FUNCTIONAL AND TECHNICAL PERFORMANCE REQUIREMENTS GAP CHECKSHEET FOR SURFACE CxD COLLISION PREVENTION SYSTEMS FOR

..... Product Name and Model

REV 1

CPS F&TPR GAP REPORT APPROVAL			
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1. Purpose

The purpose of the Functional and Technical Performance Requirements (F&TPR) specification, Gap Check sheet is to define the technical and functional performance requirements gaps that exist for a CPS product at the time of the assessment

2. Scope

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

- Surface CxD Products

3. Definitions and abbreviations

As per Functional and Technical Performance Requirements Specification.

4. Detection and Tracking Functions (D&T)

The Detection and Tracking performance requirements are documented in **Table 1.**

Req No	Function group	Function Name	Function Description	Performance Criteria	Currently Conform Y/N	Target Date	Comments
0	D&T	Detect and Track	The DTS must detect and track TMM(s) (S) or pedestrian(s) (U)) within the detection area of the TMM. The DTS must know important characteristics of all potential interactors in the detection area	See lower-level functions			
1	D&T	Detect	Detect the presence of any TMM or Pedestrian (S & U respectively) within a predefined detection area.	latency < 0.5s 5% detection accuracy 99% detection of **7** machines simultaneously			
1.1	D&T	Detect in all machine statuses	DTS must maintain full functionality in all machine statuses	bucket raised boom extended machine articulated TMM towing TMM and trailer machine drilling			

1.2	D&T	Detect robustly	DTS must be able to detect ROs in all reasonably foreseeable environmental conditions	direct and indirect detection no blind spots blind rise dust see general requirements rain, wind steep angle - working on dump side			
1.3	D&T	Be interoperable	DTS must be able to detect ROs from all other CPS fitted TMMs from different OEMs and suppliers.	detect all CPS fitted TMMs on a particular site			
2.0	D&T	Track potential interactors	Maintain detection while RO(s) is/are moving in detection area	track 7 machines simultaneously no dropouts speed up to 50km/h may not identify one of the TMMs as an 8th or more TMMs must be the same object throughout			
2.1	D&T	Track velocity	Estimate, measure or receive its LO TMM velocity and that of any other TMM (RO) within the detection area	accurate to within 0.5 km/h for V2X standard = TBD			
2.2	D&T	Determine distance	Measure or estimate the distance to any TMM or Pedestrian within the detection area	200m distance, 5% accurate or 0.5m, whichever is larger			
2.3	D&T	Determine direction	Determine the direction of any RO (TMM or Pedestrian) towards the LO (TMM) within the detection area	accurate to within 2 deg			

2.4	D&T	Determine heading	Estimate or measure or receive the heading of any TMM within the detection area	2deg accurate			
3.0	D&T	Interface with CxDC	Communicate with CxDC	as per CxD developer standards			
4.0	D&T	Pedestrian and beacon detection failure	Pedestrian sensors and beacon must communicate a failure to the CPS when failure mode is detected	off-board elements (such as cap lamps, beacons) fail to safe when a fault is detected.			

Table 1: D&T functional requirements

5. CxD Controller Functions (CxDC)

The CXD Controller requirements are documented in **Table 2.**

Req No	Function group	Function Name	Function Description	Performance Criteria	Currently form Y/N	Target Date	Comments
0	CxDC	Quantify collision risk and intervene	CxDC must determine if it has enough information to determine if a collision is imminent and intervene to prevent it from happening	See lower functions			
1	CxDC	Communicate/interface	The CxDC must receive and exchange relevant data to other LO functions as well as some RO functions.	for V2X Standard = TBD			
1.1	CxDC	Communicate with LO DTS functions	The CxDC must receive relevant data from the DT to execute its functions effectively	as per CxD developer standards			
1.2	CxDC	Communicate with LO TMM MCI	Communicate with MC via MCI	ISO TS 21815-2: 2021			

