EMESRT
Earth Moving Equipment Safety Round Table

Rev 1.0

PR – 5A

Vehicle Interaction Systems

Overview:

This Performance Requirement (PR) has been developed to augment interpretation of EMESRT Design Philosophy (DP) 5, Machine Operation Controls in the following potential unwanted event (PUE) scenarios:

- 5.2 Injury due to workstation design & external structures
- 5.3 Injury or illness from physical and/or mental fatigue
- 5.4 Harm from impaired visibility (including distorted or degraded vision) or impaired awareness of hazards in a variety of operating conditions
- 5.5 Harm from restricted or impeded operator vision of the surrounding environment and for tool operation
- 5.6 Harm from collisions due to persons and small vehicles being encouraged/forced, by the equipment design, to locate on the operator's blind side
- 5.7 Harm from loss of machine stability while operating, tramming, articulating or relocating
- 5.8 Harm from incorrect use of equipment controls, incorrect/inaccurate calibration or ineffective maintenance due to poorly designed controls and displays
- 5.9 Harm from misinterpretation of information due to displays or labels
- 5.11 Harm, including mental overload, from warnings and alarms being overlooked, ignored or not heard

This PR should be read in conjunction with DP-5.

Performance Requirement Objectives

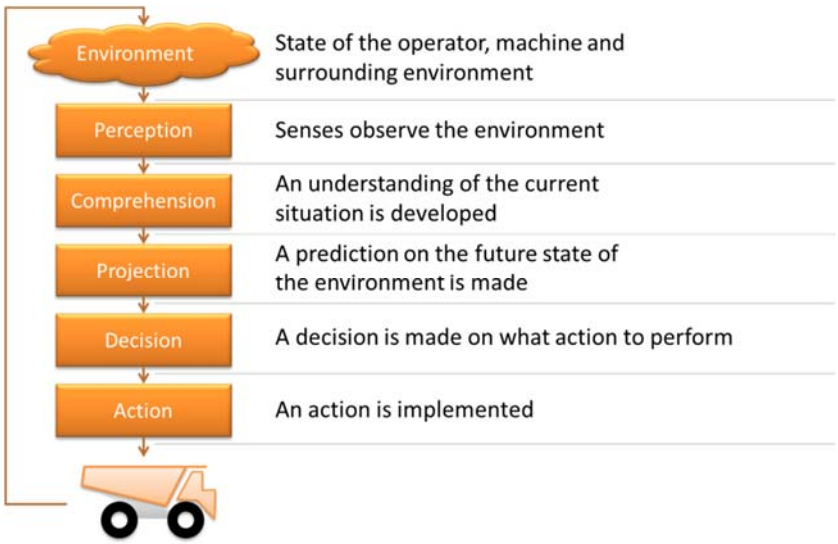
The objective is to prevent a person or equipment (machine or vehicle) causing a PUE in the following four PUE categories resulting in injury or equipment damage:

1. Equipment to person,
2. Equipment to equipment,
3. Equipment to environment, and
4. Loss of control of equipment,

by means of timely, repeatable, dependant and accurate information being presented to a person, the operator or the equipment itself so that appropriate action can be taken by the person, the operator or the equipment itself to avoid or mitigate the outcomes of the above PUE's.

