Designing a collision advisory system for surface mining equipment: A case study of human-centered design for new technology in mining

Robin Burgess-Limerick

Minerals Industry Safety and Health Centre
Sustainable Minerals Institute
The University of Queensland

ACARP project C29001 extension

Objective

To document the human-centred design process employed by Glencore and Wabtec throughout the development of the collision advisory system and develop a case-study suitable for dissemination to industry.

ICS › 13 › 13.180

ISO 9241-210:2010

Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems

❖ Understand and specify the context of use
❖ Specify user requirements
❖ Produce design solutions to meet requirements
❖ Evaluate designs against requirements

"At 11.50 pm on Saturday, 30 November 2013, 38-year-old Ingrid Forshaw … suffered fatal injuries when the Toyota Landcruiser she was driving collided with … the front right-hand side wheel of a haul dump truck. Ms Forshaw had earlier parked the haul truck she was operating at a stockpile. … Ms Forshaw was driving to collect other workers and go to a crib break. … (She) turned right onto the 9th haul road into the path of the truck."

Main Haul Road

Direction of travel of light vehicle

ROM Stockpile Ramp

Not to scale
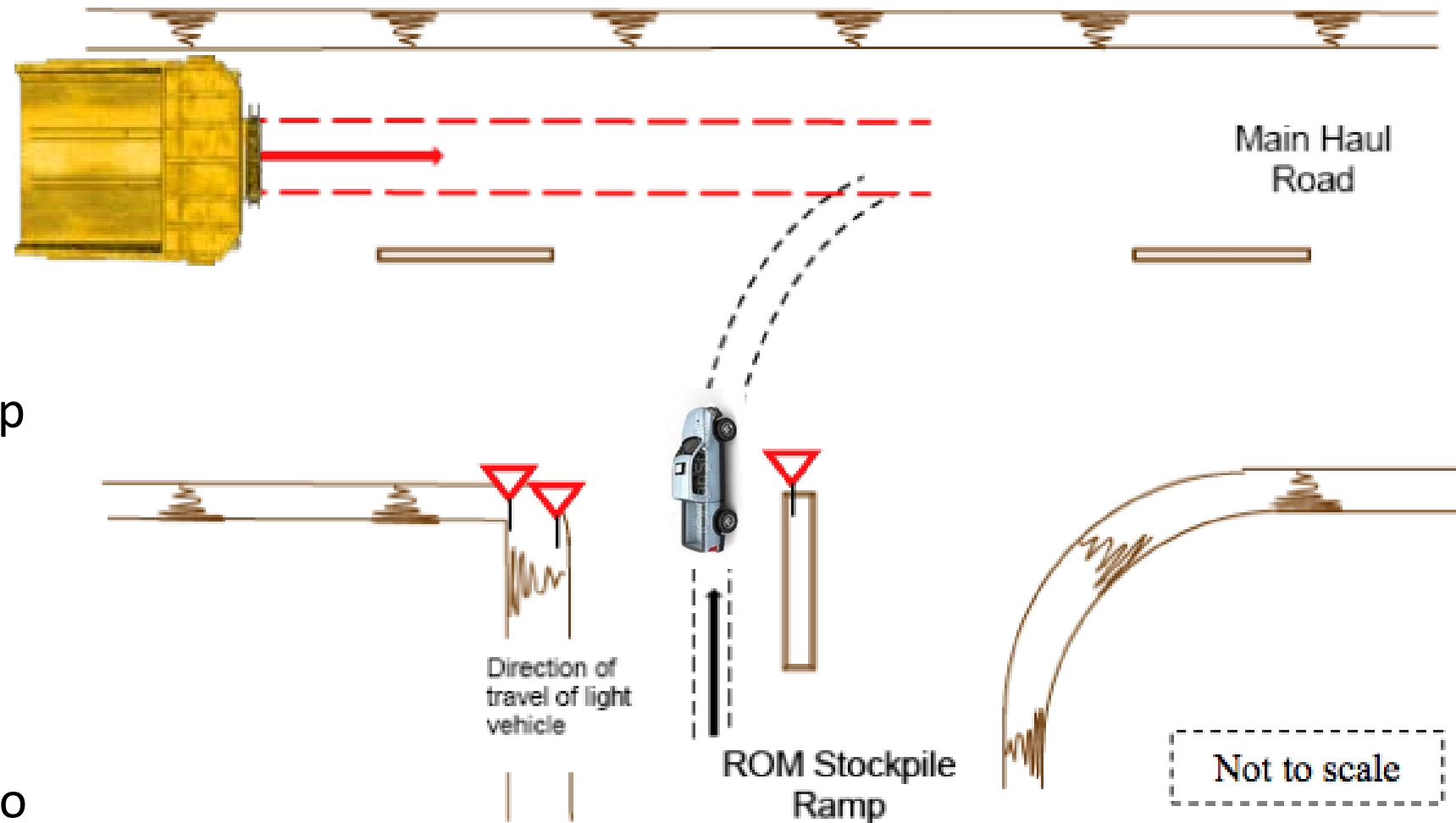
The truck

UNITED STATES
DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION
Metal and Nonmetal Mine Safety and Health

