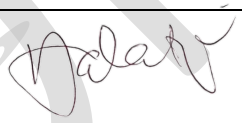
COMMERCIAL READINESS CRITERIA FOR COLLISION PREVENTION SYSTEMS

(I.E., WORK PACKAGE 8)

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

REV 2Y

CPS Readiness Criteria Acceptance			
Name	**Signature**	**Organisation**	**Date**
Kobus Blomerus		**SECDI**	**31 Jan 2022**
Stanford Malatji		**Minerals Council**	20 June 2022

i. **INDUSTRY ACCEPTANCE**

CPS Operational Readiness Criteria Acceptance			
Name	**Signature**	**Organisation**	**Date**

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1. Purpose of this document

This document sets out the criteria for the Commercial Readiness of CPS products so as to ensure minimum safety and commercial risk for mines to investing in such products.

2. Definitions and abbreviations

The following definitions and abbreviations will be used to create a common approach for all deliverables. (Note: The rationale for some of the terms and definitions is set out in the CMS Technical Specification Guideline Review Report).

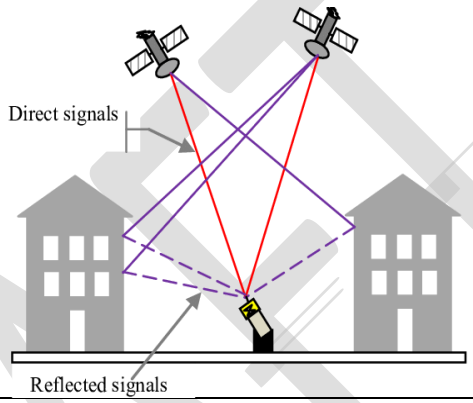
3rd Party	An entity appointed to execute work (testing, witnessing of testing and verifying portfolios of evidence) on behalf of SAMI. Note: The purpose of 3rd party execution is to establish independence and to eliminate duplication.
Accelerated Development	Development of CPS products in a coordinated and integrated way that will require less time (for the entire SAMI need), than the previous individual mine and supplier / OEM driven CPS product development approach.
Accelerated Testing	An initiative to accelerate the testing of CPS solutions with reference to the original test approach and plan.
Accuracy	The degree to which the result of a measurement, calculation, or estimate conforms to the correct value, i.e. the preciseness of the measurement.
C102-F9R	C102-F9R application board Easy evaluation of ZED-F9R with sensor fusion. Application board for ZED-F9R
CMS	Collision Management System: The overall combination of preventative controls, mitigation, recovery and supporting controls, implemented by a mine site to prevent TMM collisions.
Controlled area	Area that is dedicated to testing with no interference from vehicular or pedestrian traffic. Example: Gerotek Test Facilities, section on mine isolated from any mining activity, or demarcated area at a TMM OEM assembly plant.
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.)

CWAS/(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.
CxD	Collision warning/detection/management Device.
CxDC	CxD Controller: A sub-system of the CxD, that is typically the computer that contains the decision-making logic.
CxDI	CxD interface: A integration function between the CxD and the Machine Controller.
CxDLK	CxD Log Keeping: The function that receives, and stores CxD data.
D&T	Detect and Track: A functional group of a CxD enabling detection and tracking of TMMs and pedestrians inside the detection area of a surface TMM and an underground TMM respectively.
DAQ	Real time computer with data acquisition and control capabilities. Has ISO21815 interface. Example: DSpace MABX II.
Data scientist	Experienced person in the field of data processing and statistics. This person will analyse data collected during TRL9 pilot site roll-out testing.
Detection	Detection is sensing that an object has entered the detection area.
DMRE	Department of Mineral Resources and Energy.

