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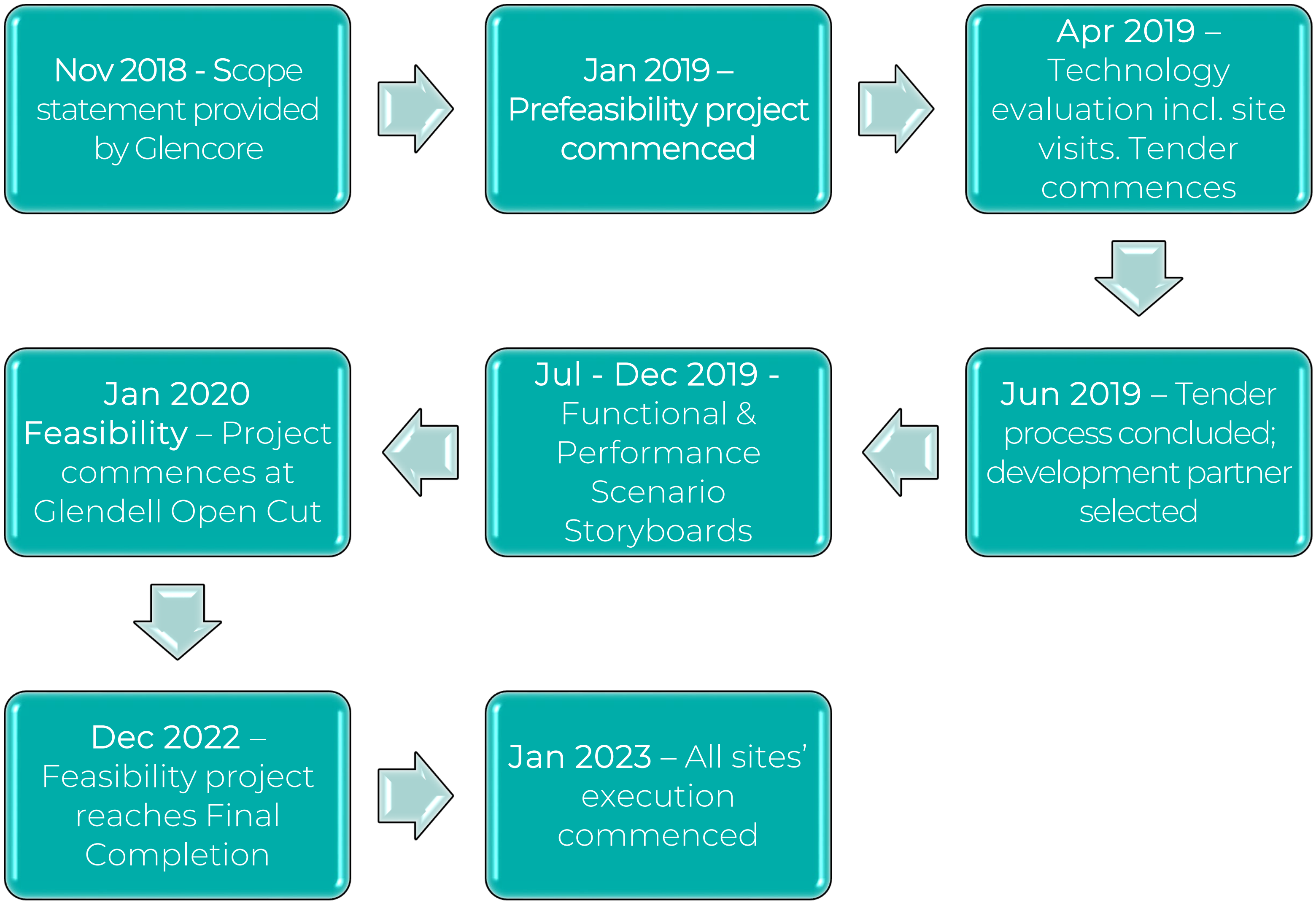
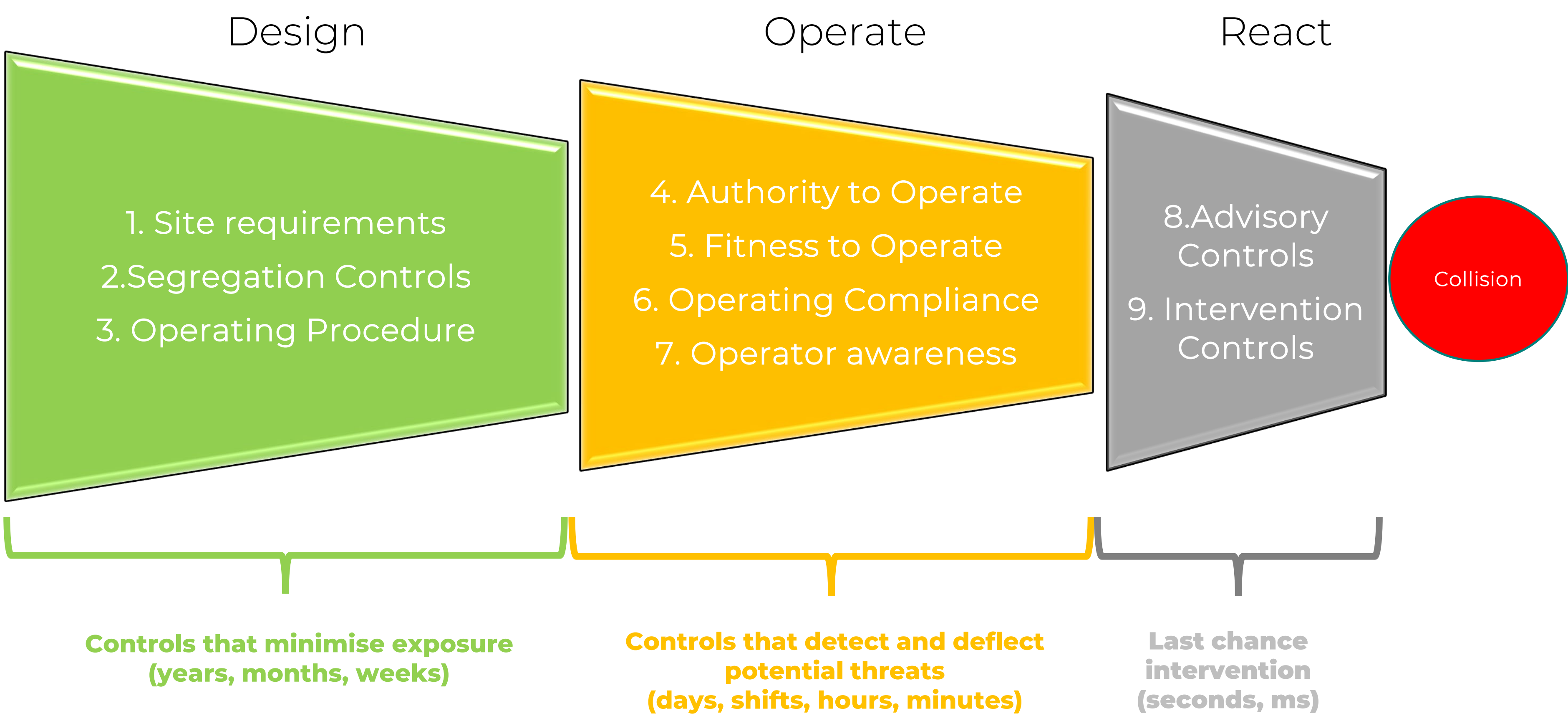
Collision Awareness System Operational Integration Glencore Coal Australia

Project Background and Timeline



Development Project Approach – EMERST 9 Layer Model



Technology Selection Criteria

Performance capability against priority scenarios:

- Adequately meets defined Functional Requirements
- Adequately meets the Performance Requirements
- Adequate system configurability / discrimination
- Adequate system repeatability of required operator responses
- Low potential for human error
- Committed and deliverable pathway to level 9 intervention

Support capability

- Technical complexity
- Hardware complexity / reliability
- Regional / site support capacity

Commercial

- Hardware / software upfront and ongoing costs
- Confidence in supplier long term viability
- Alignment with existing fleet systems

Technology Performance Criteria

Level 7 Awareness

- Ability to provide enhanced situational awareness
- Alerts the operator to a potential abnormal situation
- Provides context of the situation to the operator:

  Where is it?