REPORT OF INVESTIGATION

Surface Metal Mine
(Copper)

Fatal Powered Haulage Accident
July 27, 2017

At 8:20 p.m. the victim parked his LV next to a windrow of material used to delineate the western boundary of the dump site. The LV's operating lights and strobe light had been turned off. Personal cell phone records indicate that the victim had been using his cellphone while he was at the dump site.

At 8:33 p.m., a Komatsu 930E-4, 320-ton haul truck entered the dump site and dumped it's load. As it began leaving the dump site another truck entered the dump area and the driver of the first truck made a large arcing turn to allow more room for the second haul truck - resulting in the LV being run over and completely destroyed.

**UNITED STATES
DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION**
Metal and Nonmetal Mine Safety and Health

REPORT OF INVESTIGATION

Surface Metal Mine
(Gold)

Fatal Powered Haulage Accident
October 31, 2017

Marigold Mining Co.
Marigold Mine
Valmy, Humboldt County, Nevada
Mine ID No. 26-02081

During a stoppage for a blast, a light vehicle containing driver and eight passengers was parked on a haul road, in front and to the side of a haul truck. After the stoppage was cleared, the haul truck driver started forward to make a U-turn. The driver and one passenger were unable to exit the vehicle before the collision.

Glencore **Vehicle Interaction Control Effectiveness** (VICE) project

Controls An act, object or technological system that of itself arrests the event and is measurable, specifiable and auditable

Erosion Factor How can the control fail or what can reduce the effectiveness of the control?

Control Support What is done at the site to address the erosion factors?
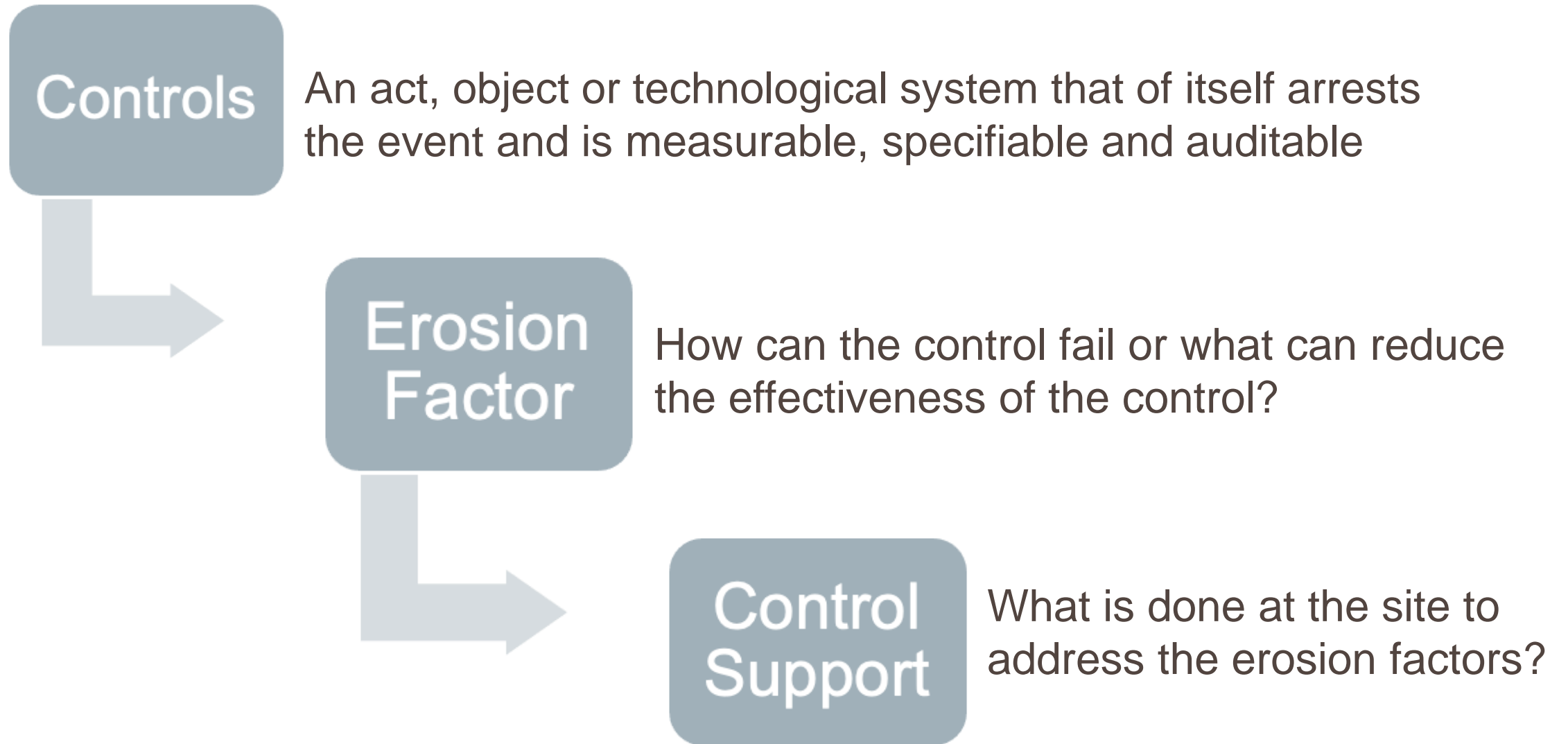
EMESRT Performance Requirements 5A - Vehicle Interaction Systems