1.3	CxDC	Communicate with ROs' CxDC	The LO CxDC must be able to receive data from all ROs within the detection area and send data to the RO CxD via V2X	V2X standard = TBD RO status RO state RO position data OWS instructions			
2	CxDC	Quantify collision risk	CxDC must quantify the risk of potential interaction between V-V or V-P respectively by predicting the path of all interactors within the detection area	See lower functions			
2.1	CxDC	Configure stop gaps and following distances	The CxDC must register the stop gap for different TMM configurations as well as for pedestrians for different operational processes.	adjustable as per individual mine requirements adjustable per TMM type adjustable for specific operating processes 2 m default stop gap for "close up" operating scenarios auto CPS override? When specific TMM Types are below 2km/h in specific operating process area = TBD 15m default stop gap for all non-close up operating scenarios 50m following distance for haulers			
2.2	CxDC	RO CxD communication	The LO CxDC must interface with the RO CxDC.	For V2X standard = TBD			
2.3	CxDC	Process RO TMMs' state	CxDC must process ROs' TMM state as part of quantifying risk of collision.	CxDC takes RO state into account			

2.4	CxDC	Predict ROs' (TMMs' and pedestrian's) paths	CxDC must calculate paths of interactors and determine vicinity boundary.	must start prediction from initial movement of ROs path prediction accuracy: 5% of stopgap value must include probability of TMM pulling away from safe-park			
2.5	CxDC	Determine collision probability	CxDC must determine the probability of a potential collision of every detected RO. Multiple collisions must be prioritised based on the probability.	prioritise most likely potential collision (highest risk) of up to 7 TMMs			
2.6	CxDC	Predict LO path	CxDC must calculate paths of interactors and determine vicinity boundary	prediction must start from initial movement of LOs path prediction accuracy: 5% of stopgap value must include probability of TMM pulling away from safe-park			
2.7	CxDC	Receive TMM LO Status	The CxDC must receive the status of a TMM in all different operational processes	refuelling, towing, broken down, drilling, dumping, loading, bucket raised, boom extend			
2.8	CxDC	Process LO TMM status	CxDC must know TMM status and adjust stop-gaps	adjust stopgap values as per configuration.			
2.9	CxDC	Configure LO TMM type	CxDC must be able to configure the different TMM types	Haul Truck, LHD, Water Cart/Bowser, Diesel Bowser, grader, road roller, LDV, FEL, Excavator, Bulldozer etc. Full list to be agreed.			
2.10	CxDC	Process LO TMM Type	CxDC must know TMM type and adjust stop-gaps	CxDC takes LO and RO type into account			

2.11	CxDC	Process LO's CPS delays	CxDC consider all CPS sensing and computational delays as part of quantifying risk of collision	ensure stop gap tolerance 5% including all delays			
2.12	CxDC	Configure TMM retardation curves	CxDC consider all TMM retardation curve per TMM type and model	register retardation curves (as per OEM specification)			
2.13	CxDC	Process LO's retardation curves	CxDC consider specific TMM retardation curves as part of quantifying risk of collision	CxDC takes LO retardation curves into account			
2.14	CxDC	Process RO TMMs' status	CxDC must process ROs' TMM status as part of quantifying risk of collision	CxDC take RO status into account			
2.15	CxDC	Process ROs' TMM type	CxDC must process ROs' TMM type as part of intervention	CxDC takes RO type into account			
2.16	CxDC	Configure Operator delay	CxDC must facilitate operator response delay	2.5sec			
2.17	CxDC	Process operator reaction time	CxDC must consider operator reaction time as part of predicting stopping distance	2.5s from effective warning ensure stop gap tolerance 5% including effective warning delay			
3	CxDC	Determine EW details	CxDC must determine what the effective warning is and communicate it to OW and PW respectively	as per developer specification			
4	CxDC	Decide intervention strategy	CxDC must decide on appropriate intervention strategy	See lower functions			
4.1	CxDC	Ensure Normal Operations	If collision risk level is below threshold level, CxDC must allow normal operation	threshold = outside vicinity zone boundary no false interventions and warnings			
4.2	CxDC	Action intervention for high risk scenarios	If collision risk level is above threshold, CxDC must be able to initiate appropriate intervention strategy	TMM intervention successfully initiated in all cases Intervention strategy must use TMM capability as reported by TMM during ISO21815 negotiation sequence.			