  What is it?

  How far away is it?

  What is its heading?

  How fast is it going?

  Supports visual confirmation for the operator

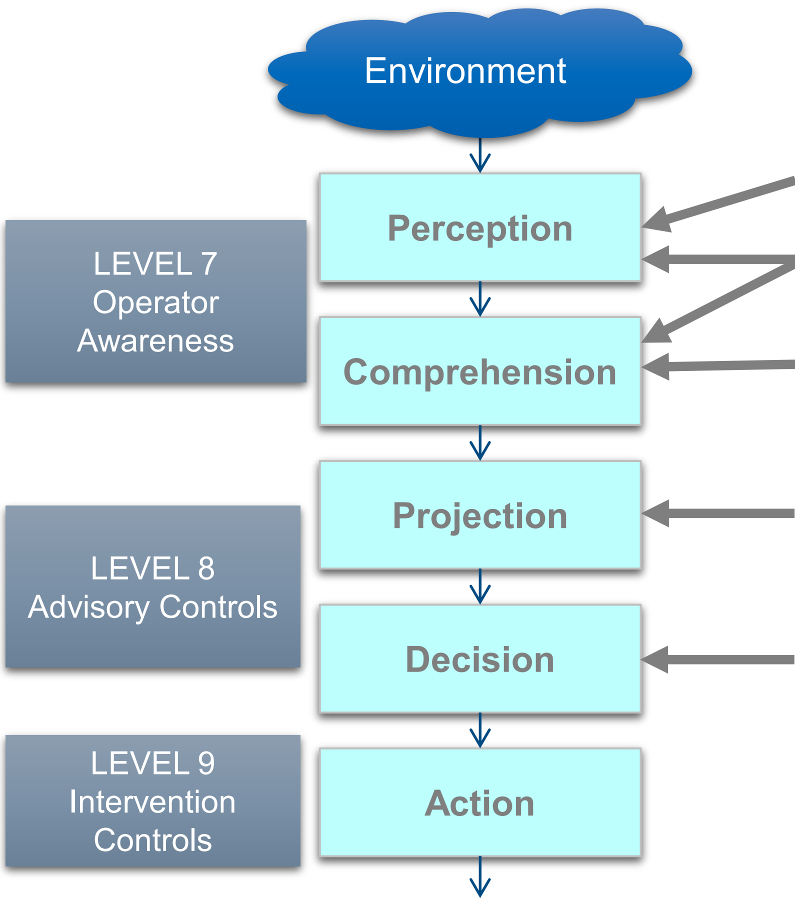
Level 8 Advisory

- Determines an imminent threat of collision
- Provides a specific instruction to the Operator to intervene (Act)
- Operator assesses the instruction in relation to other contributing factors then intervenes (Acts)

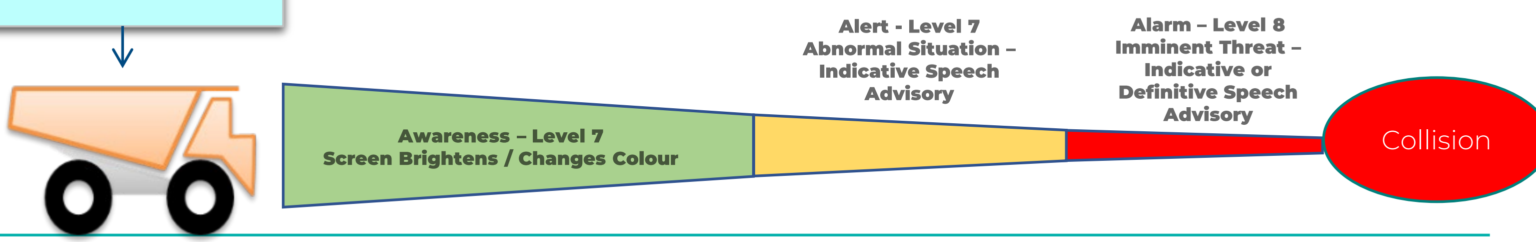
Level 9 Intervention

- Provides a specific instruction to the Machine to intervene (Act)
- Machine assesses the instruction in relation to other contributing factors then intervenes (Acts)
- Relinquish intervention control to the operator should they take evasive action
- Provides a manual over-ride to recover after a collision intervention scenario has occurred

Human Factor Interaction Model – Mica Endsley Model of Situational Awareness



Operator Notification	User Interface Output
Awareness / Alert	Display provides visual details to operator (where, what, distance, speed & heading)
Alert	Indicative speech advisory (speeding, tailgating, alert left/right)
Alarm	General indicative speech advisory based on sensing maturity of contributing factors (escalating alert left/right)
	Definitive speech advisory based on minimal contributing factors i.e. slow speed <15kph or stopped (stop, don't propel)



