

CSIR Mining – TMM Digital Twin

24 October 2025



science, technology
& innovation

Department:
Science, Technology and Innovation
REPUBLIC OF SOUTH AFRICA



CSIR
Touching lives through innovation

80th
anniversary

CSIR Mandate

“The objects of the CSIR are, through **directed** and **particularly multidisciplinary research** and **technological innovation**, to foster, in the **national interest** and in fields which in its opinion should receive preference, **industrial** and **scientific development**, either by itself or in **co-operation with principals** from the **private** or **public sectors**, and thereby to contribute to the **improvement of the quality of life** of the people of the Republic, and to perform any other functions that may be assigned to the CSIR by or under this Act.”

(Scientific Research Council Act, 1988 (Act 46 of 1988, amended by Act 27 of 2014)

CSIR at a glance



Pretoria

Johannesburg

Durban

Cape Town

Stellenbosch

Gqeberha

2 209

CSIR Total
Staff Base

1 644

Black South
Africans

997

Female
South
Africans

1 551

Total SET
base

1052

Black South
Africans in
SET base

607

Female South
Africans in SET
base

40

Employees
with disabilities

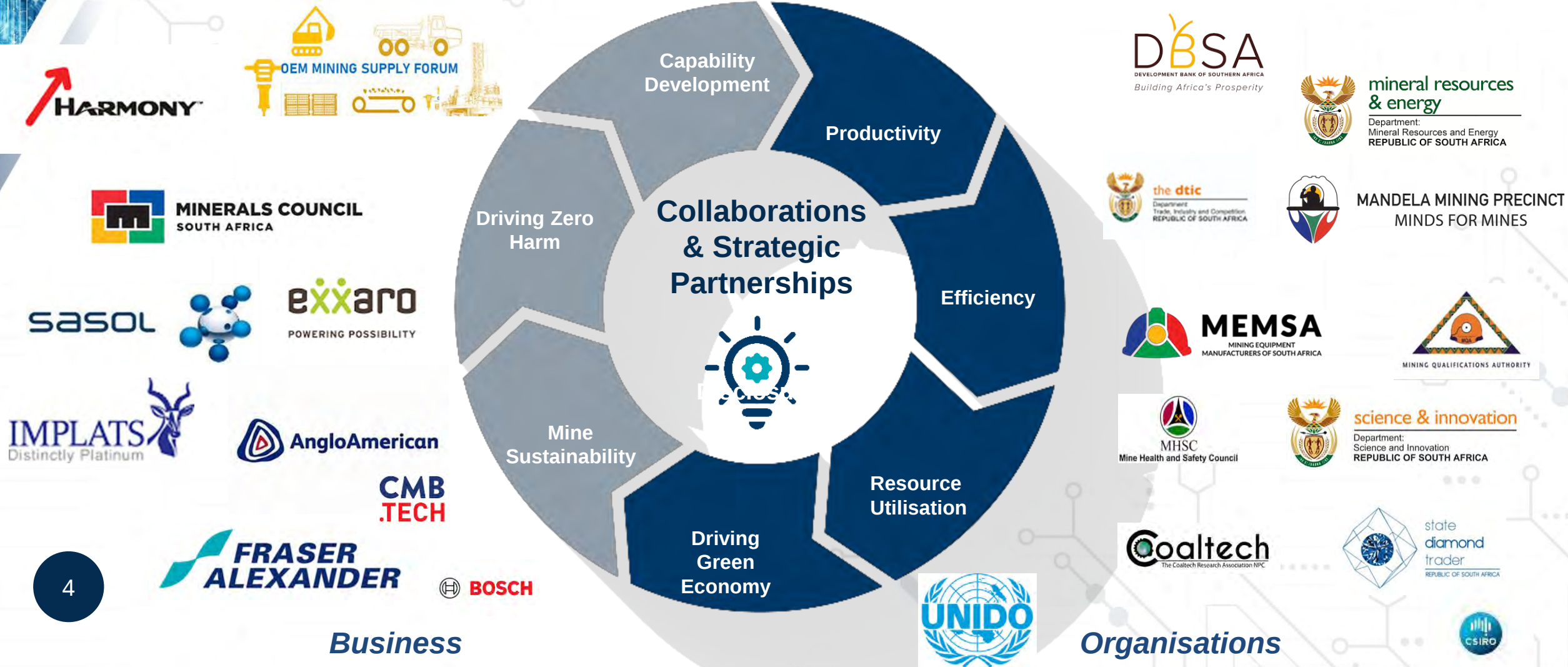
466

SET base with
Master's

318

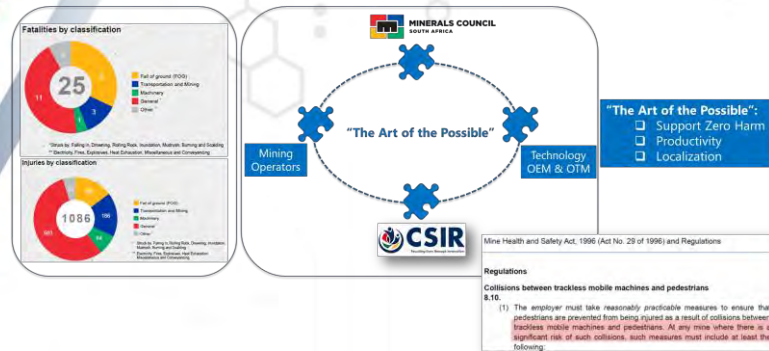
SET base
with PhDs

Delivering Innovations through Collaborations and Partnerships



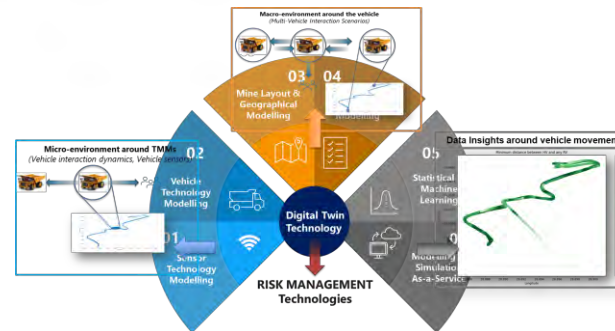
TMM Digital Twin: Inception

Strategic



- Approached by the Minerals Council South Africa to assist CAS system Productivity, Localization and achieving Zero Harm.

Tactical



- In collaboration with OEMs and Mining Houses conceptualized, designed and developed a dynamic risk profiling tool – TMM Digital Twin.