EMESRT nine layer control effectiveness model

Design

1. Site Requirements	Equipment specifications, standards, mine design/plans — years
2. Segregation Controls	Berms, access control, traffic segregation, time schedule — months
3. Operating Procedures	SOP's, maintenance, road rules, quality control, lockout — weeks

Operate

4. Authority to Operate	Training, licences, induction, access control — days
5. Fitness to Operate	Fatigue state, drug & alcohol, medicals — shift
6. Operating Compliance	Pre-start, safety tests, machine health, event recordings — hours
7. Operator Awareness	Cameras, live maps, mirrors, lights, visible delineators — minutes

React

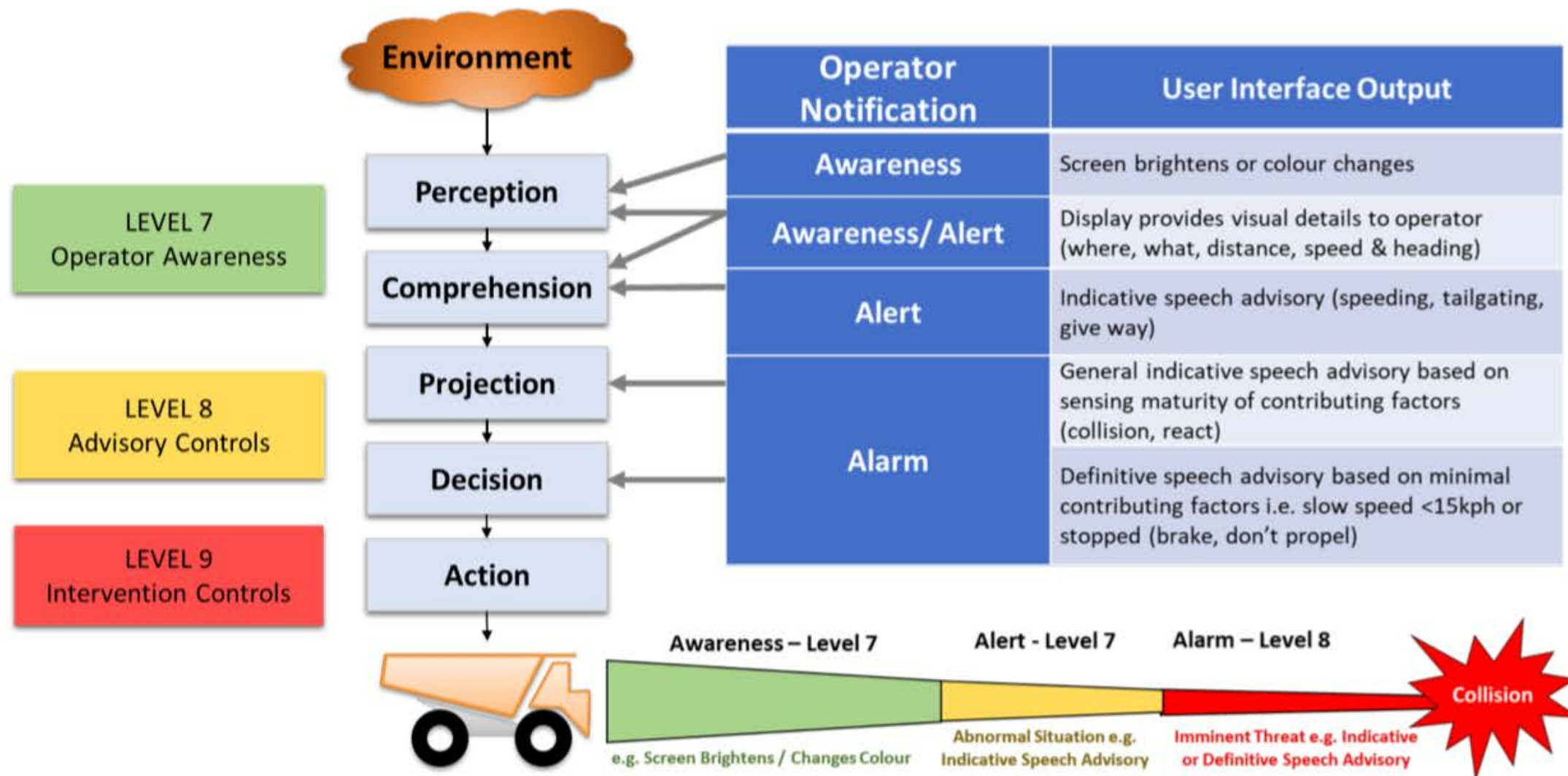|	
8. Advisory Controls	Alerts: Proximity, Fatigue, Over-speed, Vehicle stability — seconds
9. Intervention Controls	Interlocks: Prevent Start, Slow-Stop, Rollback, Retarder — milliseconds

