action **and**
4. have an auto slow and stop ability to prevent a potential collision when the operator/pedestrian does not take the appropriate action **and**
5. Have a fail to safe function without human intervention

CPS

L9

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THE TEST FOR REASONABLY PRACTICAL MEASURES TO PREVENT TMM COLLISIONS

Reasonably Practicable Test

1. Like Significant Risk, Reasonably Practicable is **not the opinion of any individual or group**; what is 'reasonably practicable' is determined **objectively**.
2. **What can be done**? **what can be done should be done**!
3. **Consider all of the relevant matters both possible and reasonable**
4. **The mine can't contract out its obligations**

What Matters to consider

5. **The likelihood of the hazard or the risk concerned occurring - Is it possible?**
6. **Degree of harm that may result if the hazard or risk eventuated – Can someone be injured?**
7. **What the 2.13.1, 3.1 and others know, or ought reasonably to know, about the hazard or risk and any ways of eliminating or minimising the risk**

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What is know about TMM collision prevention

- Guideline for the compilation of a mandatory Code of Practice for Trackless Mobile Machines.
- MOSH Traffic Management Leading Practice adoption guide for surface mines
- MOSH Traffic Management Technical Guide for for underground mines.
- MOSH Collision Prevention Systems (CPS) Guidelines. (User requirement specification, functional specification, integrated CPS testing regime).
- ISO 21815-1:2022 – Earth Moving Machinery – Collision warning and avoidance – Part 1: General Requirements.
- ISO 21815-2:2021 – Earth Moving Machinery – Collision warning and avoidance – Part 2: On board J1939 communication interface.
- ISO 21815-3: (under review not published yet) – Earth Moving Machinery – Collision warning and avoidance – Part 3: Risk area and risk level – Forward/reverse motion.
- SANS, BS, EN. ISO 12100: 2010 – Safety of machinery – General principles for design – Risk assessment and risk reduction.

Reasonably Practicable Test

8. Availability and suitability of ways to eliminate or minimise risks
9. 'The hierarchy of risk controls
10. Cost of eliminating or minimising the risk.

Capacity to pay is not relevant: A duty-holder cannot expose people to a lower level of protection simply because it is in a lesser financial position than another employer

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CPS Technology Readiness Phase

Herman Hamersma

14 April 2023

Make today matter

UNIVERSITEIT VAN PRETORIA
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Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Recap on TMM regulations – Fail to safe

What do the Regulations say?

8.10.1.2 All underground diesel powered trackless mobile machines must be provided with means:

(a) to automatically detect the presence of any pedestrian within its vicinity. Upon detecting the presence of a pedestrian, the operator of the diesel powered trackless mobile machine and the pedestrian shall be warned of each other's presence by means of an effective warning; **and**

(b) in the event where no action is taken to prevent potential collision, further means shall be provided to retard the diesel powered trackless mobile machine to a safe speed whereafter the brakes of the diesel powered trackless mobile machine are automatically applied.

The prevent potential collision system on the diesel powered trackless mobile machine must fail to safe without human intervention.

8.10 Definitions 'Fail to Safe' means so designed as to activate and effectively perform its intended function without harm to persons and without human intervention

Dictionary: causing a piece of machinery to revert to a safe condition in the event of a breakdown or malfunction.

Fail-safe

What does it mean?

- Fail-safe means:
  - In the case of a failure, the system will respond in a way that will cause minimal to no harm to other equipment, the environment or to people.
  - Fail-safe does not mean failure is **impossible or improbable** (not inherent safety)
  - When a fail-safe system fails, it remains at least as safe as it was before the failure
    - Will failure of the CPS place the operator or pedestrians at more risk of harm?
    - Probably. The operator and pedestrians have been trained to rely on the CPS to ensure safety.
    - CPS failure thus requires more than just fail-safe

Fail to safe

What does it mean?