				Intervention strategy to be consistent and repeatable			
4.3	CxDC	Decide intervention strategy considering operating rules	Intervention strategies must consider unique parameters, rules and scenarios with regards ROs	See lower-level functions			
4.3.1	CxDC	Escort vehicle	Must allow vehicle to be escorted by CPS enabled TMM	one escorted vehicle only			
4.3.2	CxDC	Priority TMMs	Intersections require priority TMMs not to slowdown and stop	emergency Vehicles haulers			
4.3.3	CxDC	Overtake slow moving TMM	Must prevent slow moving TMM (e.g. FEL) from overtaking another slow moving TMM (e.g. grader)	retain specific following distance.			
4.3.4	CxDC	Overtake slow or broken down TMM	Must allow TMM to overtake slow or broken down TMM if safe to do so	ensure specific speed restriction(s) prevent collision with oncoming TMMs			
4.3.5	CxDC	Exclusion zones	Must allow for LDV exclusion zones to accommodate safe parking areas for LDVs in congested HME operational areas (Loading, Dumping, Hard Park, Workshops etc.)	LDV can only enter area to safe park if all HMEs are in safe park HMEs can operate as normal while LDVs are parked in exclusion zone LDVs cannot exit exclusion zone unless TMMs are in safe park HMEs cannot enter exclusion zone			
4.3.6	CxDC	Maintenance and support TMMs	If support/services TMM enters the working area (e.g. water bowser in dump/pit) all other TMMs must be in safe park	allow service vehicle to approach TMM that is in safe park prevent TMM to exit safe park while service vehicle is inside 30m radius from TMM			

4.3.7	CxDC	Queuing	Enable queuing of TMMs (e.g. waiting at dump/pit/hard park) and prevent overtaking (jumping the queue)	queuing in specific operational processe CxDC does not allow overtaking in queue specific following distances ensured speed restriction upheld			
4.3.8	CxDC	Loading	Enable loading of truck by excavator / shovel / FEL	specific TMM type no passing allowed engine running allowed vicinity boundary reduced to xm adjustable enable auto CPS override when specific TMM Types are approaching below 2km/h and at xm apart (Mines to decide) reset auto CPS override when specific TMM Types are above 2km/h or more that 5m apart and moving away from each other			
4.3.9	CxDC	Hard park control	Prevent collisions in hard park	prevent collisions in hard park ensure minimum following distance based on Hard park speed limit ensure hard park speed limit priority TMM entrance and departure			
4.3.10	CxDC	Brake testing	Prevent TMM from entering or exiting brake test ramp if occupied by another TMM	TMM to enter ramp only when tested TMM exit the brake test ramp.			
4.3.11	CxDC	Pit Ramp Entrance	Prevent collisions at pit ramp entrances	ensure approaching TMM stop before turning/entering the pit ramp. ensure approaching TMM cannot enter ramp if another TMM is at ramp entrance			