Driver or operator reaction time (also known as perception response time)	The time that elapses from the instant that the driver recognises the existence of a hazard in the road, to the instant that the driver takes appropriate action, for instance, applying the brakes. The response time can be broken down into four separate components: detection, identification, decision and response. When a person responds to something s/he hears, sees, or feels, the total reaction time can be broken down into a sequence of components namely: • Mental processing time (sensation, perception / recognition, situational awareness, response selection and programming). • Movement time, and • Driver response time. Driver reaction time is also affected by several issues such as visibility, operator state of mind (fatigue), and direction or position of perceived danger.
EAV	Exposure Action Value
ELV	Exposure Limit Value
EM engineer	Qualified person (BEng, BTech) in the EMC environment, with extensive experience in EMI/EMC testing.
EMC	Electromagnetic Compatibility
EMESRT	Earth Moving Equipment Safety Round Table
EMI	Electromagnetic Interference
Employee	Employee means any person who is employed or working at a mine.
EW (Surface)	Effective Warning: For surface TMMs: The expected outcome of the operator action is that the potential collision is prevented, therefore an effective warning must inform the operators of both TMMs what the appropriate action(s) are, to prevent the potential collision.
EW (Underground)	Effective Warning: For Underground TMMs: The expected outcome of the operator and pedestrian action is that the potential collision is prevented. Therefore, an effective warning must inform the operators of TMMs what the appropriate action(s) are to prevent the potential collision and must alert the pedestrian to potential collisions, or interactions with TMMs in the vicinity.
F	Function: Indicates a function of the CPS or functional group.
F&TPR	Functional and Technical Performance Requirements
FMECA	Failure Mode Effect and Criticality Analysis
FTS	Fail to Safe: The functionality that will bring a TMM to a controlled stop
Functional Specification	Specifications that define the function, duty, or role of the product/system. Functional specifications define the task or desired result, by focusing on what is to be achieved, rather than how it is to be done.

G	General: Indicates a general requirement that is applicable to the entire CPS and all of it elements, modules, and components.
High Risk Running Period	A period when a mine change over from one brand or model of cap lamp to another. The changeover cannot be done in one shift. The period of changeover is considered to be a High-Risk Running Period.
Homologation	Homologation means to sanction or "allow." Homologation refers to the process taken to certify that a TMM fitted with a CPS is manufactured, certified, and tested to meet the standards specified for critical safety related devices fitted to TMMs.
HP GNSS	High 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 100Hz. Example Racelogic VBOX 3i.
ICASA	*Independent Communications Authority of South Africa*
ICMM	International Council on Mining and Metals.
ICNIRP	International Commission on Non-Ionizing Radiation Protection
ID	Identifier.
Independent	Separate from the CPS product developer. Note: Independent does not imply an accredited 3rd party, although where required by local or international standards, it includes accredited 3rd parties.
Independent person	A person, typically a test-, software- or EM engineer, who is not affiliated with the CPS provider or TMM OEM, that can provide an unbiased assessment.
Integrated Testing Regime	A holistic method of testing, optimising existing testing facilities that are currently available irrespective of who owns them. This method ensures specific CPS tests are only done once (CxD and TMM CPS Product combinations) and verification is done as early as possible in the development process.

Interface	A boundary across which two independent systems meet and act on or communicate with each other. Four 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. 3. V2X interface – the interface between different CxD devices. V2X is a catch-all term for vehicle-to-everything. It may refer to vehicle-to-vehicle (V-V), vehicle-to-pedestrian (V-P), or vehicle-to-infrastructure (V-E). 4. CxD-peripheral interface – This is an interface between the CxD and other peripheral systems that may be present on the TMM. Examples include a fleet management system, machine condition monitoring system, or fatigue management system. Note: An interface implies that two separate parties (independent systems), are interacting with each other, which may present interoperability and/or EMI and EMC challenges.
LO	Local Object: Denotes the TMM that is detecting other TMMs (S) or pedestrians (P)
Localization	Localization is measuring the position of the object within the detection area; it provides the local object with a map of the remote objects within the environment.
Loss of control	The uncontrolled movement of a TMM due to operator, machine, or environmental reasons. Note: Section 8.10.3 of MHS Act. Loss of control may result in several scenarios: • Machine failure – park brake, or service brake, or tyre blowout. • Operator disabled – fatigue, medical condition, inattention, distraction, or non-compliance with TMP rules (e.g., over speeding on decline, or overloading)
MBS	Machine Braking System: The physical components that makes an unintelligent TMM intelligent and enables the CPS auto slow-down and stop functionality.
MC	Machine Controller.
MCI	Machine Control Interface: The interface between the Machine Controller and the CXD interface.
MHS Act	Mine Health and Safety Act No. 29 of 1996 and Regulations.
MHSC	Mine Health and Safety Council.
Minerals Council	Minerals Council South Africa.