Operator Situational Awareness Model

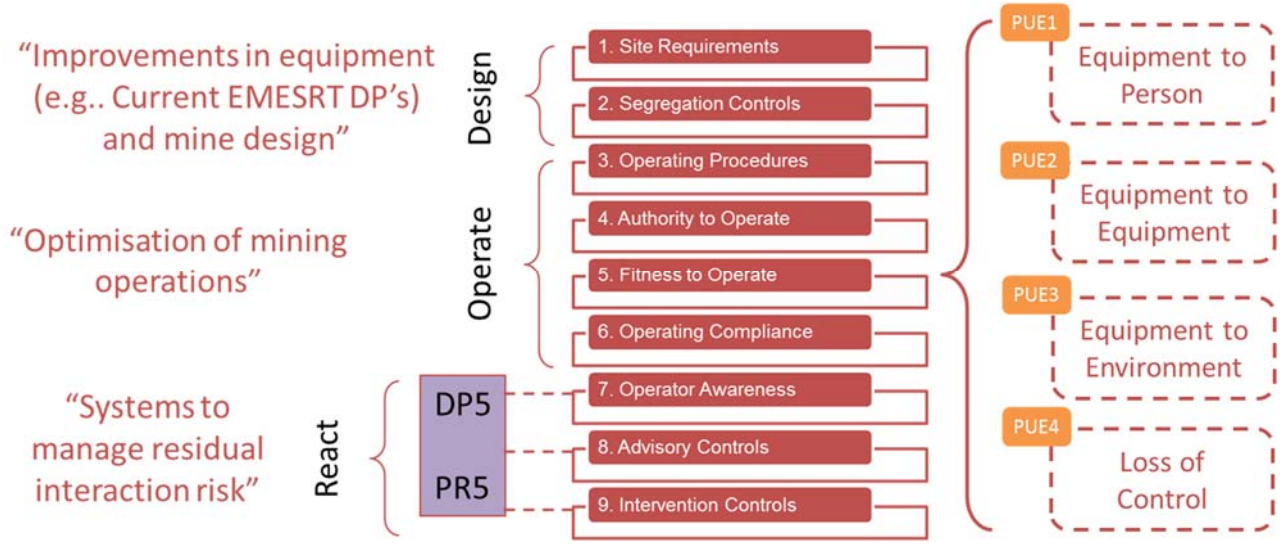
This Situational Awareness model depicts the key elements of operator interaction to control a vehicle effectively



Model of Situational Awareness – Mica Endsley 1998

Vehicle Interaction Defensive Controls Model

The controls model depicts the 9 defensive layers which provide differing levels of process controls to prevent an unwanted vehicle interaction. The PR relates to the the last three level of defence, 7, 8 & 9.



Control Classification Level Definitions

- **Level 7 – Operator Awareness**

  Technologies that provide information to enhance the operator ability to observe and understand potential hazards in the vicinity of the equipment

- **Level 8 – Advisory Controls**

  Technologies that provide alarms and/or instruction to enhance the operator ability to predict a potential unsafe interaction and the corrective action required

- **Level 9 – Intervention Controls**

  Technologies that automatically intervene and take some form of equipment control to prevent or mitigate an unsafe interaction

Design / Systems Interdependence

Given the range and brands of equipment in use in the mining industry and that there is an array of technologies and suppliers that may be utilised to meet the objectives of Levels 7, 8 & 9 designs, consideration of the differing systems/technologies interdependence will be a key requirement in design performance objectives.

Definitions

Local Object (LO) - The interactor in the best position to avoid the interaction - generally the interactor with the highest energy. There is only one Local Object in any interaction and it must be capable of taking preventative action.

Remote Object (RO) - The 'other' participant in the interaction, generally with limited preventative controls available