- What about fail-to-safe, as required in the Regulations?
  - The prevent potential collision system on the diesel powered trackless mobile machine must be so designed as to activate and effectively perform its intended function without harm to persons without human intervention
    - The CPS must activate automatically, e.g.
      - Activate CPS (boots-up) when the machine starts
      - Without operator action
      - TMM may not move until CPS is ready
    - If the CPS cannot effectively perform its intended function, it must prevent the TMM from performing anything that may lead to harm to persons (operators and pedestrians), e.g.
      - When CPS fails, TMM may not move
      - Articulation and attachment movement locked out

Key questions

- **When can the CPS not effectively perform its intended function?** (some examples)
  - Critical CPS functionality cannot be met (e.g. all sensors to detect pedestrians fail)
  - Criticality of the failure mode to determine appropriate response (fault tolerance), e.g.
    - Some redundancy may be included in the design (e.g. multiple sensors to detect pedestrians), brief failure of one sensor (e.g. loss of signal) not critical
    - Other failures may be more critical, e.g. CAN-bus unplugged
    - FMECA to determine criticality of failure mode

- **How is a failure detected?** (some examples)
  - Following proper fail-safe design principles, e.g. SAHR brakes, etc. (mechanical system)
  - Self-diagnostics to detect presence of failure modes (electronic detection)

Key questions

What happens when a failure occurs? (some examples)

- Depends on the current state of the TMM. Is it moving or stationary? Is it safe parked?
  - Safe parked: TMM remains in safe park
  - Stationary with engine running: TMM remains stationary
  - TMM moving: TMM brought to a gradual, safe stop and kept stationary
- Once a critical failure occurs, TMM must be brought to a safe stop, or kept stationary, until the failure is resolved.
  - Fail-to-safe functionality needed on both the CxD and the TMM
  - A clearly defined separation of the responsibility of each
  - If failure occurs on TMM, irrational to expect CxD to trigger fail-to-safe functionality. What about accountability?
  - Section 21 responsibility on all suppliers of equipment, unassigned/ambiguous responsibility will be assigned to the 2.13.1

Key questions

How can we achieve improved reliability to minimize FTS interventions?

- CPS reliability is a key performance criterion, e.g.:
  - Redundancy may be included in the design (e.g., multiple sensors to detect pedestrians),
    - Brief failure of one sensor (brief loss of signal) may not be critical.
  - Another example is the use of multiple independent power sources.
  - Failures such as CAN-bus unplugged may be more critical
    - Reliability will need careful oversight to prevent abuse/sabotage of CPS

Fail to safe

What happens once the TMM is in a safe state?

- Authorized, competent person to effect repairs if it is safe to do so. If necessary, authorized person may override the CPS to recover TMM to workshop (known as stand-by mode).
  - Activation of stand-by mode triggers maintenance override process
- If TMM needs to be moved, conditional release (override) may be granted, e.g.
  - In case of a medical emergency.
  - Override triggers reportable incident process
- Conditional release results in limited functionality (e.g. crawl speed only)

Key points

- Fail-to-safe functionality is required by the Regulations.
  - Products (CxD and TMMs) that does not have fail-to-safe functionality are making their clients to not comply to the TMM Regulations. This must be communicated to the DMRE.
- The CPS safe state is a stationary TMM that is prevented from moving (including no articulation/boom extension, etc.) before the issue is resolved by a competent person
- The TMM must reach the safe state without human intervention, i.e. no reliance on the operator to slow and stop the TMM.
  - This implies fail-to-safe functionality on both the CxD and the TMM, including the cap lamp
  - Responsibility on both suppliers (Section 21) to provide fail-to-safe functionality
- Once the TMM is safely parked, a conditional release (override or stand-by mode) may be granted
  - Depends on the situation, but there are consequences
  - Conditional release results in limited functionality (e.g. crawl speed only)

EMESRT vs CPS

EMESRT vs CPS?

EMESRT

- A global **non regulatory impacted** initiative to eliminate Vehicle Interaction
- EMESRT published initial performance requirements for ‘Vehicle Interaction Systems’ in 2016, updated it to**,** updated in 2019.
- Collision Management Systems Technical Specification **Guideline in 2018** was developed for the SAMI as an starting point.
- “This guideline describes performance-based requirements but does not prescribe specific technology solutions or **minimum standards** for PDS or OEM components of the CMS solution”.
- “Functional Requirements – Objectives …….”
- **Was always intended as a template for mines to develop their own specifications**
- It is not informed by the SA MHSA
  - It augments EMESRT’s Design Philosophy 5 – **Machine Operation Controls**
  - In some cases, it goes beyond what the MHSA requires (e.g. V2P for SME)
- It does not specify quantitative acceptance criteria.