MLK	Machine Log Keeping: The function that receives, and stores TMM CPS data.
MOSH	Mining Industry Occupational Safety and Health.
MRAC	Mining Regulations Advisory Committee.
MRL	Manufacturing Readiness Level. A manufacturing maturity level within a manufacturing readiness framework.
MS	Machine Sensing: Sensing functionality on a TMM that enable a fully functional CPS.
Multipath	Multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths, typically some direct signals, but also some reflected signals. 
OWS	Operator Warning System: The system that provides the effective warning and other warnings to the operator of a TMM.
PDS	Proximity Detection System – see CxD.
Pedestrian	A person lying, sitting, or walking rather than travelling in a vehicle.
Project	Industry Alignment on TMM Collision Management Systems Project: CAS READINESS PHASE.
PWS	Pedestrian warning System: The system that provides the effective warning to pedestrians.
Quality Assurance	Verifying a process, product, or service; usually conducted by an experienced person in the specific field.
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. © 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.
Reliability (sensor)	Sensor reliability refers to the consistency of a measure. Achieving the same result by using the same methods under the same circumstances, is considered a reliable measurement.

RO	Remote Object: Denotes TMM(s) (S) or pedestrian(s) (U) being detected by the LO.
Robustness (sensor)	Sensor robustness is the ability of the sensing device (sensor), to remain functional in the presence of normal operating conditions of TMMs on a mine, such as electromagnetic interference, mechanical vibration, dust, adverse weather conditions, etc.
S	Surface: Indicating that a specific aspect is applicable to surface TMMs/operations.
Safe Park	A way that a TMM is parked, namely: Machine static, engine switched of and park brake applied.
Safe speed	The speed that will ensure the controlled stopping of a TMM without any immediate negative impact on the operator or machine. Note: This is a conditional variable value, depending on multiple input variables.
SAMI	South African Mining Industry.
Sensor fusion	Sensor fusion is the process of combining sensory data, or data derived from disparate sources, such that the resulting information has less uncertainty than when the sources were to be used individually.
Significant risk (of collision)	The reasonable possibility of a TMM collision, given all the controls that a mine has put in place to prevent a TMM collision.
Slow down	ISO/TS 21815-2: 2021 defines slow down as: "The SLOW-DOWN action is sent by the CxD to reduce the speed of the machine in a controlled / conventional manner, as defined by the machine control system. The intent of this command is to slow down the machine when the CxD logic determines that a collision / interaction can be avoided by reducing speed".
SME	Surface Mobile Equipment (Surface TMMs)
Software engineer	Qualified person in the communications/computer environment, with extensive experience in ISO 21815 – 2:2021 programming and testing.
SP GNSS with self-recorder	Standard Precision Global Navigation Satellite System: A system that is capable of measuring position with an accuracy of 1.5m, with an update rate of 10Hz. Can also store its own data. Example: UBlox C102-F9R.
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.

Stop	ISO/TS 21815-2: 2021 provides for two definitions, an emergency stop, and a controlled stop, both of which are a 'Stop'. The definitions are: 1. "The EMERGENCY-STOP action is sent by CxD to instruct the machine to implement the emergency stop sequence defined by the machine control system. The intent of this command is to stop the machine motion as rapidly as possible, to reduce the consequence level, if the CxD logic determines that a collision is imminent. The equivalent of an emergency stop is the operator slamming on the brakes in an emergency." 2. "The CONTROLLED-STOP action is sent by CxD to instruct the machine to implement the controlled stop sequence, defined by the machine control system." The intent of this command is to stop the machine motion in a controlled / conventional manner, when the CxD logic determines that a collision / interaction can be avoided by slowing down and stopping. The equivalent of a controlled stop is slowing down and stopping when approaching a red traffic light.
System	A combination of interacting elements organized to achieve one or more stated purposes (ISO/IEC/IEEE 2015).
T	Technical: Indicates a technical requirement of the CPS or functional group.
Technical specification	Specifications that define the technical and physical characteristics and/or measurements of a product, such as physical aspects (e.g. dimensions, colour, and surface finish), design details, material properties, energy requirements, processes, maintenance requirements and operational requirements.
Technician	Competent person with testing experience in the mining / vehicle environment, e.g. testing technician, TMM OEM technician, CxD technician, auto electrician, etc.
Test engineer	Experienced person in the engineering/mining environment with extensive experience in CPS testing.
This document	CPS Commercial Readiness Criteria
TMLP	Traffic Management Leading Practice: The MOSH Traffic Management Leading Practice for Open Cast/Cut mines in South Africa.
TMM	Trackless Mobile Machine. (Machine, vehicle, etc.)
TMM CPS	The functional group comprising all TMM CPS related functions.
TMM CPS Product	The product that will make a non-intelligent TMM intelligent and CxD ready.