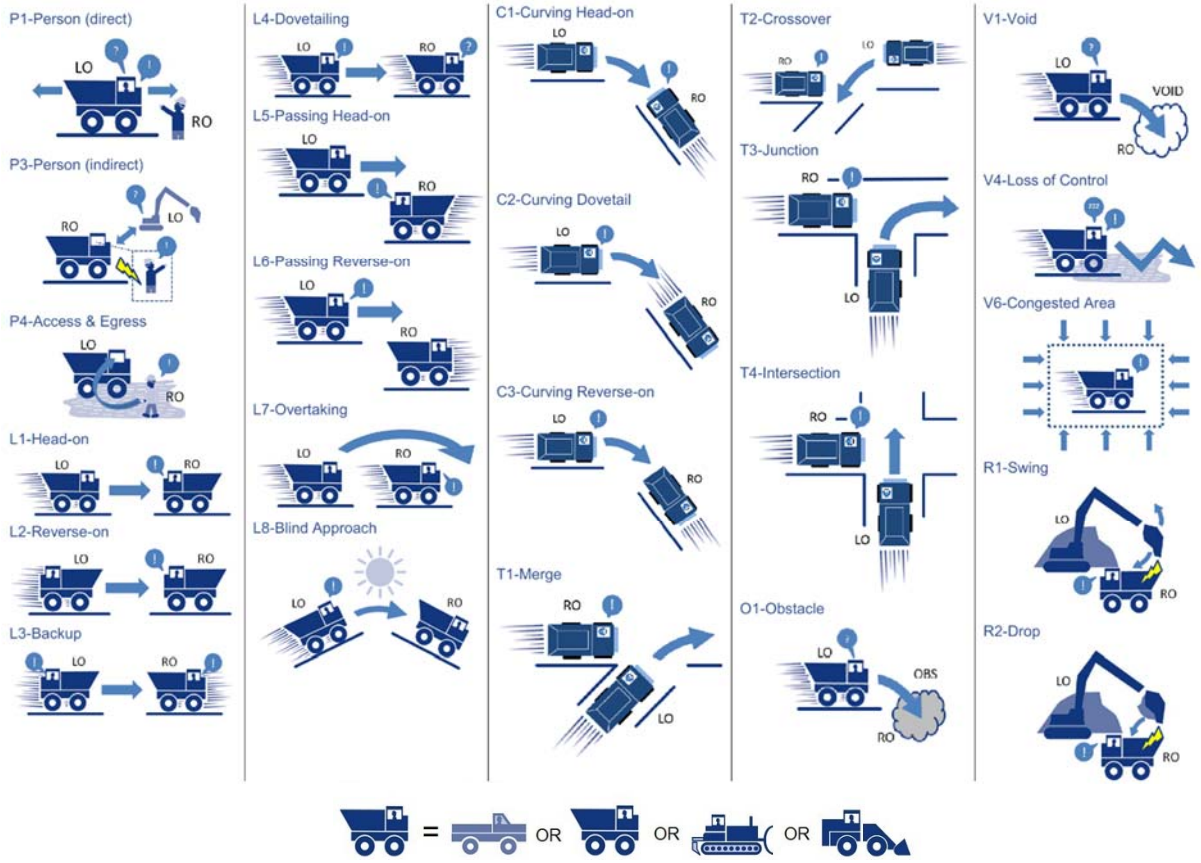
Vehicle Interaction Scenarios

The intended design outcome should include/consider but not be limited to the following interaction scenarios:

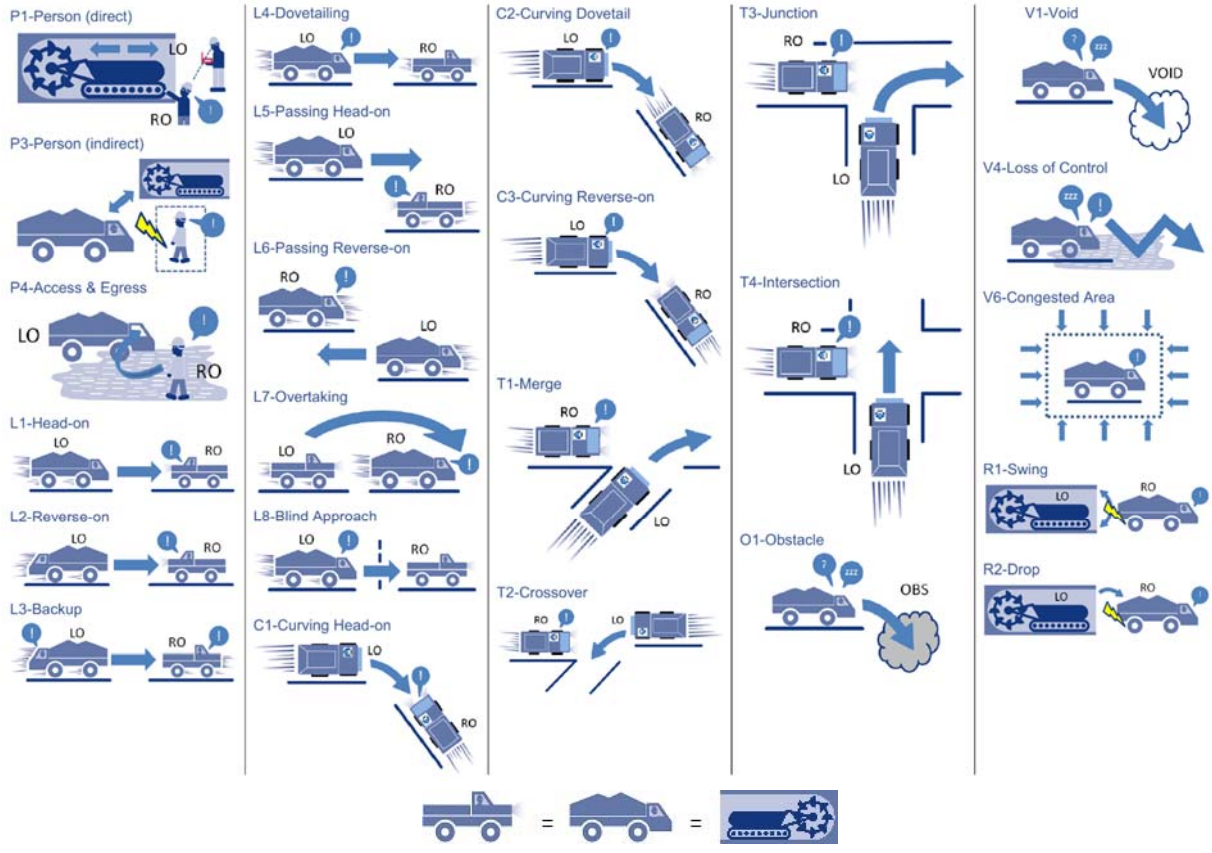
Scenario	Definitions
P1-Person (direct)	Person on foot (RO) in immediate vicinity around machine (LO)
P3-Person (indirect)	Person on foot that is a bystander in an interaction between machines and/or infrastructure
P4-Access & Egress	Person getting on or off stationary machine (see Access & Egress DP)
L1-Head-on	RO directly in the path of a LO moving (or intending to move) forward
L2-Reverse-on	RO directly behind a LO moving (or intending to move) in reverse
L3-Backup	Two machines (LO & RO) reversing towards each other
L4-Dovetailing	LO following a RO with both moving in the forward direction
L5-Passing Head-on	Two machines (LO & RO) passing each other in opposite directions with both moving forward
L6-Passing Reverse-on	Two machines oriented in same direction with the forward-moving LO passing a stationary or reversing RO
L7-Overtaking	LO pulling out and overtaking a RO with both moving forward
L8-Blind Approach	Forward-moving LO with limited or no visibility approaching a stationary or moving RO (blinded or obstructed)
C1-Curving Head-on	Two machines (LO & RO) approaching in opposite directions around a bend with both moving forward
C1-Curving Dovetail	Two machines (LO & RO) following each other around a bend with both moving forward
C3-Curving Reverse-on	LO approaching a stationary or reversing RO around a bend
T1-Merge	LO approaching a merge intersection with a RO travelling straight-through