Combining Models for a deeper understanding

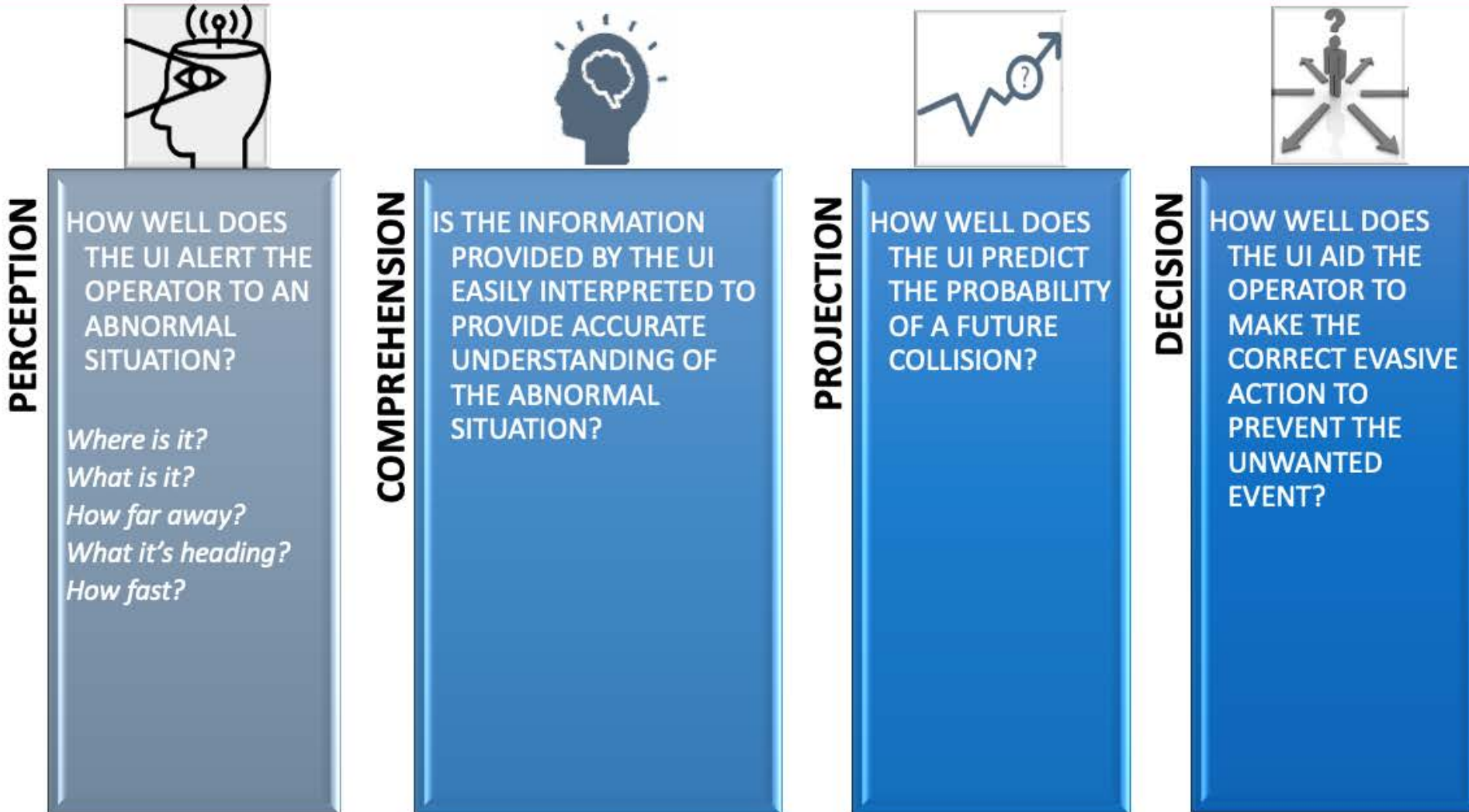Example from a Glencore Surface Mining Vehicle Interaction Technology Implementation Project