EMESRT vs CPS?

EMESRT

- Defines 3 **Technology related** control levels,
  - Level 7 – Operator awareness – **Alerts the Operator**
    - Enhances situational awareness
    - E.g. a map of all **nearby** TMMs but mostly alarms
    - **Nearby is undefined**
    - **L7 alarms mostly considered counter effective and a nuisance due to the number of alarms.**
  - Level 8 – Advisory control- **Advises the Operator**
    - Determines an **imminent** collision
    - Provides **instruction** to operator to act
  - Level 9 – Intervention control- **Take Control from the Operator**
    - Provides specific instruction to machine to act

EMESRT vs CPS?

EMESRT

- EMESRT includes (not in MHSA):
  - V2V for UG
  - V2P for SME
  - V2E for UG and SME
  - LoC for UG and SME

EMESRT vs CPS?

MOSH CPS

- Originated from the **GAPS** in the EMESRT Approach
- Facilitated by Minerals Council SA due to actual and implied pressure from Stakeholders
- Technical input from SECDI, TerreSauver and UP using EMESRT guidelines as a basis.
- Specifically intended for South Africa TMM Regulatory Compliance
  - Started with a **regulatory** review
  - Review of CMS Test Specification Guideline that was based on EMESRT performance requirement
- Based on a Systems Engineering approach
- Products that comply to MOSH specifications referred to as Collision Prevention Systems (CPS)
  - Aim is to prevent collision (taken from MHSA)

EMESRT or CPS?

MOSH CPS

- MHSA Regulations require a CPS to: (summarized)
  - Automatically detect (TMM or pedestrian) in its **“vicinity”**
    - **Effective warning** to **operator(s)/operator and pedestrian** to act immediately
  - If operator does not act
    - **Auto slow and stop** of machine
  - System must be fail to safe without **human intervention**.
- ISO 21815 - 2 2021 with handshake – nothing else
- Specific CxD requirements and specific TMM CPS requirements
- Fail to Safe without human intervention – no normal operation override.
- Self Diagnostic requirements
- Specific Log keeping requirements
- Specific detection and tracking requirements
- EMC requirements
- Sec 21 requirements

EMESRT or CPS?

MOSH CPS

- MOSH includes:
  - User requirements
  - Functional requirements
  - Detailed performance criteria
  - Clear acceptance criteria
  - Detailed test specifications for all functional requirements