Functional



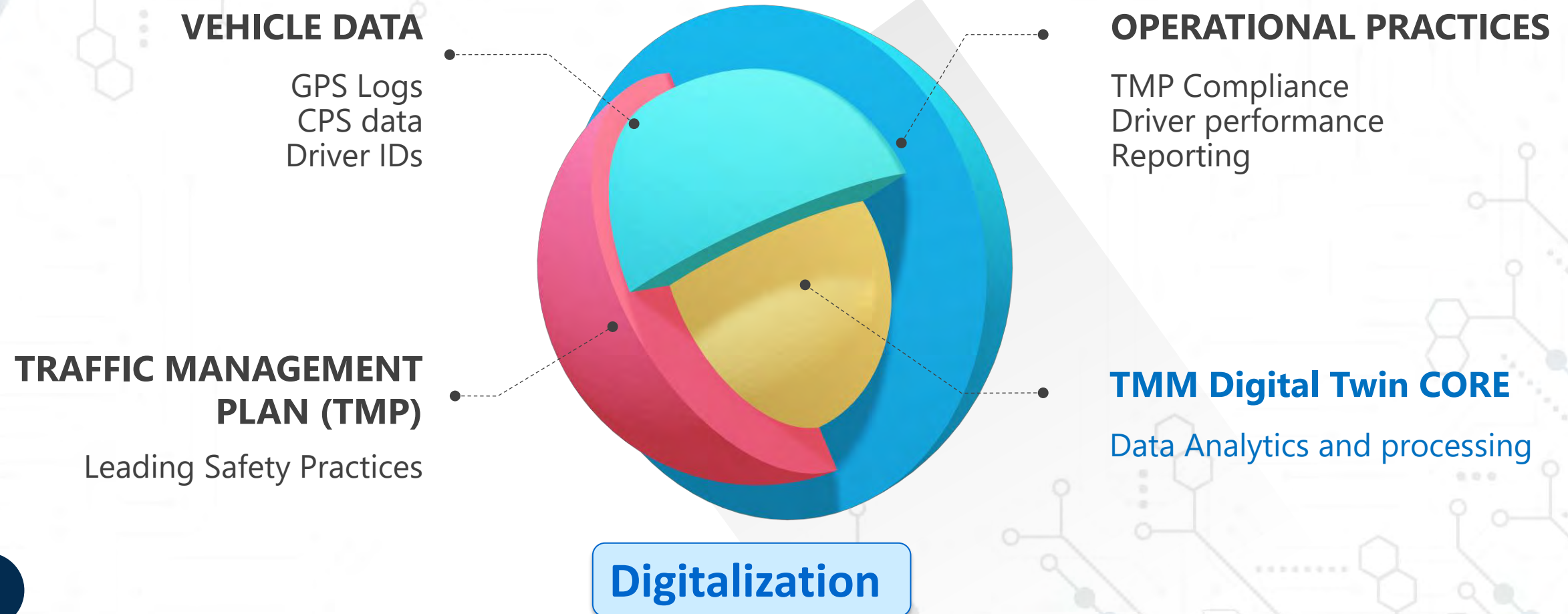
- Successful operational pilot at a large coal mine – assessed TMP risks and highlighted high potential incidents
- Commercialization partner

The TMM Digital Twin platform : Strategic Objective

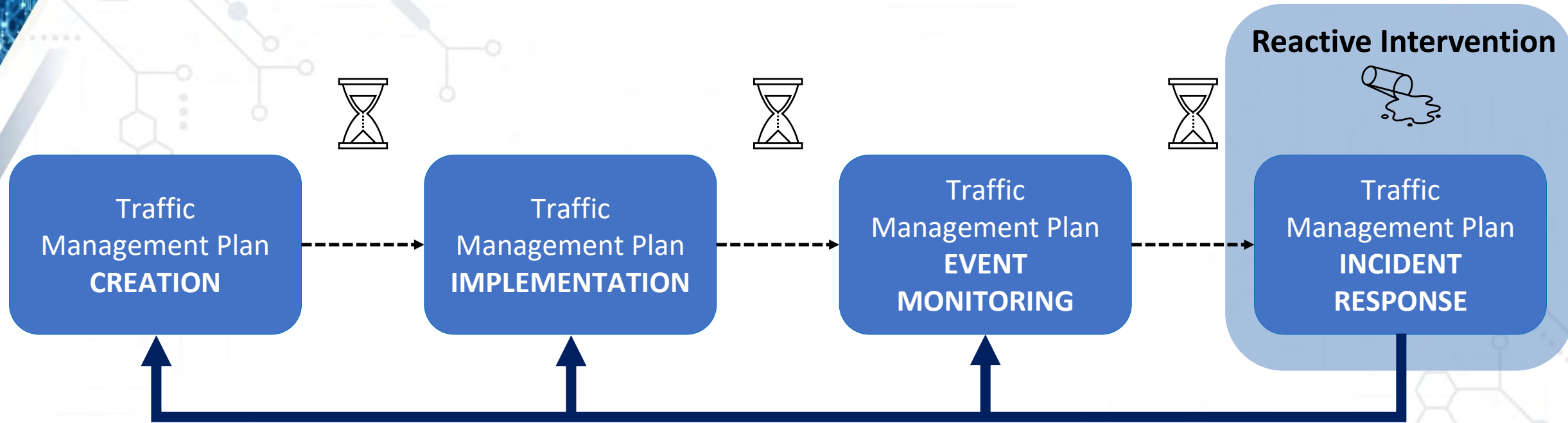
To provide mining houses with a tool to assist with risk profiling and productivity that takes an objective approach to assessment based on the Mine Health and Safety regulations (Act no. 29 of 1996 – clause 8.10)