TMM OEM	Original Equipment Manufacturer of TMMs. Original Equipment Manufacturer of a TMM may be the organisation which originally supplied, or 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).
TMP	Traffic Management Plan: A document that defines the traffic management system that a mine employs to ensure the safe movement of TMMs and pedestrians on the mine.
Tracking	Tracking is the monitoring of the progress of the objects in the detection area over time.
TRL	Technology Readiness Level: A technology maturity framework for measuring and monitoring technology maturity in 9 increasing levels from TRL 1 to TRL 9.
U/UG	Underground: Indicating that a specific aspect is applicable to underground TMMs/operations.
UTC	Coordinated Universal Time.
V2X	Vehicle to anything.
V2XIF	Vehicle to anything interface
Vicinity (Surface TMMs) Vicinity (Underground TMM and pedestrians)	The distance/time of two TMMs from the point of a potential collision, such that, if the operators of both machines are instructed to take action to prevent a potential collision, and one or both does not act, then the CPS will be able to prevent the potential collision. Note: Vicinity is a conditional, variable value, depending on multiple input variables. It is smaller than any value that is within the range of normal operation. The distance/time of a TMM from a pedestrian, such that, if the operator of the TMM and the pedestrian do not take action to prevent a potential collision, an emergency slow down and stopping of the TMM can be successfully executed, to prevent a potential collision between the TMM and the pedestrian. Note: Vicinity is a conditional, variable value, depending on multiple input variables. It is smaller than any value that is within the range of normal operation.
V-E	Vehicle to environment.
V-P	Vehicle to pedestrian.
V-V	Vehicle to vehicle.
Walking speed	In the absence of significant external factors, the average human's walking speed is 1.4meters per second. This is included to help define the crawl speed of vehicles.
WP 8	Work Package 8 CAS Readiness Criteria One of the work packages of the Industry Alignment on TMM Collision Management Systems Project: CPS READINESS PHASE
WP 9	Work Package 9: Testing protocols (including legacy equipment). One of the work packages of the Industry Alignment on TMM Collision Management Systems Project: CAS READINESS PHASE.

3. Context of this document

This document is part of the deliverable for Work package 8: Readiness Criteria, of the Industry Alignment on TMM Regulations Collision Management Systems Special Project of The Minerals Council South Africa: CPS TECHNOLOGY READINESS PHASE work.

The deliverable will be released in 4 parts:

- Part 1 Functional Readiness.
- Part 2 Manufacturing Readiness
- Part 3 Operation Readiness.
- Part 4 Commercial Readiness. (this document)

4. Background

TMM regulations for the SAMI were promulgated in 2015. Some of the clauses related to diesel powered TMMs were suspended as a result of non-availability of technology to provide the functionality that is required to auto slowdown and stop the TMMs.

The Industry Alignment on TMM Collision Management Systems Special Project of The Minerals Council South Africa was initiated to facilitate the accelerated development of CPS products.

As a safety system that ultimately takes away the control of a TMM from an operator, specific functional requirements and manufacturing conformance criteria are needed in order to minimise the potential safety and production disruption emanating from the introduction of CPS products to the entire mining industry.

Considering that the introduction of CPS products into the SAMI is driven by the MHSA and regulations it could be perceived that commercial readiness for CPS products is not relevant. Whilst the limitation of the current commercial readiness frameworks is acknowledged, a practical application of the principles is proposed.