4.3.12	CxDC	Pit Ramp	Prevent collisions on pit ramps	ensure no entry of TMM onto ramp when another TMM is at ramp entrance ensure TMM stops at ramp entrance, ensure TMM maintains correct gear and retarder (when fitted) down ramp, maintain speed limit down ramp, maintain following distances (xm)			
4.3.14	CxDC	LDV/Service Vehicle - HME proximity	Must prevent HME to LDV/service vehicle collisions	LDV/service vehicle can approach HME when HME has engaged safe park (park brake engaged, neutral, engine off) 30m radius before entry			
4.3.15	CxDC	Prevent unauthorised access	Must be able to detect restricted areas via beacons or geo fence and prevent unauthorised TMMs from entering a restricted area based on TMM type (HMEs and LDVs segregated)	CxDC must prevent the TMM from entering restricted areas			
5	CxDC	Communicate effective warnings and TMM interventions	CxDC must communicate effective warnings and TMM interventions to all relevant LO and RO functions	See EW functions			
5.1	CxDC	Communicate effective warning to OWS	Communicate specific operator actions to OWS	specific warning: slow down and stop or stop			
5.3	CxDC	Communicate EW and intervention instructions data to CxDLK	Communicate effective warning and auto slow and stop interventions to CxDLK for log keeping	log keeping must start 5s before potential interaction at a rate of 10Hz see CxDLK functions			
5.4	CxDC	Communicate TMM interventions to central control room/authorised person	CxD must communicate all interventions to central control room/authorised person	interventions reported to central control room or cell phone communication standards = TBD for V2X standard = TBD			

6	CxDC	Isolate operators & passengers	Provide effective exclusion zone to ensure operators and passengers do not trigger warnings from inside the cab;	See lower functions			
7	CxDC	Configure TMM information	The CxD must be able to register TMM information	See lower-level functions			
7.1	CxDC	Identify TMM	Each TMM must have a unique ID for log keeping purposes	The CxD must be able to accommodate TMM unique numbers (Alpha-numeric up to 30 characters)			
7.2	CxDC	Identify operator	Each operator must be assigned a unique ID that can be registered when operator starts his/her shift for log keeping purposes	biometric or electronic access card			
7.4	CxDC	Register speed limits	The CxD must be able to demarcate operational areas and sections of roads with specific speed limits associated to it so that the CPS intervention strategies remain functional	physical location based – road sections, operational processes, operational areas variable speed limits			
8	CxDC	Prohibit unauthorised use	CxDC must prevent unauthorised use of the TMM	TMM is prevented from operating if operator is not authorised			
10	CxDC	Override CPS	Override LO CPS in emergency situations by authorised person by means of a code or an RFID card.	only overrides LO by authorised person TMM can move at predetermined "emergency" speed limit. only for limited period - variable			
11	CxDC	Control maximum TMM speed	The CxDC must prevent the TMM from exceeding speed limits to ensure that the CxDC's intervention strategy remains effective	ensure speed restriction within 1km/h from the CPS design speed no speed limit being exceeded timeous intervention +- 2m accurate for GPS = absolute accuracy, maximum CPS design speed 40km/h			

12	CxDC	Return to normal operation.	After collision has been successfully prevented, the CxD must allow the TMM to return to normal operation	authorised person activation only (bio metric or electronic access card) CxDC must allow system to return to normal operation repeat initiation/start-up sequence			
13	CxDC	Initiate FTS	Upon detection or reporting of any CPS failure message, the CxD must initiate a fail to safe intervention	within 100ms from receipt of failure message warn operator – CPS failure			

Table 2: CxDC performance requirements.

6. Effective Warning Functions (EW)

The Effective Warning performance requirements are documented in **Table 3.**

Req No	Function group	Function Name	Function Description	Performance Criteria	Currently Conform Y/N	Target Date	Comments
0.0	EWS	Provide effective warning	An effective warning must be provided to all operators and pedestrian(s) in case of a potential collision	See lower-level functions Formal human factors and people centric design outcomes.			
1.0	EWS	Provide concise warning	The system must avoid repetitive alarms issued for the same collision	no more than 3 repetitive alarms per vicinity detection continuous warning even during auto slow-down and stop intervention			
2.0	EWS	Communicate only highest priority	Operators and pedestrians must only be warned of the collision with the highest priority	display element clearly indicates RO with highest collision priority audible warning should only address highest collision priority			
3.0	OWS	OWS must be the outcome of human centred design	Ergonomics of operator cabin should not be compromised due to improper positioning of components				