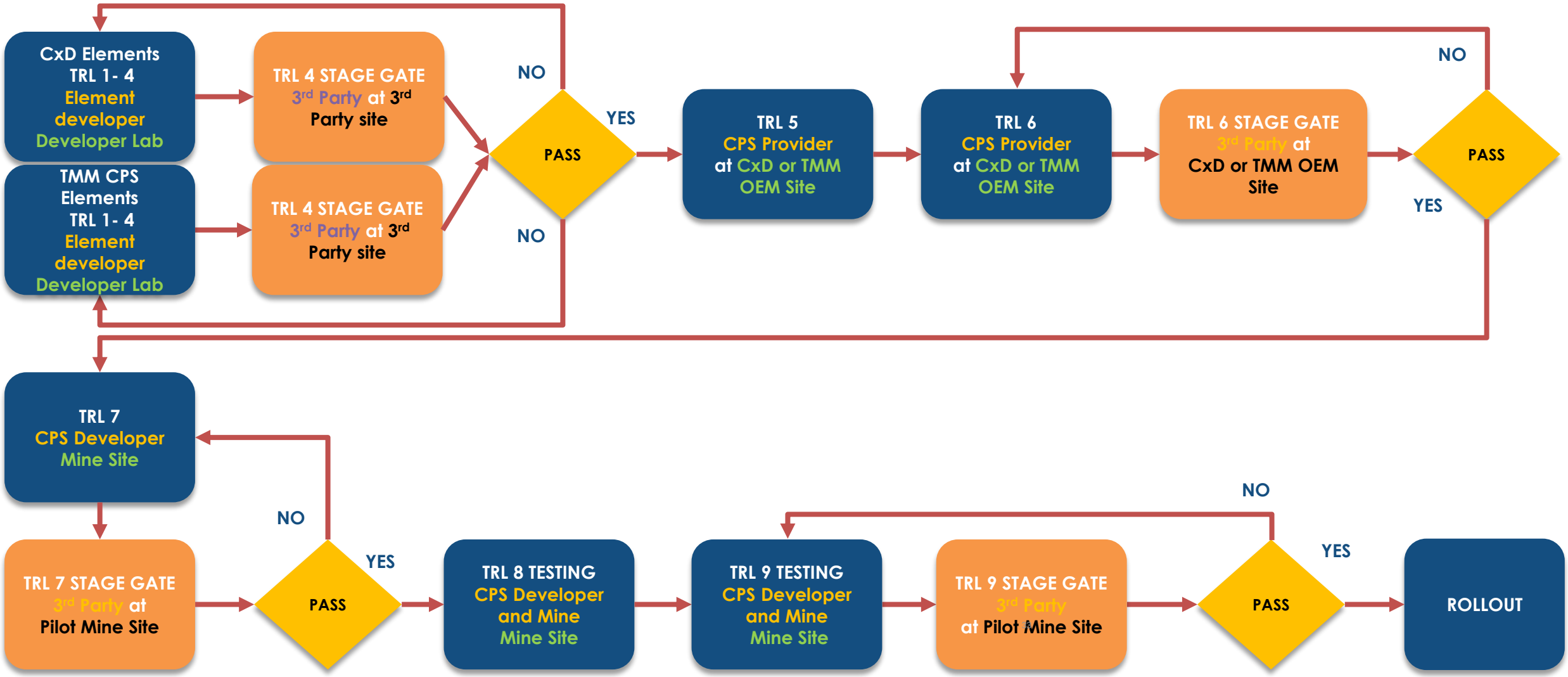
CPS TESTING

“UP” tests or CPS Tests?

- Product providers continue to rely on the “UP” tests for Sec 21 Compliance.
- The UP test did not test the following based on defined acceptance criteria.
  - ISO 21815 - 2 2021 with handshake – nothing else
  - Specific CxD requirements and specific TMM CPS requirements (deceleration rated, safe state etc.)
  - Multi vehicle scenarios
  - Emergency override only – (limited functionality)
  - Fail to Safe without human intervention
  - Self Diagnostic requirements
  - Specific Log keeping requirements
  - Specific detection and tracking requirements
  - EMC requirements

CPS testing process

CPS test regime



CPS testing

TMM testing (TRL4 Stage Gate)

No.	TRL	Test protocol	Status	Commercially ready
1	4	TMM ISO 21815 Interface Test	On track	17 April
2	4	TMM Log keeping test	On track	17 April
3	4	TMM Machine sensing test	On track	17 April
4	4	TMM self – diagnostic test	On track	17 April
5	4	Surface TMM Machine Controller Test	On track	17 April
6	4	Underground TMM Machine Controller Test	On track	17 April

CPS testing

CxD testing (TRL4 Stage Gate)

No.	TRL	Test protocol	Status	Commercially ready
7	4	CxD ISO 21815 Interface Test	On track	17 April
8	4	CxD Log keeping Test	On track	17 April
9	4	Surface TMM CxD Self-diagnostic Test	On track	17 April
10	4	Underground TMM CxD Self-diagnostic Test	On track	17 April
11	4	Surface TMM Effective Warning Test	On track	TBC (2 May target)
12	4	Underground TMM Effective Warning Test	On track	TBC (2 May target)
13	4	Surface TMM CxD Basic Detection and Tracking Test	Concern	TBC
14	4	Underground TMM CxD Basic Detection and Tracking Test	On track	TBC (15 May target)
15	4	Surface TMM CxD Scenario Test	Concern	TBC
16	4	Underground TMM CxD Scenario Test	On track	TBC (15 May target)

CPS testing

CPS testing (TRL7 and higher)

No.	TRL	Test protocol	Status	Commercially ready
18	6	Surface TMM CPS Integration Test	On track	TBC (2 May target)
19	6	Underground TMM CPS Integration Test	On track	TBC (2 May target)
17	4	Underground CxD Robustness Test	Concern	TBC
20	7	Surface TMM Advanced CxD Test	On track	TBC (15 May target)

Thank You