Human Factor Interaction Model
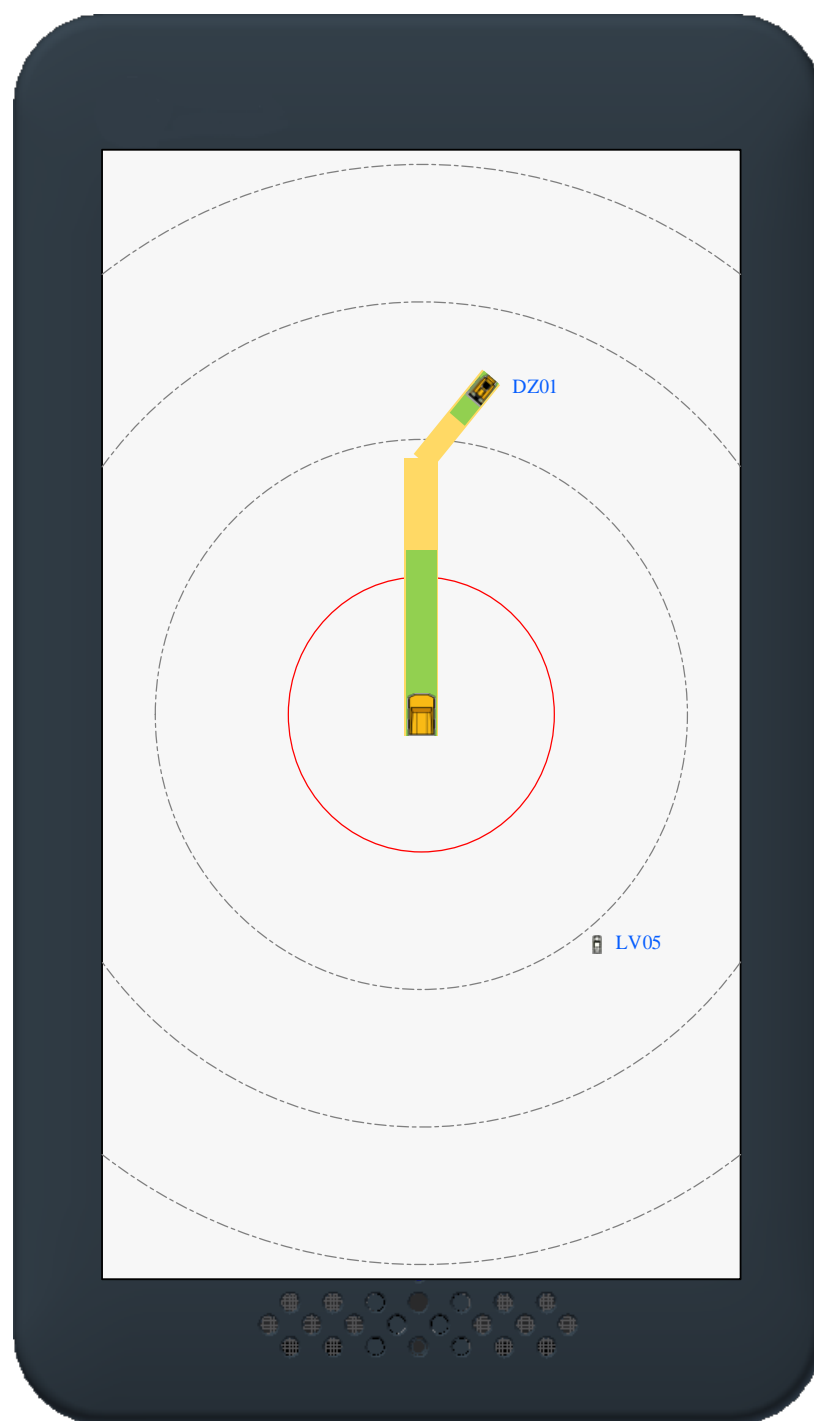EMESRT Nine Layer Model of Control Effectiveness
Mica Endsley Model of Situational Awareness