				must be able to accommodate 5th percentile Female and 95th percentile Male			
3.1	OWS	Simultaneous warning	Simultaneous warning to operators (s) or operator and pedestrians (U) of CPS fitted TMMs irrespective of type, brand or model.	communication with all other TMMs EW functions For V2X standardisation, standard = TBD			
3.2	OWS	Be audible	An audible warning shall be provided to all operators inside the vicinity	10 dB above ambient. 5 x programmable language sets (TBD) programmable volume setting only (operator must not be able to turn off the volume clear voice instruction			
3.3	OWS	Communicate unambiguously	Clearly provide the operator with the correct action to be taken to prevent the potential collision (based on instruction from the CxDC).	use verbal and visual communication use appropriate icons specific instruction slow down and stop validated with representative sample of TMM operators			
3.4	OWS	Provide visual warning indicator	A visual warning shall be provided to all operators in the interaction	Cab interior to be lit up with a non-intrusive but clearly visible light at the time that the operator must take action			

3.5	OWS	Provide visual information display	A visual information display shall be provided for each CPS fitted TMM	minimum size is 150mm x150mm display located taking cognisance of existing in cab displays display element clearly visible from operator normal seating position display located not to distract operator from normal operational focus display location not to restrict operator vision SANS 259 (operator field of view) display location approved by TMM OEM display to be backlit automatic brightness adjustment a) bright enough to be viewed in sunlight b) dimmable to not blind operator in low light conditions display only the current relevant information display only the top priority information - warning and/or instructions multi-mode display e.g. default, map, failure, configuration, health, shift summary, etc. display battery health on all modes display current date and synchronised time			
3.6	OWS	Single CPS visual display	Provide one Visual display for all CPS needs.	Integrate all CPS display requirements into single visual display. Multi-mode display of types of information			

3.7	OWS	Display CPS health and fault information, inform operator	OWS must display all CPS failure modes and CPS health information. Warn operator when system fails.	fault mode screen faults are displayed per functional breakdown standardised fault codes and icons sufficient info for quick component replacement specific warning: CPS failure			
3.8	OWS	Display power supply health	The backup battery charge level must be displayed on the display element	battery backup charge level is displayed as a percentage operator is warned if charge level falls below 20% specific verbal warning CPS battery low			
3.9	OWS	Display mini map	Operators must have a display element that displays all detected ROs' position and heading within the detection area	display element showing all detected ROs' position and heading highest risk RO must flash ROs must be shown on the display element in relation to the normal driving position of the operator auto map switch-off on auto slow and stop instruction			
3.10	OWS	Remain functional in the presence of multiple interactors	Display element should function correctly independent of the number of interactors within the detection area	mini map must not be cluttered, display must not freeze up with bigger data load			
3.11	OWS	Provide speed limit warning	OWS must warn operator when he/she is about to exceed the programmed speed limit	operator warned when speed is close to (within 2km/h) of the speed limit verbal warning: speed restriction x km/h visual warning: TBD continuous warning while above limit			

Table 3: EW performance requirements.

7. CxD Log Keeping Functions (CxDLK)

The CxD Log Keeping performance requirements are documented in **Table 4.**

Req No	Function group	Function Name	Function Description	Performance Criteria	Currently Conform Y/N	Target Date	Comments
0	CxDLK	Provide CPS log keeping functionality	Log and provide a permanent auditable record of all specified information sets	see lower-level functions			
1	CxDLK	Synchronise	CxD and TMM logs must be synchronised with a Universal Time Frame	UTC + 2h synchronised every hour			
2	CxDLK	Record continuously	Record functions continuously at 1Hz	record data continuously at 1Hz			
3	CxDLK	Store TMM ID data	Store the LO unique identification and configuration data	non-volatile data storage			
4	CxDLK	Date and time stamp	Uniquely identify every data entry by date and timestamp per data type.	UTC + 2h			
5	CxDLK	Receive and store CxD data	Receive and store data from all CxD functions	data receipt capability at 1Hz continuously non-volatile data storage capability of 30 days before overwriting			
6	CxDLK	Data Transfer	Provide for periodic data transfer to mine data infrastructure	at least once per shift Wi-Fi, Local Area Network (e.g. Ethernet), Personal Area Network (e.g. Bluetooth), USB / serial, removable storage;			
7	CxDLK	Data Security	Provide data security for stored and transfer of data	as per specialist recommendation			
8	CxDLK	Store data redundantly	Log keeping must be done on multiple independent storage devices	at least 2 fully independent storage devices used to record and store data (RAID)			