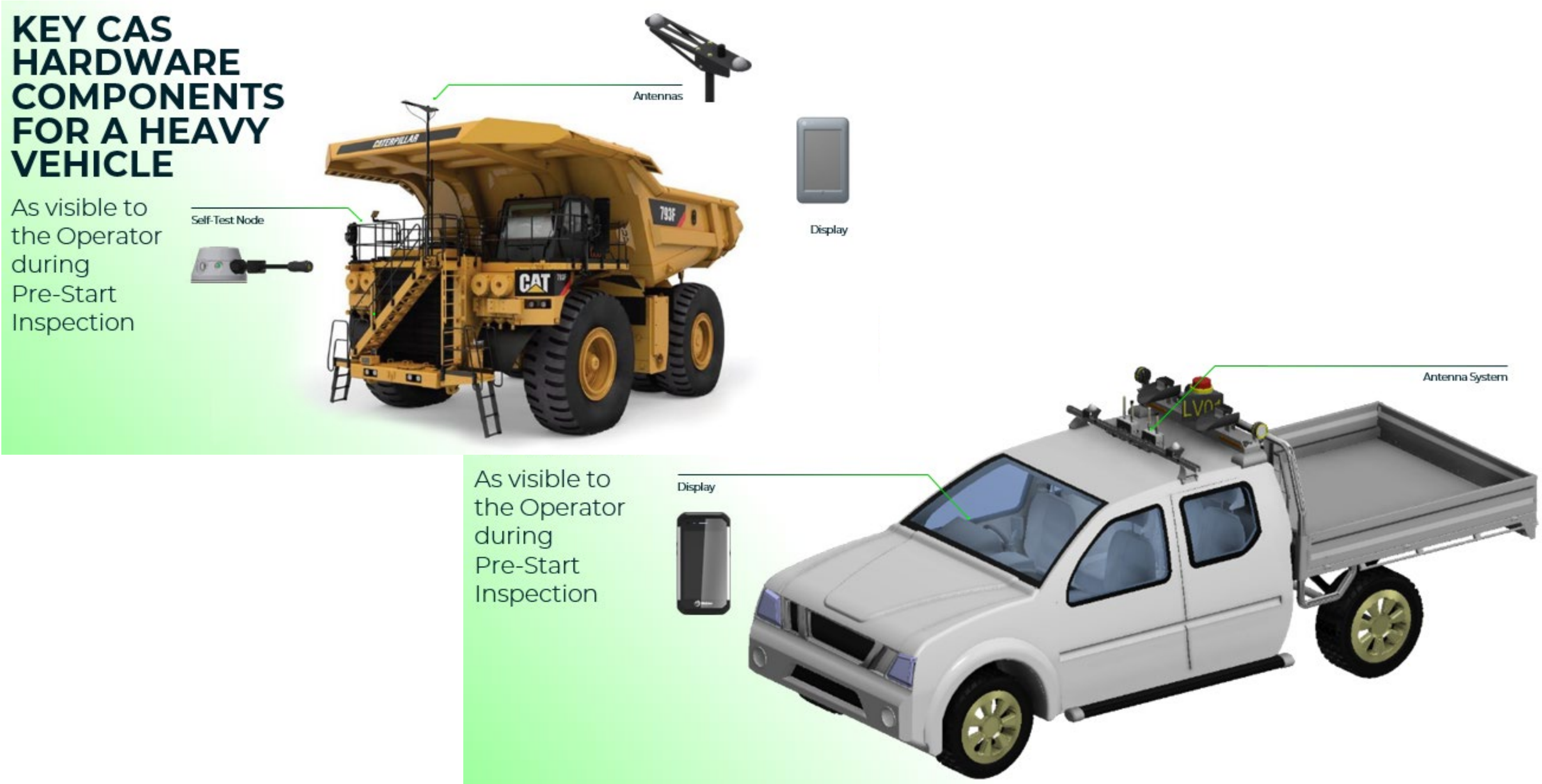
C - Mica Endsley

Project Principles

- Scope the problem from an operator's perspective.
- In cabin alarming should only be the final line of defence not the primary means of preventing vehicle interactions.
- Monitor global technology progress.
- Utilise sound engineering assessment processes and industry studies to select and develop technology solutions.
- Recognise human factors in the design.
- Aim for zero nuisance events.
- Focus on operator 'zero harm' vehicle interactions.
- Undertake engineering trial.
- Look for technologies that support site's operating standards.
- Standard system configuration for all sites.
- Consistent involvement / engagement from site personnel.

Hardware Installation - Glendell

- 100 units installed – approximately 50 HVs, 30 LVs & 20 portable units



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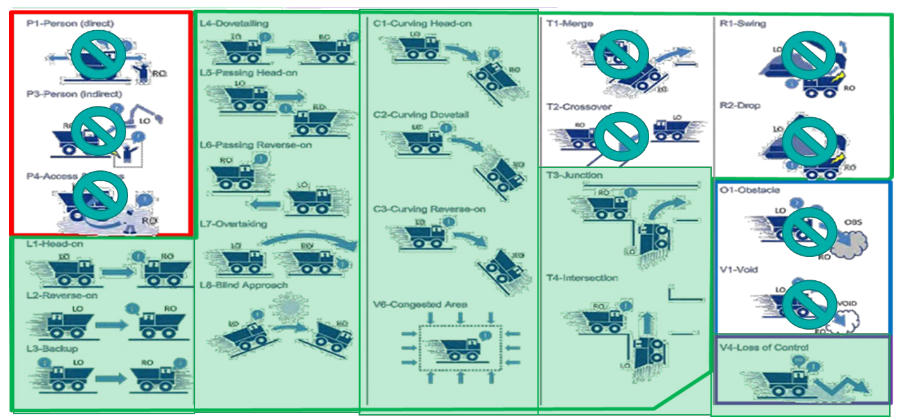
Scenario Validation and Verification Activities

Factory acceptance testing & onsite system functionality and scenario testing occurred monthly. Activities included:

- Implementation and refinement of curved and dynamic beam software.
- Stopping distances parameters based on known references and statistical data (deceleration rates) collected from CAS.
- User interface design and configuration (visual and audio) based on known standards with operator evaluation / input.
- Configuration changes implemented based on practical exercises with a variety of equipment and operators.



EMESRT PR5A Surface Scenarios

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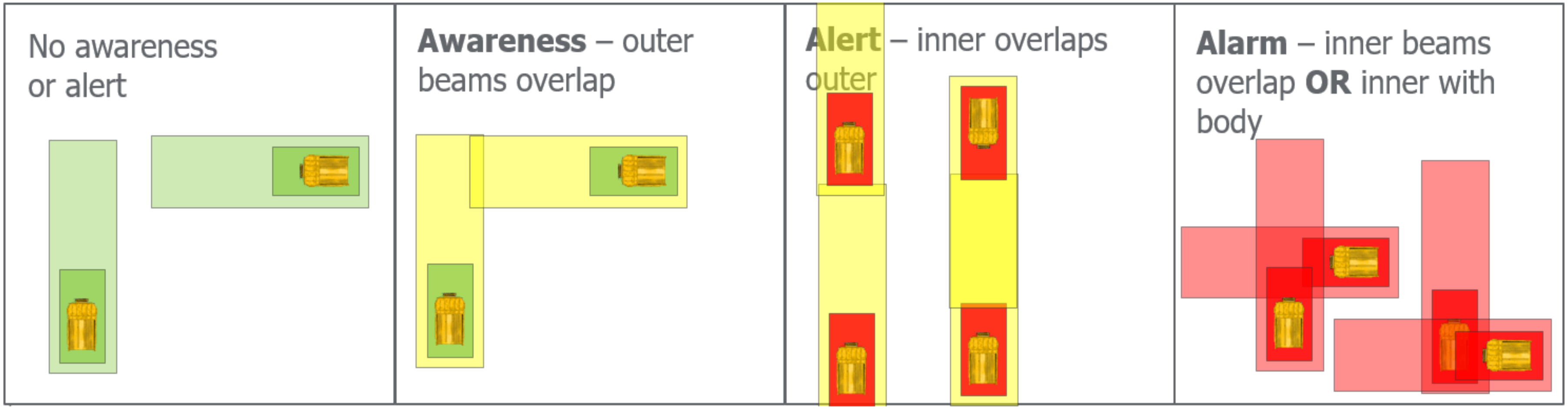
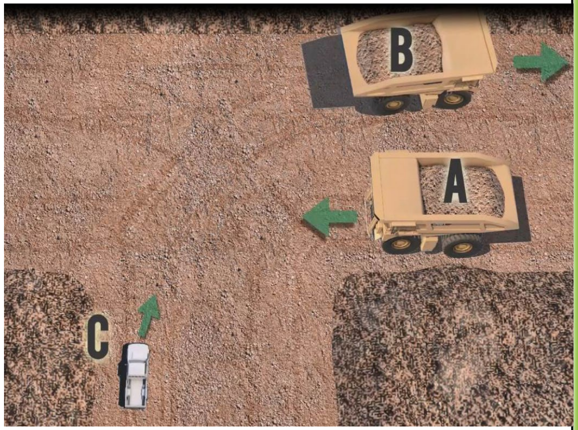
Basic Sensing Logic & Interaction Levels

- Accuracy of system sensing directly effects the amount of nuisance alarming.
- For low precision sensing, detection zones are enlarged to compensate for vehicle position inaccuracy leading to a high level of nuisance events / alarms.