Operator Notification	User Interface Output
Awareness	Screen brightens or colour changes
Awareness/ Alert	Display provides visual details to operator (where, what, distance, speed & heading)
Alert	Indicative speech advisory (speeding, tailgating, give way)
Alarm	General indicative speech advisory based on sensing maturity of contributing factors (collision, react)
Alarm	Definitive speech advisory based on minimal contributing factors i.e. slow speed <15kph or stopped (brake, don't propel)

LEVEL 7 Operator Awareness

LEVEL 8 Advisory Controls

LEVEL 9 Intervention Controls

Environment → Perception → Comprehension → Projection → Decision → Action

Awareness – Level 7
e.g. Screen Brightens / Changes Colour

Alert - Level 7
Abnormal Situation e.g. Indicative Speech Advisory

Alarm – Level 8
Imminent Threat e.g. Indicative or Definitive Speech Advisory

Collision

User interface evaluation

GLENCORE

General User Interface Requirements - Example

Sleep Mode

- Dimmed Display
- Manual Touch Display
- No Audible
- No detection beams visible

Awareness

- Outer beams on two vehicles intersect
- Detection beams on both vehicles turn yellow
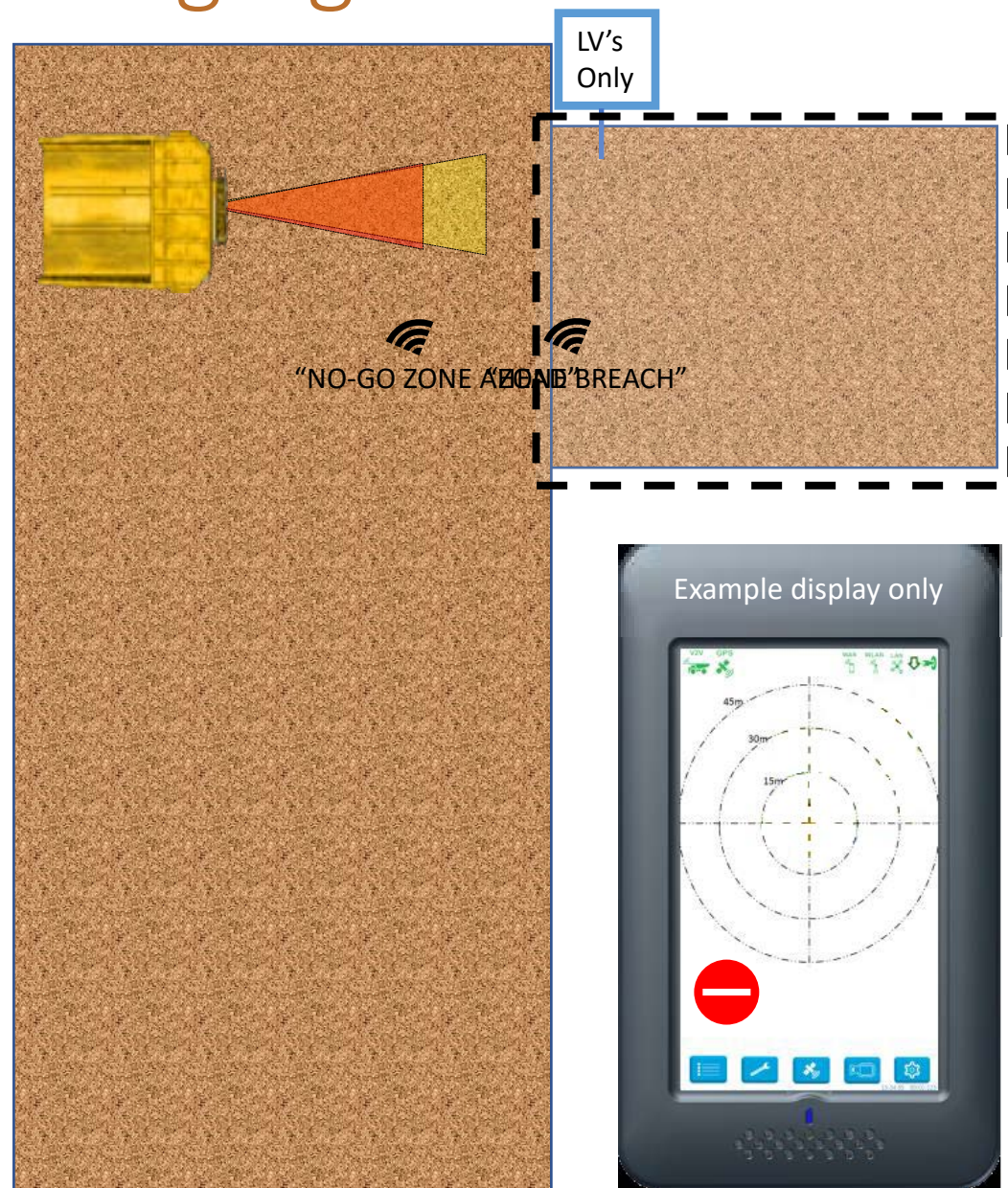- Screen brightens
- Audible for specific VI scenarios only