5. Commercial Readiness Frameworks

Commercial readiness indexes are a relative new addition to the initial Technology Readiness Level (TRL) framework developed by Stan Sadin with NASA in 1974 (1). In 2014 the Australian Government's Renewable Energy Agency (ARENA) published a Commercial Readiness Framework (2), for use in its Renewable Energy Sectors. The framework has been used and applied by others since then, mostly in the renewable energy sectors of other jurisdictions/countries. A discussion of the details of document is not warranted here, however the following key principles directly related to CPS are of value:

- It is acknowledged that technology risk is largely disposed of by application of a relevant TRL framework, however commercial uncertainty and risk remaining in the product demonstration and deployment phases.

This is true for both the primary commercial stakeholders of CPS namely the SAMI and the technology providers.

- It is acknowledged that other aspects of the Ecosystem are as important as technology readiness. These include supply chain, skills, stakeholder acceptance and the regulatory environment.
- It is acknowledged that commercial readiness can only be achieved post technology readiness.
- CPS and Renewable Energy Technology faces a similar challenge when it comes to commercial survivability of the new technology products, namely market acceptance and supplier return on investment.

Whereas the Commercial Readiness Index as developed by ARENA aims to facilitate government policy and investment into a strategic national and global objective, namely; environmental preservation, that of CPS is focussed on managing the commercial risk related to CPS regulation for the SAMI.

The commercial risk for the SAMI lies in the financial implications for a mine and the SAMI collectively if CPS products fails on a large scale at the beginning of the operational life cycle stage. The commercial consequences of CPS failure post regulation are:

- Sunk cost spent on the development of the CPS ecosystem, and its components and products, by mines individually and collectively (SAMI)
- Loss of production (revenue) as a result of a mine's inability to comply with the TMM regulations and therefore it cannot legally operate.

The Industry Alignment on TMM Regulations; Special Project of The Minerals Council South Africa identified the importance of the need to address all elements of the CPS ecosystem and initiated specific work packages to develop different aspects of the ecosystem. The project based the work to be done on a Systems Engineering Life Cycle approach. This approach ensured that a number of Ecosystem aspects are already addressed.

6. The CPS Life Cycle System (Ecosystem)

The CPS Life Cycle System (Ecosystem) is defined in Part 1 of the CPS Readiness Criteria document. It is partially repeated here for purposes of context.

The CPS Life Cycle System is shown in figure 1.

Based on the CPS Life Cycle the project identified four areas that require specific readiness focus:

- Functional Readiness
- Manufacturing Readiness
- Operational Readiness
- Commercial Readiness