Rules & Intelligence – T-Intersection Scenario



CONTROL

VEHICLE OPERATORS MAINTAINS GIVEWAY TO OTHER VEHICLES

EROSION FACTOR

LVs FAILS TO GIVEWAY TO HVs

CAUSED BY: LACK OF VISIBILITY (BLINDSPOTS, NIGHT, DIRTY WINDSCREEN)

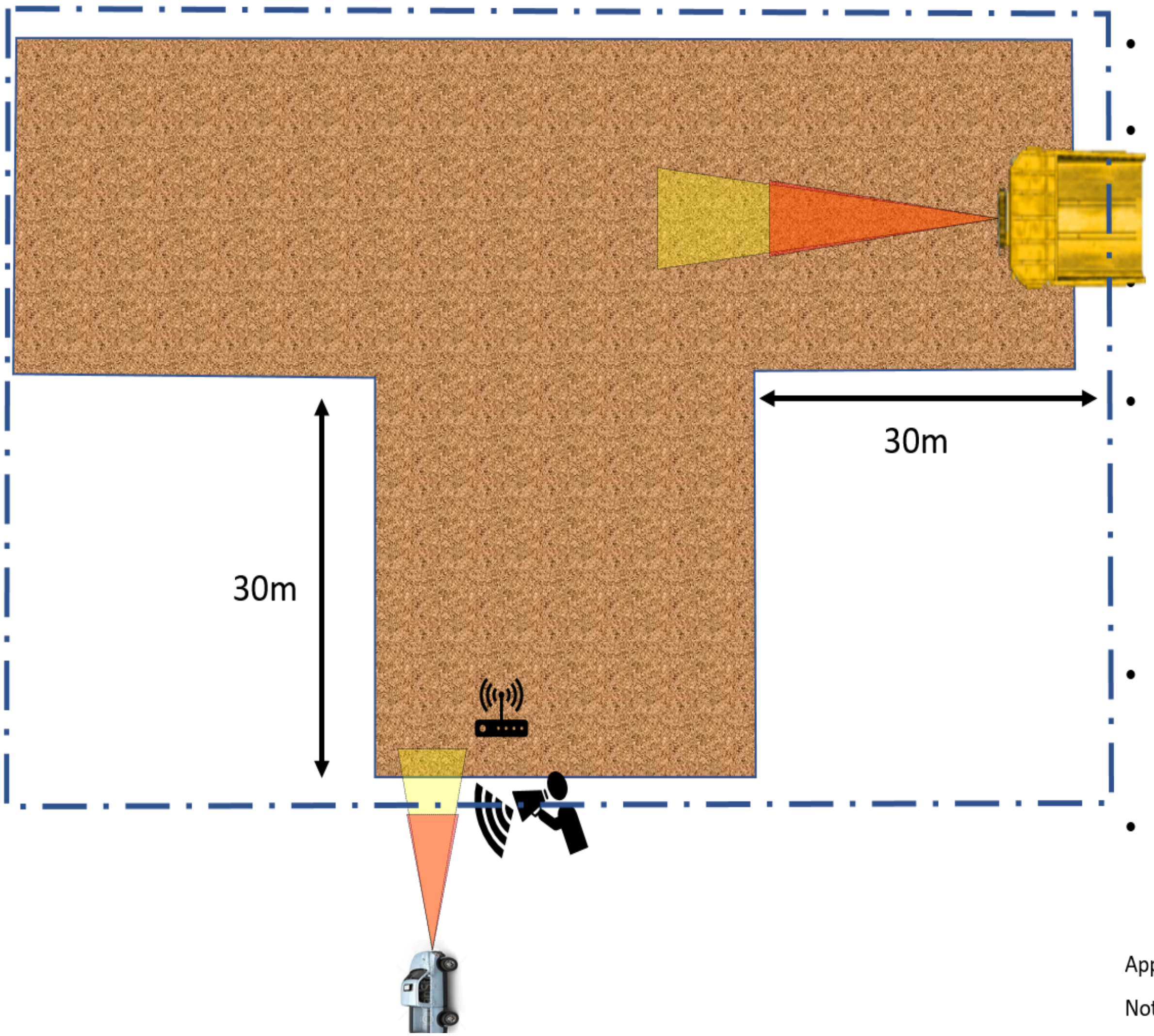
FUNCTIONAL REQUIREMENT

AS AN OPERATOR I WANT TO BE WARNED WHEN THE HIERARCHY RULE HAS BEEN BREACHED

PERFORMANCE REQUIREMENT

TECHNOLOGY TO PREVENT LVs FROM ENTERING INTERSECTIONS WHEN HVs ARE PRESENT

Storyboard Example – T Intersection



- LO (LV) approaches a formal T intersection configured with a CAS geo-fence.
- When the inner beam of the LO (LV) enters the geo-fenced intersection (30m from intersection) CAS will scan for other CAS units that are located within the geo-fence.
- The geo-fence will have a speed limit of 40 km/h applied and will be activate when LVs and MVs enter regardless of the presence of an RO.
- If T intersection geo-fence becomes occupied by the body of any other vehicle whilst the LO (LV) is in the intersection the following will occur:
  - User interface will brighten in LO and RO
  - The icon for speeding and give way will appear
  - Audible message of “Give Way” repeated twice will only activate in LV designated vehicles not in HVs
- If the LO (HV or LV) becomes the only vehicle inside the geo-fenced intersection or departs the geo-fenced intersection the user interface will then dim
- Audible message will activate once only per entry into geo-fence

Applicable for LVs and MVs when they are the LO

Not applicable for dozers, drills and tracked loading units when they are the RO

Storyboard Training Material – T Intersection

Complex Scenarios

System configuration modified based on trends in data and feedback from vehicle operators for specific “standard practice” production interaction scenarios.

Examples of high nuisance alarming situations included:

- Dozers in close proximity cleaning up around diggers
- Trucks interacting closely at low speed with other trucks, dozers and diggers in loading areas
- Maintenance LV’s attending heavy vehicles and parking in close proximity
- Service carts refuelling equipment in close proximity
- Haul trucks interacting around switch backs with bunded centre islands
- Haul trucks alerting to dozers working on dumps at low speed and in close proximity (ramp dumps)
- Franna crane working on heavy equipment in close proximity
- MMU, stemming trucks and Shot Firer LV’s working in close proximity on blasts

Configuration Change Management

Process for determining if a configuration change was required:

1. Receive user feedback or notice a trend in data.
2. Check system functionality – confirm system behaving as designed. No hardware or software issues present.
3. Check event's location – is the working environment influencing the situation, can the environment be altered?
4. Check procedure – is operator technique or performance correct?
5. What is the maximum consequence for the interaction scenario? Is it necessary for the operator to receive awareness for the situation based on the consequence. If so, at what minimum speed and / or clearance should the operator be made aware to prevent the consequence from occurring.
6. Brainstorm potential effects of the config change to other unrelated interaction scenarios. Could altering the configuration in this scenario have repercussions in other VI situations?