Alert

- Inner beams on two vehicles intersect
- Screen remains bright
- Detection beams change from yellow to red
- Indicative speech "CAS Alert" or "Threat" repeated 2-3 times and on loop with 2-3 second break
- 5 dB above ambient noise

Alarm

- Inner beam intersects the body of another vehicle
- Screen remains bright
- Detection beams are red
- Definitive speech where applicable – "Don't Propel", "Brake" repeat until situation rectified
- 10 dB above ambient noise

Segregated Roads

LV's Only

"NO-GO ZONE AHEAD" "BREACH"

Example display only

- Geofence is created to prevent specified unauthorized LOs (vehicle type) to enter a specific road in the mine –
    1. Awareness - When LO's outer beam breaches the No Go zone/geofence, then the CAS screen will brighten and No Go Zone icon will appear
    2. Alert – If the LO's inner beam breaches the No Go zone/geofence an in cab verbal prompt will be triggered "No-Go Zone Ahead"
    3. Alarm - If the LO's body breaches the No Go zone/geofence an in cab verbal prompt will be triggered "No Go Zone Breach"
   - Prompt will continue until vehicle exits the zone
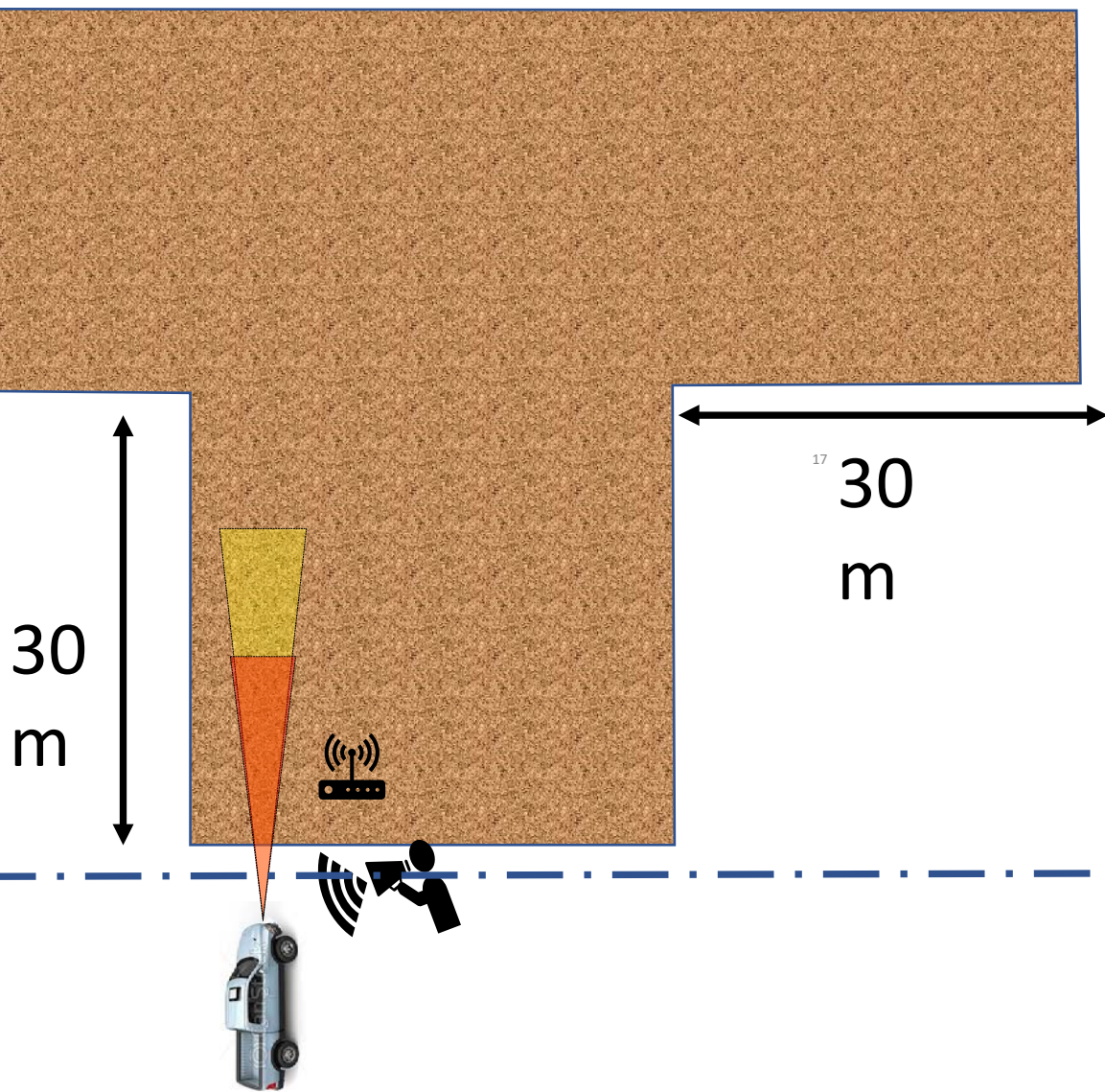
- LO (LV) approaches intersection