T2-Crossover	LO intending to turn across path of oncoming RO
T3-Junction	LO approaching an tee intersection with RO travelling straight-through
T4-Intersection	LO approaching a ~90 degree four-way intersection with RO travelling straight-through
R1-Swing	Machine with rotating body (LO) operating with another machine (RO) near-by – e.g. shovel-truck
R2-Drop	Machine with elevated load (LO) transferring material to another machine (RO)
O1-Obstacle	Machine (LO) approaching a fixed object (RO) – e.g. high-wall, foot-wall, hanging-wall, infrastructure
V1-Void	Machine (LO) entering a no-go area (RO) - e.g. road or tip edge, limited clearance, soft barrier, electrical cable
V4-Loss of Control	Operator not in control of machine (LO) and none of the above scenarios apply (P1,P3,L1-8,C1-3,T1-3,O1,R1-2,V1)
V6-Congested Area	Machine (LO) operating with multiple (more than 2) other machines in close proximity – e.g. workshop area

Surface Vehicle Interaction Scenarios



Underground Vehicle Interaction Scenarios



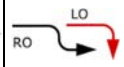
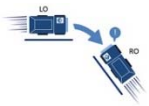
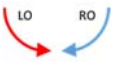
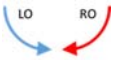
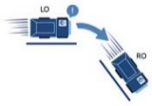
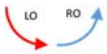
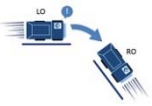
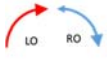
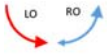
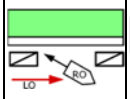
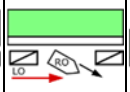
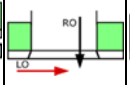
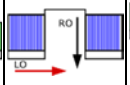
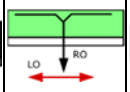
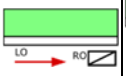
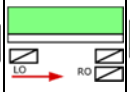
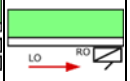
Scenario Codes – Surface