Configuration Change Management

System events will be caused by only three elements:

System	Environment	People
1. Check system functionality 2. Confirm system is behaving as designed 3. Are there hardware or software issues present?	4. Check event location 5. Is the work environment influencing the situation? 6. Can the environment be altered?	7. Check Procedure 8. Is operator technique and / or performance in line with procedure? 9. Are certain behaviours contributing to excessive events?

Determining root cause will aid in determining required action:

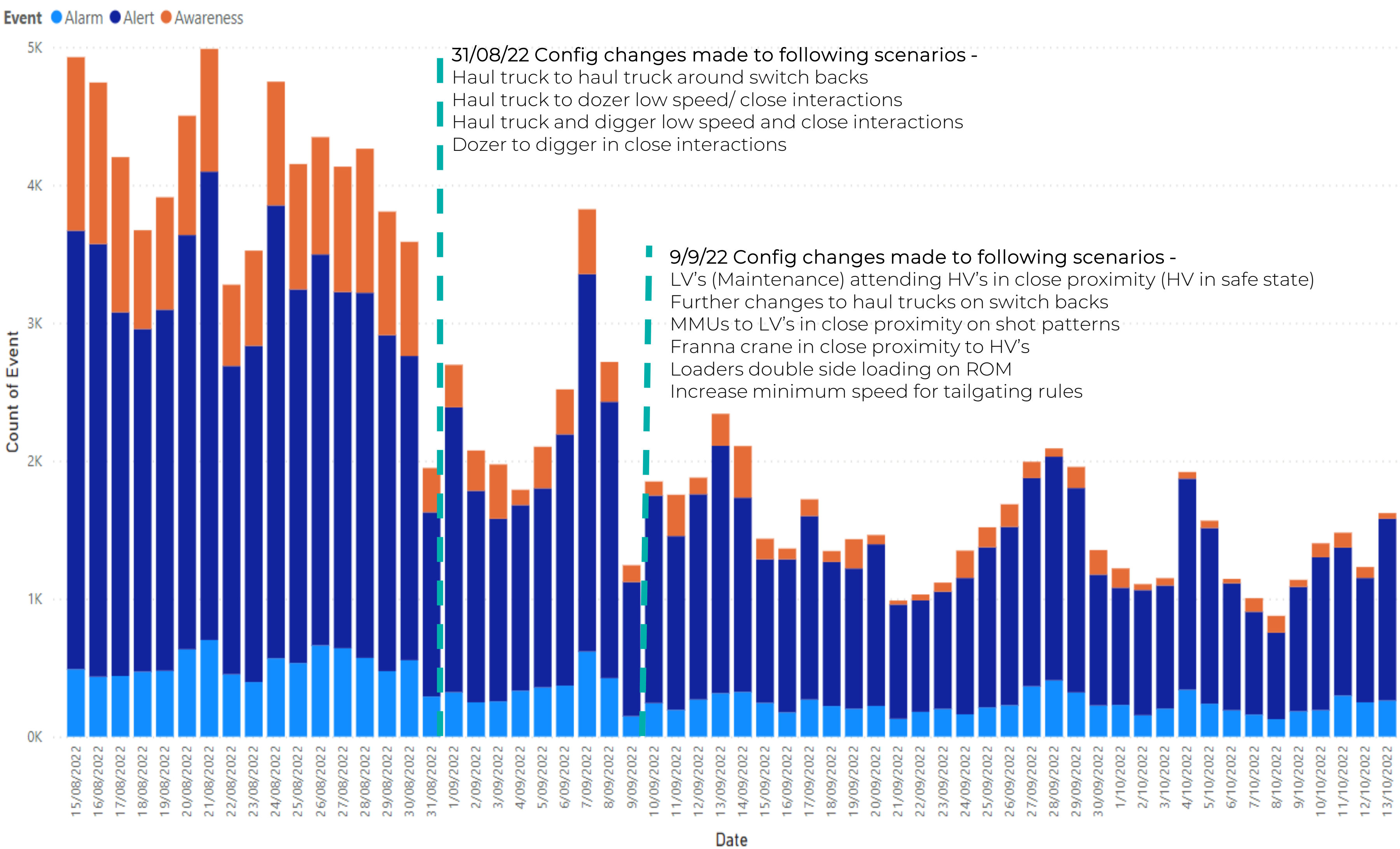
- Repair hardware.
- Update software version.
- Consider configuration change.
- Alter working environment.
- Check road widths.
- Check intersections are compliant.
- Check geofences are in correct locations and still relevant.

Configuration Change Management – Nuisance v Valid Events

Further considerations:

- What is the maximum consequence for the interaction scenario?
- Is it necessary for the operator to receive awareness for the situation based on the consequence. If so, at what minimum speed and / or clearance should the operator be made aware to prevent the consequence from occurring.
- Brainstorm potential effects of the config change to other unrelated interaction scenarios. Could altering the configuration in this scenario have repercussions in other VI situations?

Overall Configuration Change Results



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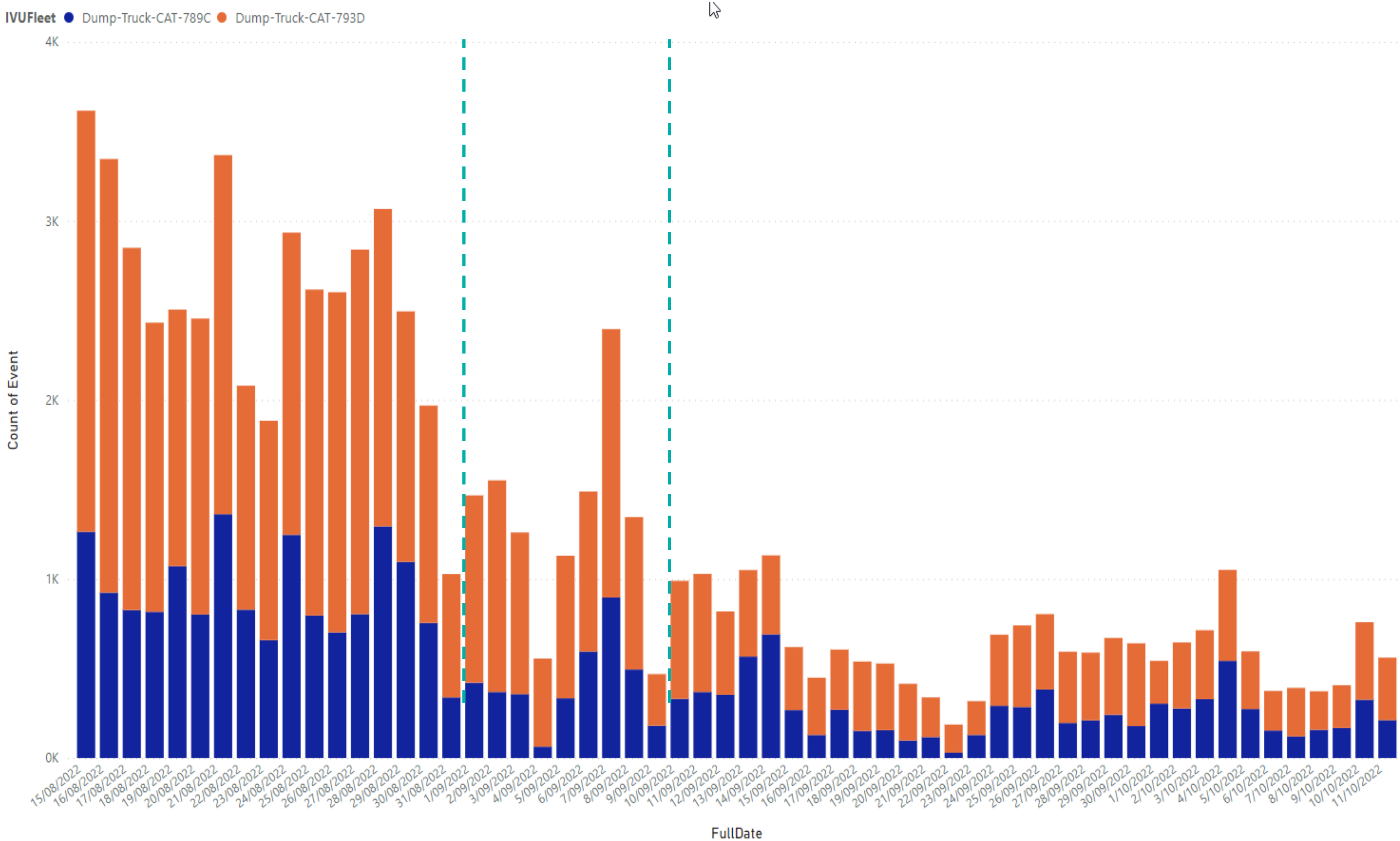
Truck Configuration Change Results