9	CxDLK	Store firmware configuration	Store the current version of all CPS firmware elements	unique ID and revision date installed/updated			
10	CxDLK	Record unique ID for all interactors	The unique IDs for every interactor must be recorded during interaction	all TMMs inside the detection area			
12	CxDLK	Record LO and ROs' statuses	The status (e.g. refuelling, drilling, etc) of the LO and all ROs within the detection area must be recorded	from 10s preceding the interaction, the statuses of all TMMs within the detection area must be recorded			
13	CxDLK	Record LO system health	The CxD and TMM CPS system health must be recorded at every TMM start up and after health status changes	TMM health status indicators green light on Visual display functional failure red light within 1ms from detection			
14	CxDLK	Record LO failure data	All failure modes communicated by any CxD or TMM CPS module must be recorded.	module, fault code, date, and time stamp			
15	CxDLK	Fail to Safe log keeping	CPS must fail to safe when log keeping system does not work	failure mode communicated to CxDC			
16	CxDLK	Record all machine data received via MCI	All data communicated via the MCI must be recorded	from 5s preceding the interaction at 10Hz			
17	CxDLK	Record emergency override	Relevant data for every emergency override must be recorded	TMM ID operator ID date and time authorised overrider unique ID duration of override			
18	CxDLK	Record interactions	Instructions and responses to be recorded at 10Hz for later analysis	save data at 10Hz 5s before potential interaction			
19	CxDLK	Record effective warning	All communicated warnings from the CxDC must be recorded by the CxDLK	save data at 10Hz 5s before potential interaction			

20	CxDLK	Record auto slow and stop	All communicated auto slow and stop interventions from the CxDC must be recorded by the CxDLK	save data at 10Hz 5s before potential interaction			
21	CxDLK	Record ROs' states	The state (e.g. gear, velocity, heading) of all TMMs in the vicinity for surface, and the state (e.g. distance, direction) of all pedestrians for underground within the vicinity must be recorded	save data at 10Hz 5s before potential interaction for all TMMs within the vicinity			
22	CxDLK	Record LO status	The LO's status must be recorded at 1Hz continuously	save status data of the LO at 1Hz continuously			
23	CxDLK	Store all data	Data gathered at each shift must be stored for a specific period before it is overwritten.	data must be stored for 30 days before overwriting			

Table 4: CxDLK performance requirements

8. CxD Machine Interface (CxDI)

The CxD Machine interface functional requirements are documented in ISO TS 21815-2: 2021

9. CPS General Requirements

All CPS product elements must comply with the requirements as per Table 6.

Req No	Function group	Function Name	Function Description	Performance Criteria	Currently Conform Y/N	Target Date	Comments
1	G	Risk informed	The CPS and all its individual modules must be informed by formal design risk assessment	mineral composition a) Coal b) Iron content operator and pedestrian health operator and pedestrian safety environment impact			
2	G	Be EMC	The CPS must be electromagnetically compatible with other electronic systems on the mine (including detonation systems, V2X) It must not have any negative health impact on operators or pedestrians and no negative functional impact on any other sensing device used on the TMM.	SANS 13766:2013 human impact: ICNIRP ICASA TA			
3	G	Be Robust		See lower-level functions			
3.1	G	Prevent dust and water ingress	CPS must prevent ingress of dust and water (including cap lamp)	IP67 rating			
3.2	G	Survive exposure to shock	CPS components must be able to withstand typical vibration, shocks, etc. as normally experienced by TMMs (including cap lamps)	Mil-STD-810G shock			
3.3	G	Survive exposure to vibration		Mil-STD-810G vibration			
3.4	G	Operate at high and low temperatures	CPS components able to withstand elevated internal temperatures and external temperatures (high and low) as	Mil-STD-810G temperatures			