PUE1-Equipment to Person

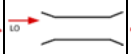
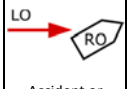
		01	02	03	04	05	06	07	08	09	XX
P1	P1-Person (direct)	Near-side	Emerging	Far-side	Working lying, standing	Walking with traffic	Walking against traffic	Driveway	On walkway		Other
P3	P3-Person (indirect)	Spotting	Materials handling	Sprung, coiled energy release	Suspended load	Electrical contact	Pressure release				Other
P4	P4-Access & Egress	Boarding	Alighting	Hot-seat change	Training	Falling off					Other

PUE2-Equipment to Equipment

		01	02	03	04	05	06	07	08	09	XX
T1	T1-Merge	Left-Merge	Right-Merge	Merge-Left	Merge-Right	U-Turn	Right-Swipe	Left-Swipe			Other
T2	T2-Crossover	Left-Crossover	Right-Crossover	Right-Left	Right-Right						Other
T3	T3-Junction	Right-Thru	Left-Thru	Thru-Right	Right-Right	Left-Right	Thru-Left	Left-Left	Thru-Left		Other
T4	T4-Intersection	Thru-Thru	Right-Left	Left-Left	Right-Straight						Other
L1	L1-Head-on	On-path	U-Loop								Other
L2	L2-Reverse-on	Reversing									Other
L3	L3-Backup	Reversing at dump	Reversing at park-up area	Loading							Other
L4	L4-Dovetailing	Rear-end	Left-Rear	Right-Rear	Pullout-Rear						Other
L5	L5-Passing Head-on	Head-on into oncoming path	Misjudged clearance								Other
L6	L6-Passing Reverse-on	Lane incursion	Pulling out	Cutting in							Other

		01	02	03	04	05	06	07	08	09	XX
L7	L7-Overtaking 	 Pulling out	 Overtake-Right								Other
L8	L8-Blind Approach 	 Sun Glare	 Bright Light	 Reflection							Other
C1	C1-Curving Head-on 	 LO Cutting Corner	 LO Swinging Wide	 RO Oversteer	 RO Understeer						Other
C2	C2-Curving Dovetail 	 Outside Head-Tail	 Inside Head-Tail								Other
C3	C3-Curving Reverse-on 	 Outside Reverse-up	 Inside Reverse-up								Other
V6	V6-Congested Area 	 Enter park-bay	 In park-bay	 Leave park-bay	 Leaving driveway	 Loading bay	 From footway	 Limited space	 Double park	 Door / ladder	Other

PUE3-Equipment to Environment

		01	02	03	04	05	06	07	08	09	XX
O1	O1-Obstacle 	 Reversing into object	 Permanent construction	 Temporary roadworks	 Temporary object on road	 Animal on road	 Animal off road	 Load hits vehicle	 Drove into berm	 Drove into infrastructure	Other
V1	V1-Void 	 Accident or breakdown	Maintenance area	Unstable ground	On rail tracks						Other

PUE4-Loss of Control

		01	02	03	04	05	06	07	08	09	10
V4	V1-Loss of Control	Operator not in control	Out of control on straight road	Off road to left	Off road to right	Off road to left into object	Off road to right into object	Lost control turning left	Lost control turning right	Rollaway on road	
		11	12	13	14	15	16	17	18	19	XX
		Lost control into berm	Out of control on bend	Off road on right bend	Off road on left bend	Off road on right bend into object	Off road on left bend into object	Lost control on left bend	Lost control on right bend		Other

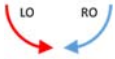
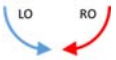
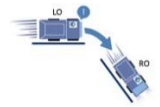
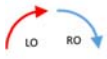
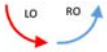
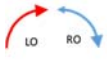
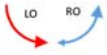
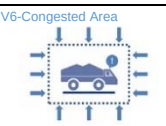
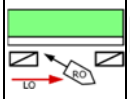
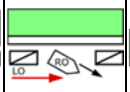
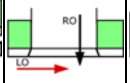
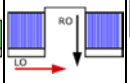
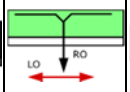
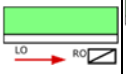
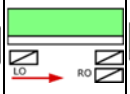
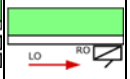
Scenario Codes – Underground