TMM Digital Twin: Digital Components



TMM Digital Twin: Problem Space



Qualitative/Subjective Risk Assessment
Historic Data & Operational Experience

Intervention controls: Level 1 – Level 9

Level 1: Site Requirements

Level 2: Segregation Controls

Level 3: Operating Procedures

Level 4: Authority to Operate

Level 5: Fitness to Operate

Level 6: Operating Compliance

Level 7: Operator Awareness

Level 8: Advisory Controls

Level 9: Intervention Controls

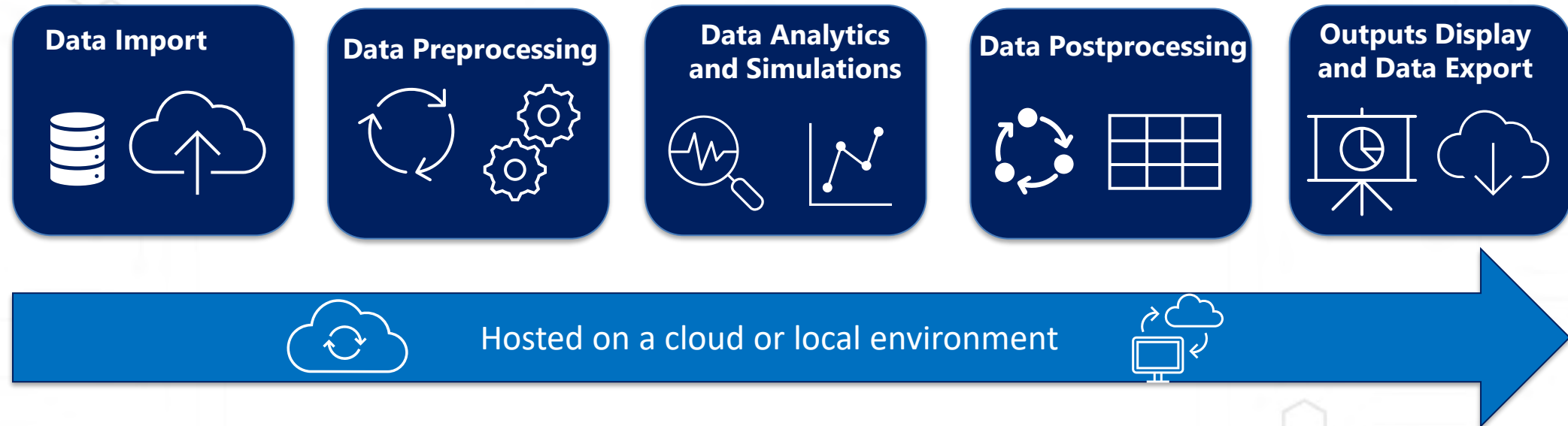
Work Area Controls for all equipment that could reduce
“**Significant Risk**” and costs

“**Residual Risk**”
Management
(CPS)



TMM Digital Twin

Data Flow Process : Full cycle



The background is a deep blue with intricate, glowing white circuit-like patterns. A large, dark blue chevron shape points towards the center. A teal diagonal bar is visible in the upper right corner.