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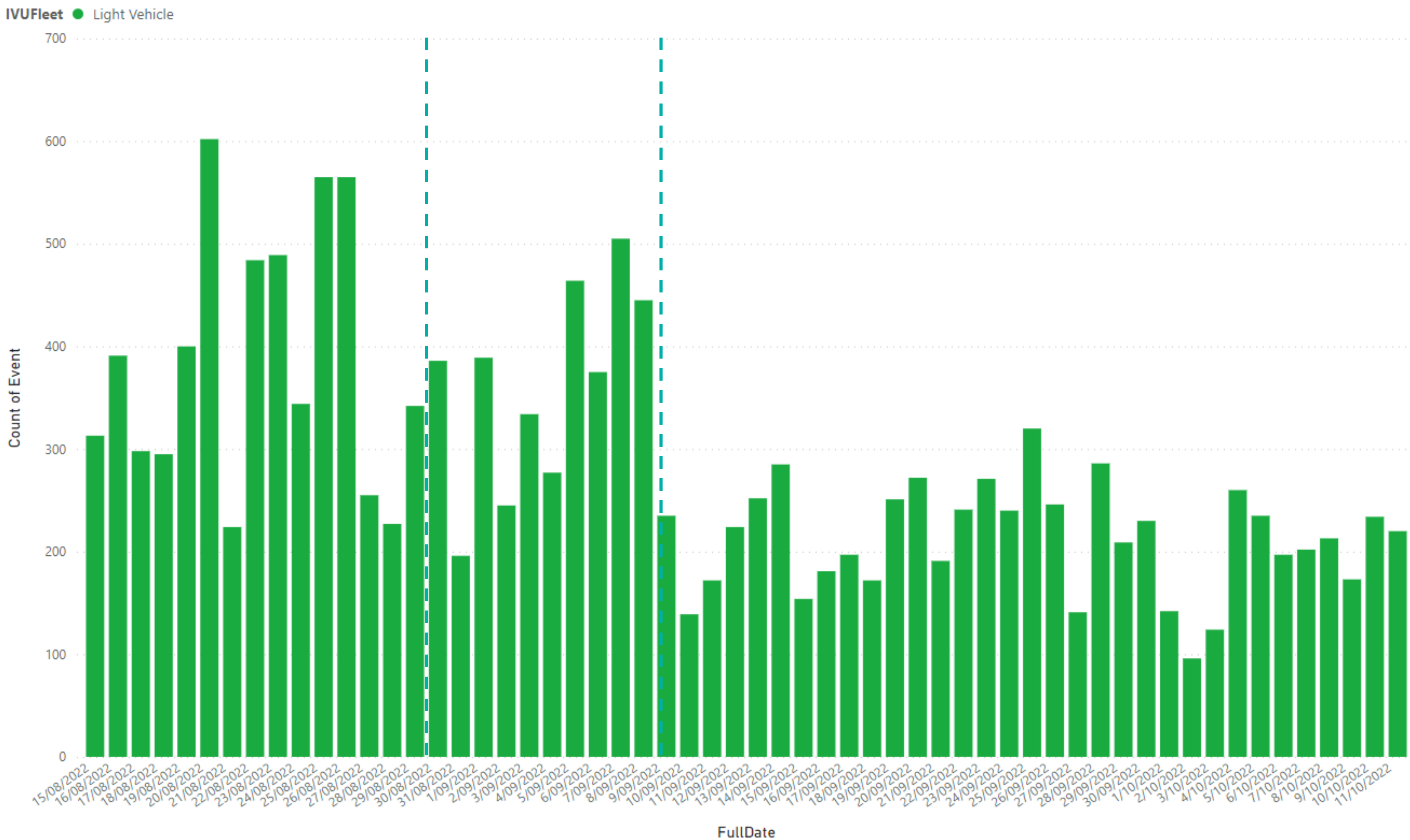
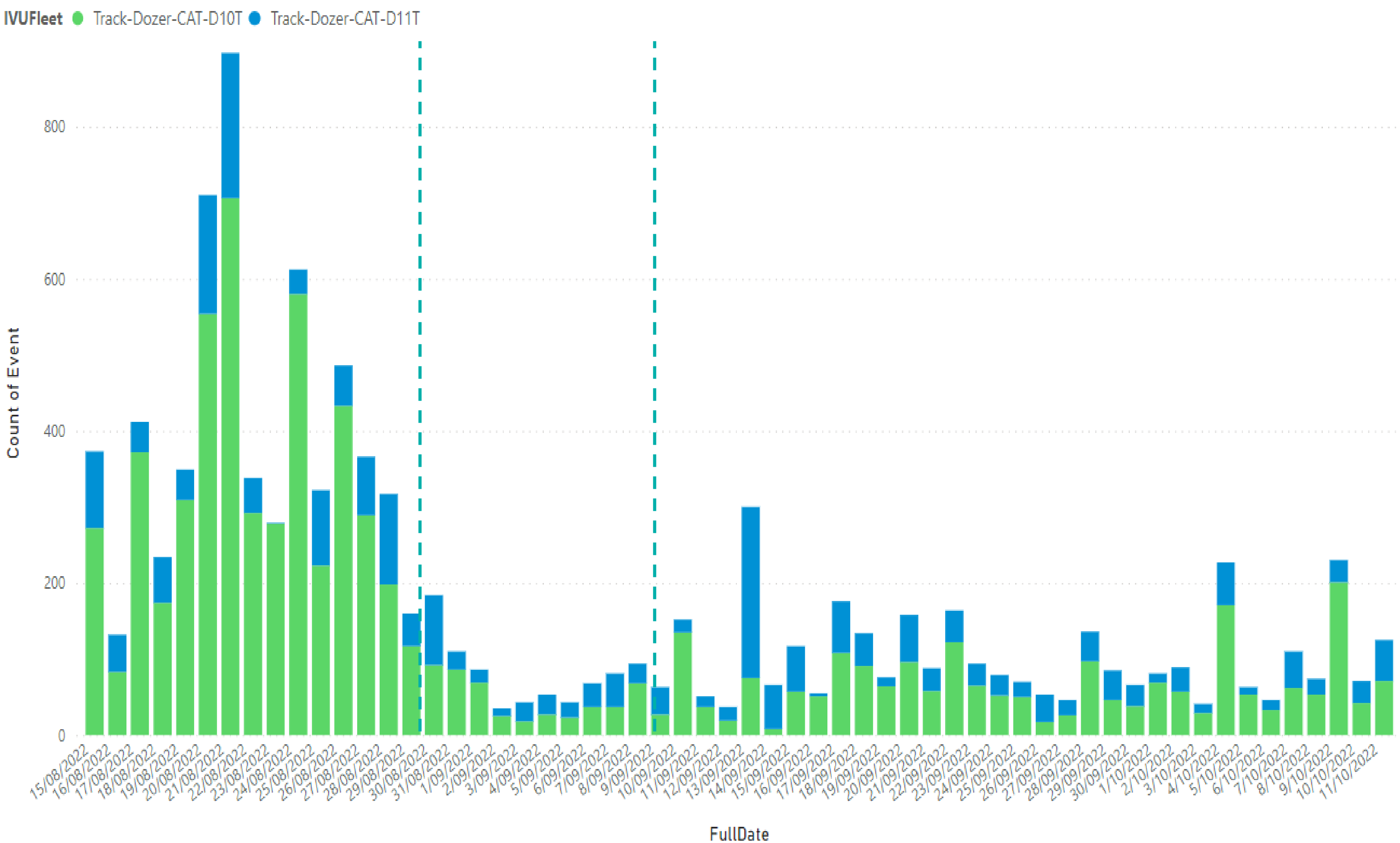
Light Vehicle Configuration Change Results