PUE1-Equipment to Person

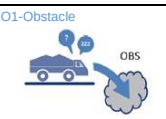
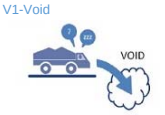
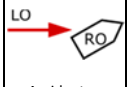
		01	02	03	04	05	06	07	08	09	XX
P1	P1-Person (direct)	Near-side	Emerging	Far-side	Working lying, standing	Walking with traffic	Walking against traffic	Driveway	On walkway		Other
P3	P3-Person (indirect)	Spotting	Materials handling	Sprung, coiled energy release	Suspended load	Electrical contact	Pressure release				Other
P4	P4-Access & Egress	Boarding	Alighting	Hot-seat change	Training	Falling off					Other

PUE2-Equipment to Equipment

		01	02	03	04	05	06	07	08	09	XX
T1	T1-Merge	Left-Merge	Right-Merge	Merge-Left	Merge-Right	U-Turn	Right-Swipe	Left-Swipe			Other
T2	T2-Crossover	Left-Crossover	Right-Crossover	Right-Left	Right-Right						Other
T3	T3-Junction	Right-Thru	Left-Thru	Thru-Right	Right-Right	Left-Right	Thru-Left	Left-Left	Thru-Left		Other
T4	T4-Intersection	Thru-Thru	Right-Left	Left-Left	Right-Straight						Other
L1	L1-Head-on	On-path	U-Loop								Other
L2	L2-Reverse-on	Reversing									Other
L3	L3-Backup	Reversing at dump	Reversing at park-up area	Loading							Other
L4	L4-Dovetailing	Rear-end	Left-Rear	Right-Rear	Pullout-Rear						Other
L5	L5-Passing Head-on	Head-on into oncoming path	Misjudged clearance								Other
L6	L6-Passing Reverse-on	Lane incursion	Pulling out	Cutting in							Other

		01	02	03	04	05	06	07	08	09	XX
L7	L7-Overtaking 	 Pulling out	 Overtake-Right								Other
L8	L8-Blind Approach 	 Sun Glare	 Bright Light	 Reflection							Other
C1	C1-Curving Head-on 	 LO Cutting Corner	 LO Swinging Wide	 RO Oversteer	 RO Understeer						Other
C2	C2-Curving Dovetail 	 Outside Head-Tail	 Inside Head-Tail								Other
C3	C3-Curving Reverse-on 	 Outside Reverse-up	 Inside Reverse-up								Other
V6	V6-Congested Area 	 Enter park-bay	 In park-bay	 Leave park-bay	 Leaving driveway	 Loading bay	 From footway	 Limited space	 Double park	 Door / ladder	Other

PUE3-Equipment to Environment

		01	02	03	04	05	06	07	08	09	XX
O1	O1-Obstacle 	 Reversing into object	 Permanent construction	 Temporary roadworks	 Temporary object on road	 Animal on road	 Animal off road	 Load hits vehicle	 Drove into berm	 Drove into infrastructure	Other
V1	V1-Void 	 Accident or breakdown	Maintenance area	Unstable ground	On rail tracks						Other

PUE4-Loss of Control

		01	02	03	04	05	06	07	08	09	10
V4	V4-Loss of Control	Operator not in control	Out of control on straight road	Off road to left	Off road to right	Off road to left into object	Off road to right into object	Lost control turning left	Lost control turning right	Rollaway on road	Other
		11	12	13	14	15	16	17	18	19	XX
		Lost control into berm	Out of control on bend	Off road on right bend	Off road on left bend	Off road on right bend into object	Off road on left bend into object	Lost control on left bend	Lost control on right bend	Rollaway off road	Other