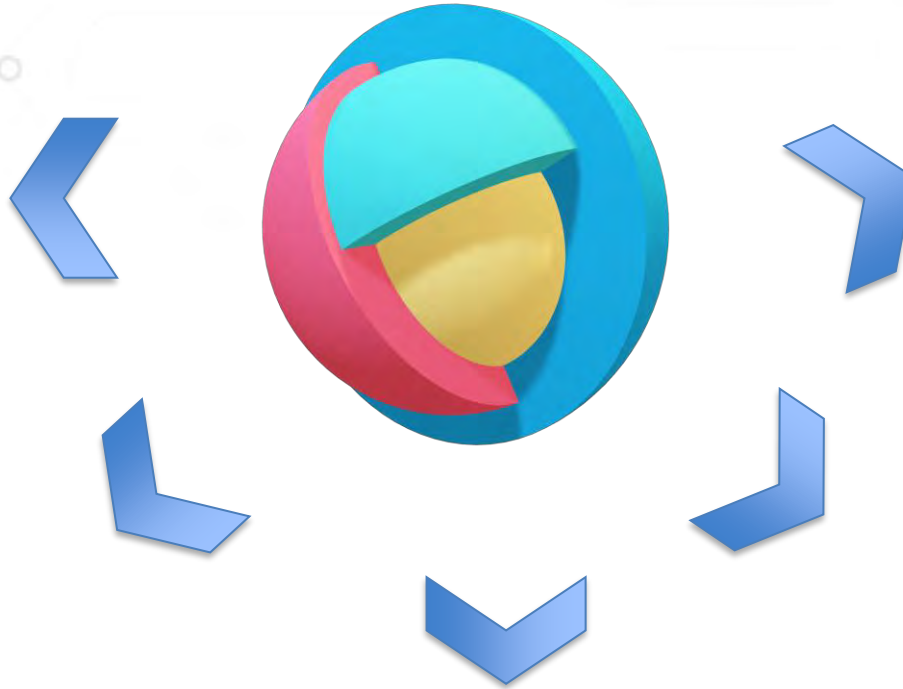
Data analysis

Primary analysis types

TMP non-conformance



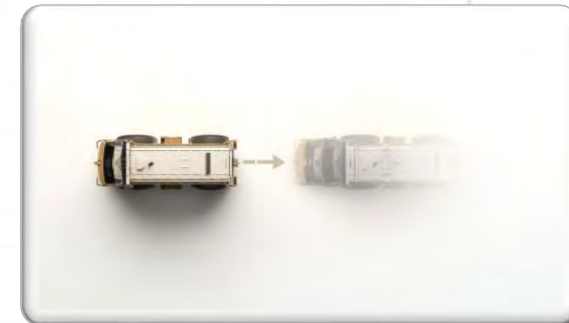
Vehicle interactions



Harsh driving



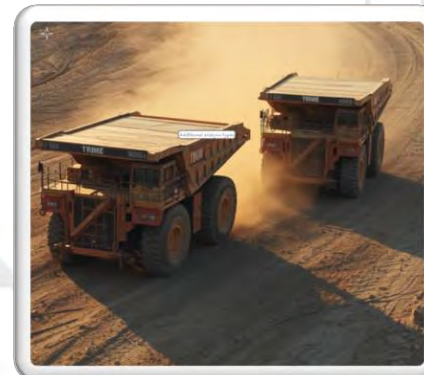
Reversing



Blast zone keep out



Follow distance



Additional analysis types

Vehicle Movement