- When the body of the LO (LV) enters the geo-fenced intersection (30m from intersection) the CAS will scan for other CAS units in that intersection

- If intersection becomes occupied by any other vehicle whilst the LO (LV) is in the intersection the following will occur

  - Screen will brighten in LO and ROs
  - Verbal prompt "Intersection Occupied" will only trigger in LV designated vehicles not in HV's

- If the LO (HV or LV) becomes the only vehicle inside the geo-fenced intersection or departs the geo-fenced intersection the screen will then dim

- Audible should trigger once only per entry into geofence

Not applicable for dozers, drills nor tracked loading units

Tailgating – HV to HV

50 m
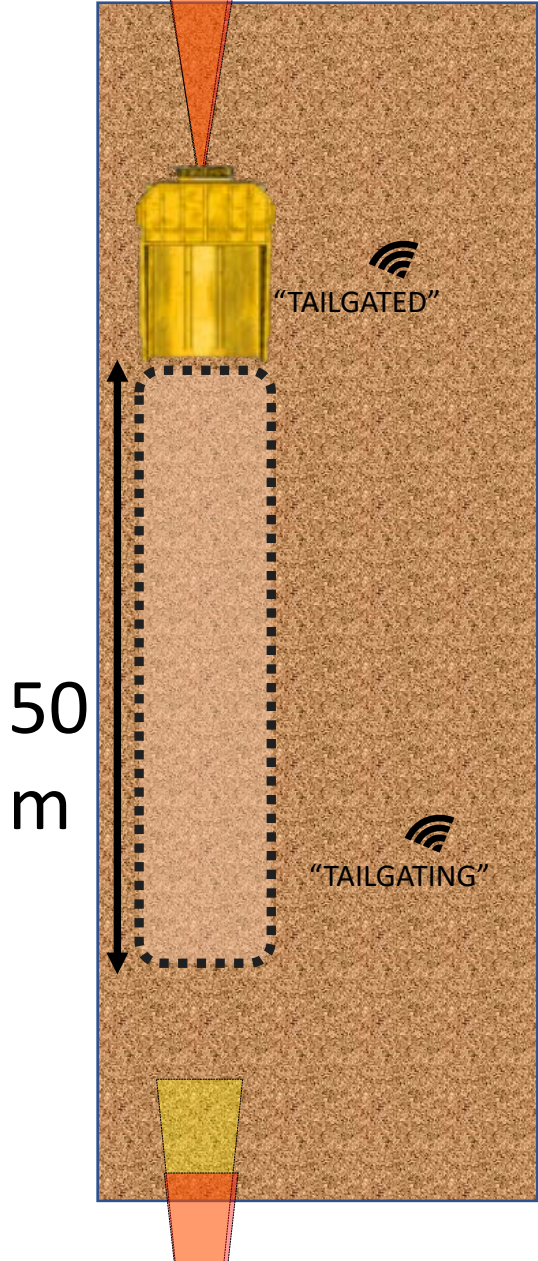
- Two Vehicles traveling in the same direction the following logic will apply

- Speed of following vehicle is between 15 kph – 34 kph
    - A 50m Static Zone will be applied between the two vehicles

- If the following distance between vehicles becomes <50m at speeds between 15kph – 34 kph
    - Front vehicle CAS display will brighten and verbal prompt "Tailgated"
    - Rear vehicle CAS display will brighten and verbal prompt "Tailgating"

- If the speed of the following vehicle is greater than 35 kph than dynamic CAS would apply tailgating logic above

Not applicable for wheel loaders, dozers, graders, drills, scrapers, cable reelers, fuel trucks and tracked loading units

Applicable for LVs, MVs only when they are the RO