			typically encountered on the mine (including cap lamps)				
3.6	G	Survive solar radiation	CPS components must be able to withstand high temperatures and photo degradation	Mil-STD-810G solar			
4	G	Power supply		See lower-level functions			
4.1	G	Out of cab functions	Off-board sensors as part must be supplied with suitable power supply (e.g. battery)	formal FMECA informed last at least 48 hours before recharging			
4.2	G	In cab	In cab functions must be powered	Powered via ISO/TS 21815-2:2021 connector			
4.3	G	Physical interface	Power cables plugs	ISO/TS 21815-2:2021 connector			
4.4	G	Battery backup	The CPS must have a battery backup capability	48h capacity auto charged able to prevent collisions when on battery backup			
5	G	Be self-diagnostic	CPS functional elements to be self-diagnostic and continuously monitor function availability	be informed by formal FMECA			
6	G	Report Failure(s) to CxDC	All self-diagnostic functions to report failure(s) to the CxD	reporting within 100ms As per CxD developer specification ISO/TS 21815-2:2021			
7	G	Data Logging	The CxD and TMM CPS must have separate data logging capabilities	See CxDLK and MLK functional requirements			
8	G	Installation (Buildability)	All CPS physical components and elements to be designed for effective installation	retrofittable to existing TMMs see lower-level requirements			

8.1	G	Mounting	Mountings not to deteriorate TMM integrity	positioned as per TMM OEM specification not be exposed to operational hazards - falling material, TMM articulation not affect structural safety ie. mountings, drilling and welding. not cause operator injury - bumping, nipping, cutting not cause EMI to other TMM systems			
8.2	G	Cable routing	All cable routing to support TMM maintainability	positioned as per TMM OEM specification as per appropriate cable specification/standard. be protected from normal operating damage ease of securing and removal of all CPS modules and components protected from physical damage not negatively impact on maintainability of other in cab systems			
9	G	Availability	All CPS modules must be designed for availability	98% components (CxD and TMM CPS respectively) 95% CxD availability maintained			
10	G	Maintainability	The CPS to be designed for optimal maintainability	formal maintenance and repair strategy informed quick removal and mounting of modules modular design to facilitate quick fault finding and lower replacement unit cost MTTR = 90min critical spares identified maintenance spares to be plug and play			

				where applicable maintenance tools to be “special tools” designed for correct removal and fitment.			
11	G	Operability	All CPS modules to be operable/configured/tested after maintenance or component replacement. CPS not to degrade TMM operating or production capability	quick reconfigurable/commissioning Not negatively impact TMM operability/production capability – as per TMM OEM specifications			
12	G	Reliability	All CPS modules must be designed for reliability	Formal FMECA informed CPS MTBF > 2000 operating hours redundancy if required			
13	G	Identification and marking	All CPS modules and sub systems to be uniquely identified and marked	item no item name serial number version physically marked data stored in CxDLK/MLK as relevant data displayed on OW display on request.			
14	G	Firmware requirements	Version controlled and electronically updatable	unique identifier version date installed or last updated updatable via TBD recommissioned after update data logged specifically			
15	G	Reporting	The CPS must have a reporting, trending and business intelligence function that is configurable by the mine	Requirements are TBD.			
16	G	Safety integrity	The CPS must be designed for safety integrity	Comply with GMG GUIDELINE FOR			

				APPLYING FUNCTIONAL SAFETY TO AUTONOMOUS SYSTEMS IN MINING - 18 Aug 2020			
17	G	Off board components	Off-board components/units must initiate a fail to safe instruction when they fail.	Initiate FTS For V2X standard = TBD			
18	G	Calibration	All relevant components and/or modules must be calibrated	Calibration items identified specifically Calibration specifications including frequency and calibration standards.			

Table 6: CPS general performance requirements.