Vehicle Interaction Scenario Performance Requirement Definitions

		Control Type		
Potential Unwanted Event types	**General Requirements**	**(Level 7) Operator Awareness**	**(Level 8) Advisory**	**(Level 9) Intervention**
Equipment to person **People enter, or are in the at-risk zone of the machine**	Machine is in control by the operator The at-risk zone is mobile equipment type and closure speed dependent. The system is active during machine start-up, running and shut-down.	*Operator is made aware of people by:* • Correcting a specific significant operator blind-spot • Correcting multiple significant operator blind-spots • Providing information on the presence of personnel in the at-risk zone • Providing information on the location of personnel in the at-risk zone • Providing information on the location of personnel in the surrounding area	*Operator is alerted to the presence of people by:* • Alarming the presence of people in a significant operator blind-spot • Alarming the presence of people in the at-risk zone • Alarming the location of people in the at-risk zone *Operator is advised to undertake a prescribed action to avoid/mitigate a collision with people by:* • Alarm with advice to prohibit specific actions • Alarm with advice to undertake specific actions	*Automatic control of particular machine functions is taken in order to avoid/mitigate a collision with people by:* • Modifying or limiting operator inputs for specific machine controls • Modifying or limiting specific machine functions • Asserting full control over the machine
Equipment to equipment **Equipment enters or is in the at-risk zone of the machine**	Machine is in control by the operator The at-risk zone is mobile equipment type and closure speed dependent. The system is active during machine start-up, running and shut-down.	*Operator is made aware of other equipment and vehicles by:* • Correcting a specific significant operator blind-spot • Correcting multiple significant operator blind-spots • Providing information on the presence of equipment and vehicles in the at-risk zone • Providing information on the type, location, heading and speed of equipment and vehicles in the at-risk zone • Providing information on the location, type, heading and speed of equipment and vehicles in the surrounding area	*Operator is alerted to the presence of other equipment and vehicles by:* • Alarming the presence of other equipment and vehicles in a significant operator blind-spot • Alarming the presence of other equipment and vehicles in the at-risk zone • Alarming the type, location, heading and speed of equipment and vehicles in the at-risk zone *Operator is advised to undertake a prescribed action to avoid/mitigate a collision with mobile equipment or vehicles by:* • Alarm with advice to prohibit specific actions • Alarm with advice to undertake specific actions	*Automatic control of particular machine functions is taken in order to avoid/mitigate a collision with other equipment and vehicles by:* • Modifying or limiting operator inputs for specific machine controls • Modifying or limiting specific machine functions • Asserting full control over the machine

Equipment to infrastructure, Object	Machine is in control by the operator The at-risk zone is mobile equipment type and closure speed dependent. The system is active during machine start-up, running and shut-down.	*Operator is made aware of infrastructure and objects by:* • Correcting a specific significant operator blind-spot • Correcting multiple significant operator blind-spots • Providing information on the presence of infrastructure and objects in the at-risk zone • Providing information on the type and location of infrastructure and objects in the at-risk zone • Providing information on the type and location of infrastructure and objects in the surrounding area	*Operator is alerted to the presence of infrastructure and objects by:* • Alarming the presence of infrastructure and objects in a significant operator blind-spot • Alarming the presence of infrastructure and objects in the at-risk zone • Alarming the type and location of infrastructure and objects in the at-risk zone *Operator is advised to undertake a prescribed action to avoid/mitigate a collision with infrastructure and objects by:* • Alarm with advice to prohibit specific actions • Alarm with advice to undertake specific actions	*Automatic control of particular machine functions is taken in order to avoid/mitigate a collision with infrastructure and objects by:* • Modifying or limiting operator inputs for specific machine controls • Modifying or limiting specific machine functions • Asserting full control over the machine
Equipment to Environment *Loss of control includes loss of drive, traction, steering, braking, and stability due to adverse operating surface conditions.* *Includes entry into prohibited areas*	Machine has been in control by the operator The at-risk zone is mobile equipment type and closure speed dependent. The system is active during machine start-up, running and shut-down.	*Operator is made aware of environmental conditions by:* • Correcting a specific significant operator blind-spot • Correcting multiple significant operator blind-spots • Providing information on the conditions in the at-risk zone • Providing information on the type and location of conditions in the at-risk zone • Providing information on the type and location of conditions in the surrounding area	*Operator is alerted to the environmental conditions by:* • Alarming the presence of adverse conditions in the at-risk zone • Alarming the type and location of adverse conditions in the at-risk zone • Alarming the type of loss of control *Operator is advised to undertake a prescribed action to avoid/mitigate the loss of control by:* • Alarm with advice to prohibit specific actions • Alarm with advice to undertake specific actions	*Automatic control of particular machine functions is taken in order to avoid/mitigate the loss of control by:* • Modifying or limiting operator inputs for specific machine controls • Modifying or limiting specific machine functions • Asserting full control over the machine