Dozer Configuration Change Results

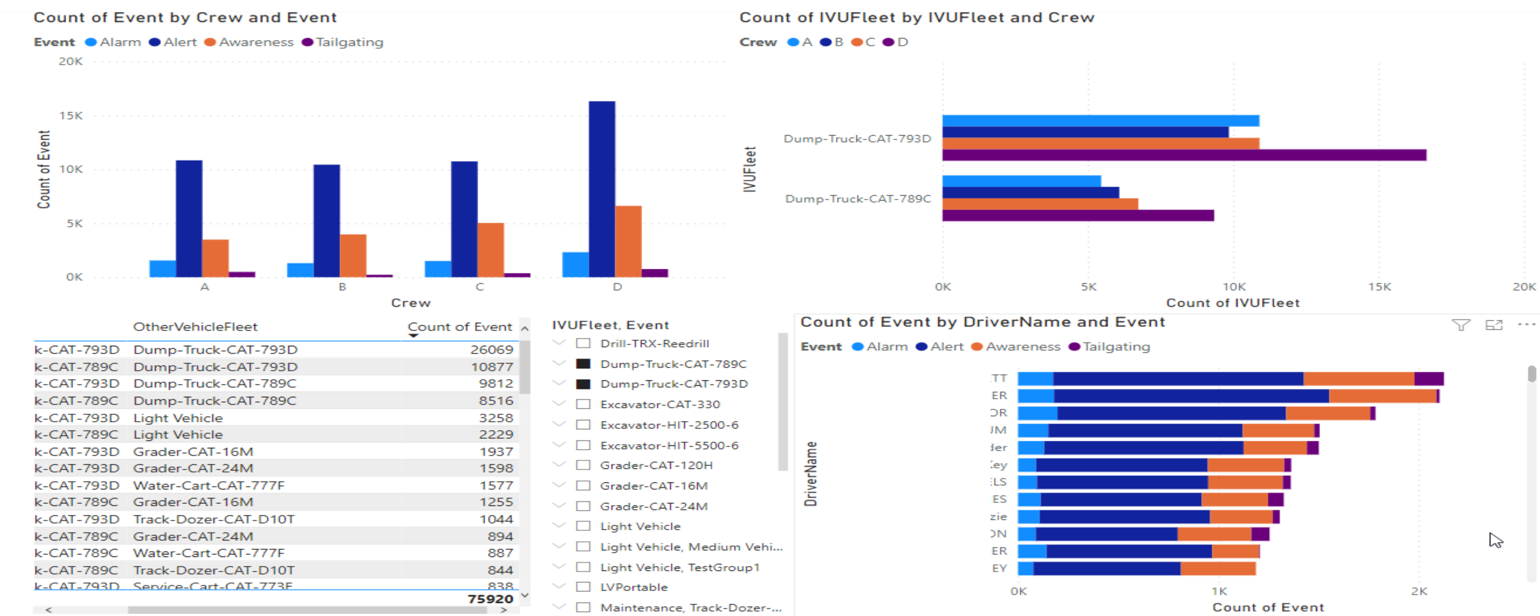


Data Analysis

Utilise CAS data to identify:

- CAS hardware issues
- Geographical interaction hotspots
- Operator coaching opportunities performance / operating techniques

Early intervention will assist with progressive event reduction and system acceptance.



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Acceptance and Useability

When introducing CAS;

- Develop and maintain the system to a high standard to generate trust in the technology (as a vehicle operator when I need it, it is working and I believe it is correct).

- Reduce nuisance events to prevent normalization (as a vehicle operator when I hear/see an event, I react to it).

- Provide appropriate consultation and context without confusion (as a vehicle operator I want to understand how to use the system and how to know if it is defected and not to be relied upon).

The user's trust of the system increases user acceptance.

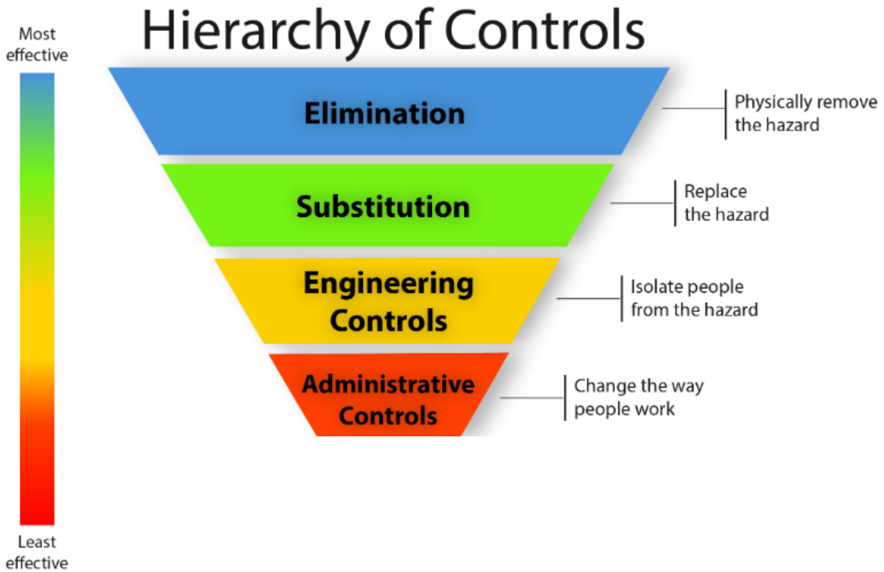
As users accept and utilise the system, its criticality and reliance on the system increases.