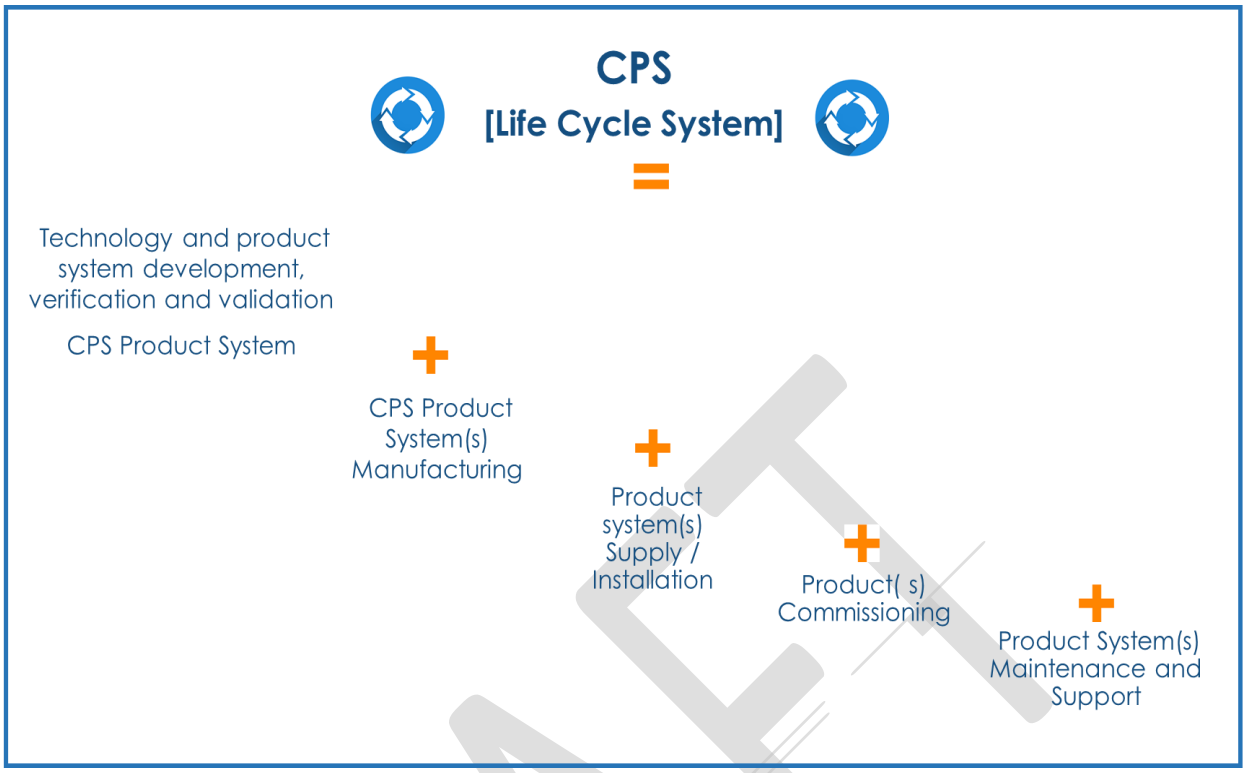


Figure 1: The CPS Life Cycle System

7. Commercial Readiness Criteria

Commercial Readiness for Collision Prevention Systems is the **final** milestone that will give mining executives the confidence to invest in CPS technology on a mine and industry wide, without undue commercial (financial and operational) risk. Commercial Readiness has an Ecosystem focus to ensure that all aspect of the CPS Ecosystem has been adequately and timeously matured. Commercial Readiness has several aspects that must be mature or close to maturity to ensure successful introduction of CPS products into the SAMI. These are:

- Successful completion of all CPS functional Readiness Criteria (Part 1 of this deliverable)
- Successful completion of all CPS Manufacturing Readiness Criteria (Part 2 of this deliverable)
- Successful completion of all CPS Operational Readiness Criteria (Part 3 of this deliverable)
- Regulatory alignment
- An established supply chain strategy for CPS product and spares supply, including localisation considerations
- Human skills competence and capacity
- Maintenance and support contracts

The criteria for functional readiness, manufacturing readiness and operational readiness all relates directly to the physical/technical aspects of the Ecosystem.

The remaining Commercial Readiness Criteria for CPS are aimed at the Ecosystem aspects not covered by the other readiness criteria.

8. Regulatory Readiness Criteria

There are two regulatory readiness criteria namely:

- A signed agreement between SAMI and the DMRE for the TMM regulations transition/rollout period by end 2022
- Evidence of a national DMRE CPS introduction roadshow ensuring that all machinery inspectors and principal inspectors are fully aligned with the stakeholder agreement by end October 2023.

9. Established Supply Chain Readiness Criteria

Whilst the manufacturing readiness criteria addresses the quality and capacity aspect of manufacturing and supply it but briefly mentions the risk and opportunities related to CPS product manufacturing and supply.

The readiness criteria for the CPS supply chain are:

- A signed CPS supply strategy and plan between the SAMI, OEMs and CPS technology providers before end June 2022
- Positive supply chain plan review reports by end September 2022 and end February 2023

10. Human Skills, Competence and Capacity Readiness Criteria

The following readiness criteria will be applied for human skills:

- CPS human skills needs report by end March 2022
- CPS human skills development plan by end April 2022
- A positive human skills development plan review by end Nov 2022
- Availability of 85% of required human skills by July 2023 (or as per plan)

11. CPS Maintenance and Support Readiness Criteria

Although the operational readiness criteria include a criteria that the mine must ensure that it has developed and implemented a CPS maintenance and Support strategy and plan in time for the introduction of CPS on the mine, there is a need for ecosystem level readiness criteria:

- SAMI CPS Maintenance and Support capacity needs report by end June 2022
- SAMI CPS Maintenance and Support capacity plan by end December 2022
- A positive CPS Maintenance and Support plan review report by end June 2023.

12. References

1. Jim Banke (2010) Technology Readiness Levels Demystified
2. ARENA Emerging Renewables Program use of CRI framework https://arena.gov.au/assets/2014/02/Commercial-Readiness-Index.pdf