Planned Maintenance

- Inspection sheets developed early in the project.
- FMEA completed and planned maintenance strategy developed.
- Scheduled planned maintenance tasks and inspections, including their frequency, have been developed and loaded into SAP.

Unplanned Maintenance

- Assess how loss of critical functionality affects the user.
- Identify what additional controls could be effectively implemented.
- Eight controls identified.
- Controls will be developed into a TARP.

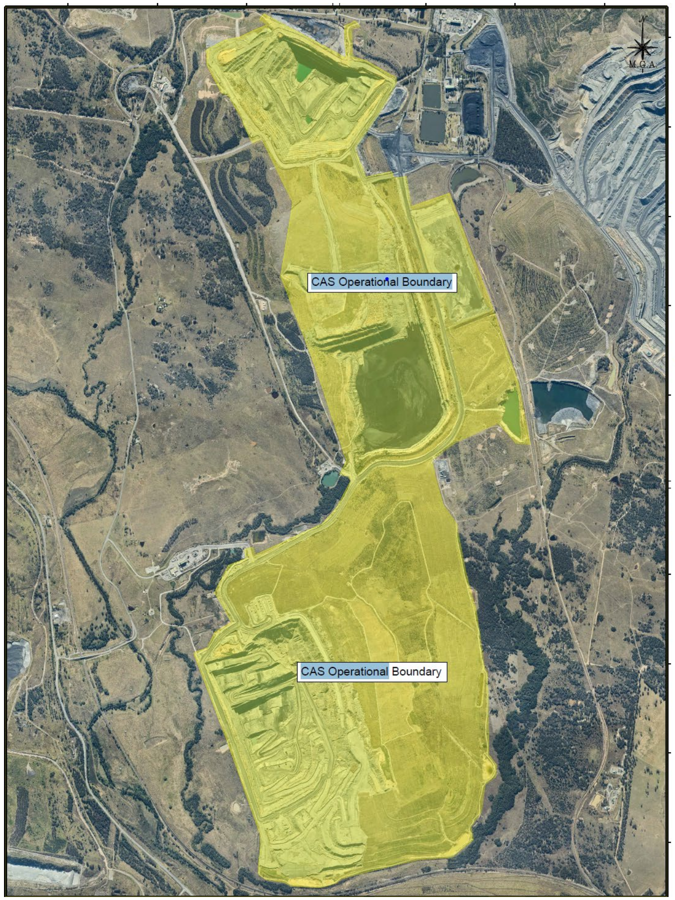


RACI

Role	Hrs/wk	Task Example
Systems Engineer	1.7	Maintaining system, reporting, investigations
Surveyor	0.1	Supply maps for CASWeb
Dispatcher	1.4	Manage geofences
Training Department	1.2	Provide user training
Supervisor	0.9	Dynamic Intersections, interventions
Superintendent	0.3	Permanent intersections
Manager	0.1	Reports
Mine Engineer	1.7	Dynamic no go zones
Maintenance Planner	0.3	New installs, planned Maintenance
Stat Electrical Engineer / OT Engineer	0.6	Manage configurable hardware
Technology Technician	150.6	Respond to maintenance defects
IT Engineer	0.0	Informed of system requirements
CAS End User	0.2	Defect reporting
Contractor CAS users	0.0	Defect reporting
Site Contractor Manager	0.1	Organise contractor equipment installs

CAS Operational Area

- Review personnel licensing requirements
- Assess controls for mine access - physical, signage



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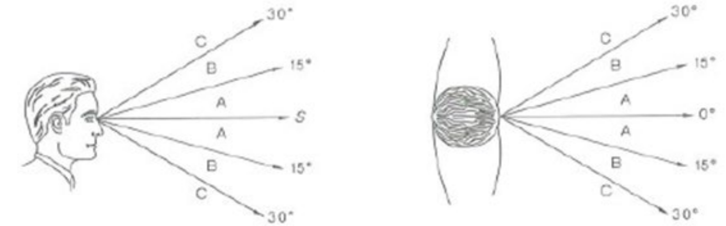
Cabin Ergonomic Assessment

Aspects of cabin ergonomics were assessed for compliance against relevant standards:

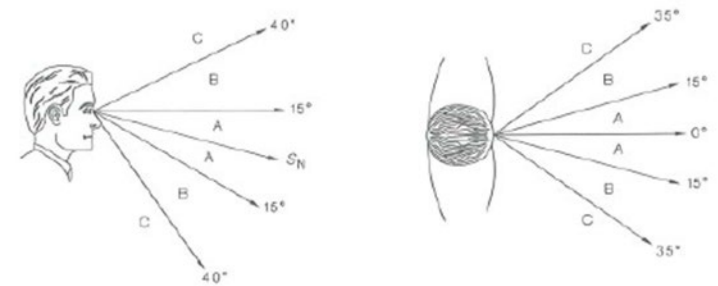
- For reach range with reference to AS2956.5 / ISO6682
- For visual range with reference to AS4924.1902
- Operator survey conducted to gauge the frequency of operator visual and physical interaction with key controls, monitors and devices in the cabin.



(a) Vertical field of vision for detection
(b) Horizontal field of vision for detection

LEGEND:
S = Line of sight, direction is imposed by external task requirements

FIGURE 1 DETECTION TASKS



(a) Vertical field of vision for monitoring
(b) Horizontal field of vision for monitoring

LEGEND:
S_N = Normal line of sight, 15° to 30° below the horizontal

FIGURE 2 MONITORING TASKS

CAS Portable Unit Management

- Contractor management
- Replacement for permanent installation when failed

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Other Operational Integration Considerations

- Consider all vehicle interaction scenarios.
- Provide simply but thorough user training.
- Modify position descriptions based on new tasks.
- Integrate into existing site procedures / develop new procedures.
- Integrate learnings back into 1-6 controls.
- Utilise event information to improve performance.
- Modify behavioural management processes.
- Verify IT and Wi-Fi capability and capacity.
- Understand operational and engineering resource load.

Outcomes

- Nil production loss through spot and cycle times analysis.
- Event reduction through system configuration changes and operator performance improvement.
- Users operating in Levels 1-7, staying away from Level 8 vehicle interactions.
- Average of 0.8 critical events per hour across the fleet (range: 0.06 – 2.35).
- Average of 3.4 total events per hour across the fleet.

Outcomes - User Acceptance

User acceptance and use of system reported to be high

- Improves visibility of other vehicles in the vicinity – **71% strongly agree / agree**
- Has CAS become part of your normal cab environment – **59% strongly agree / agree**
- Has there been a situation where CAS has alerted you of another vehicle in your vicinity that you were unaware of – **42% yes**
- How often do you reference the CAS screen each hour – **61% more than three times an hour**

Operator identified high use cases

- General situational awareness
- Increased visibility at intersections particularly for LVs
- During poor visibility (night, distance)
- Vehicle identification (pos comms)

Thank you