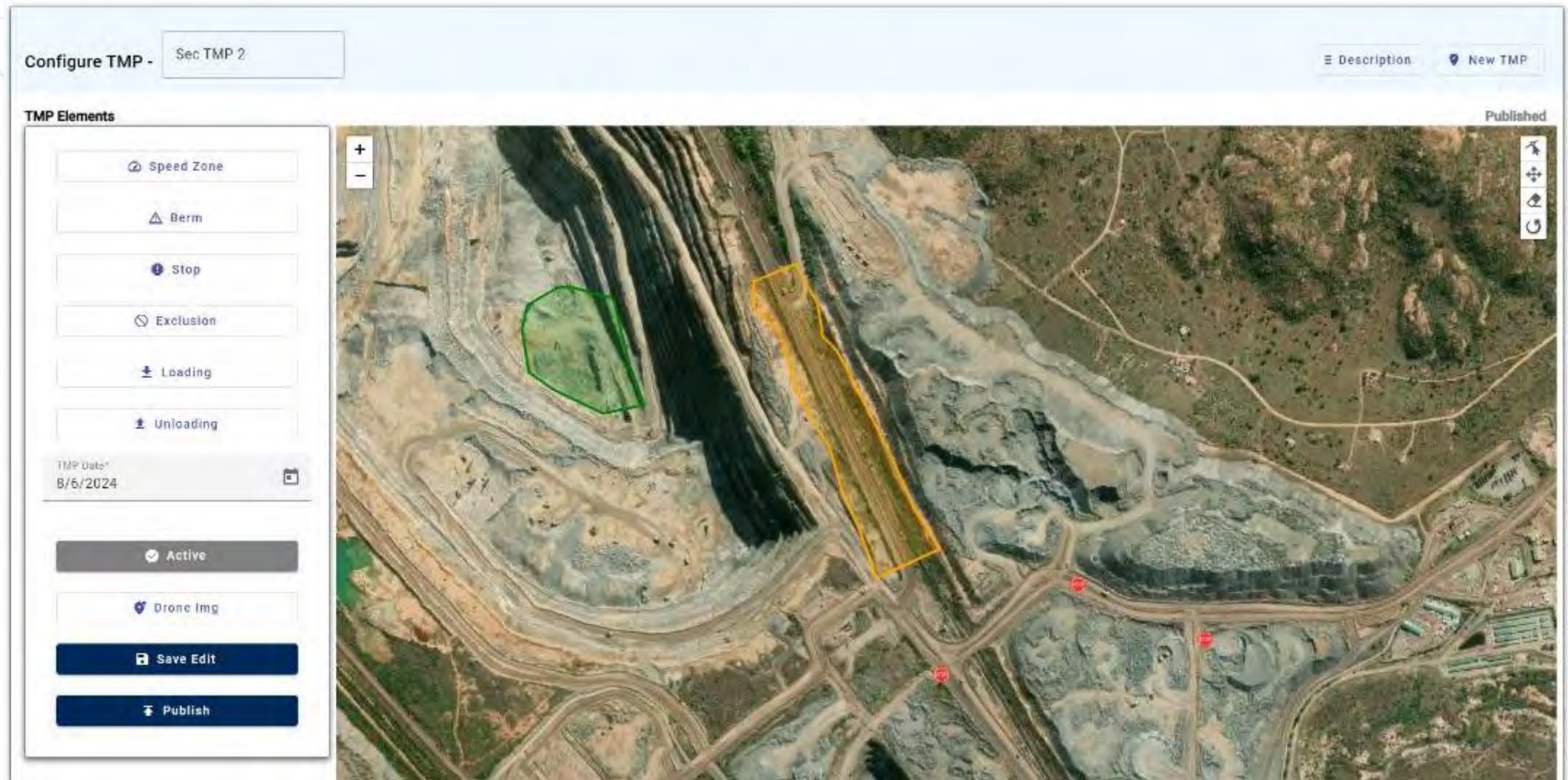
Vehicle Average Braking



Vehicle Average Speed



TMP Tool: Configure, update, revise TMP



TMP Tool: Configure, update, revise TMP

SmartMine x +

Not secure <https://tmmdt.csir.co.za/dev/edit-mine/8>

Edit Mine

CSIR Campus

Revise TMP TMP List Configure Site

Active TMP:
Demo TMP - 2025-10-16

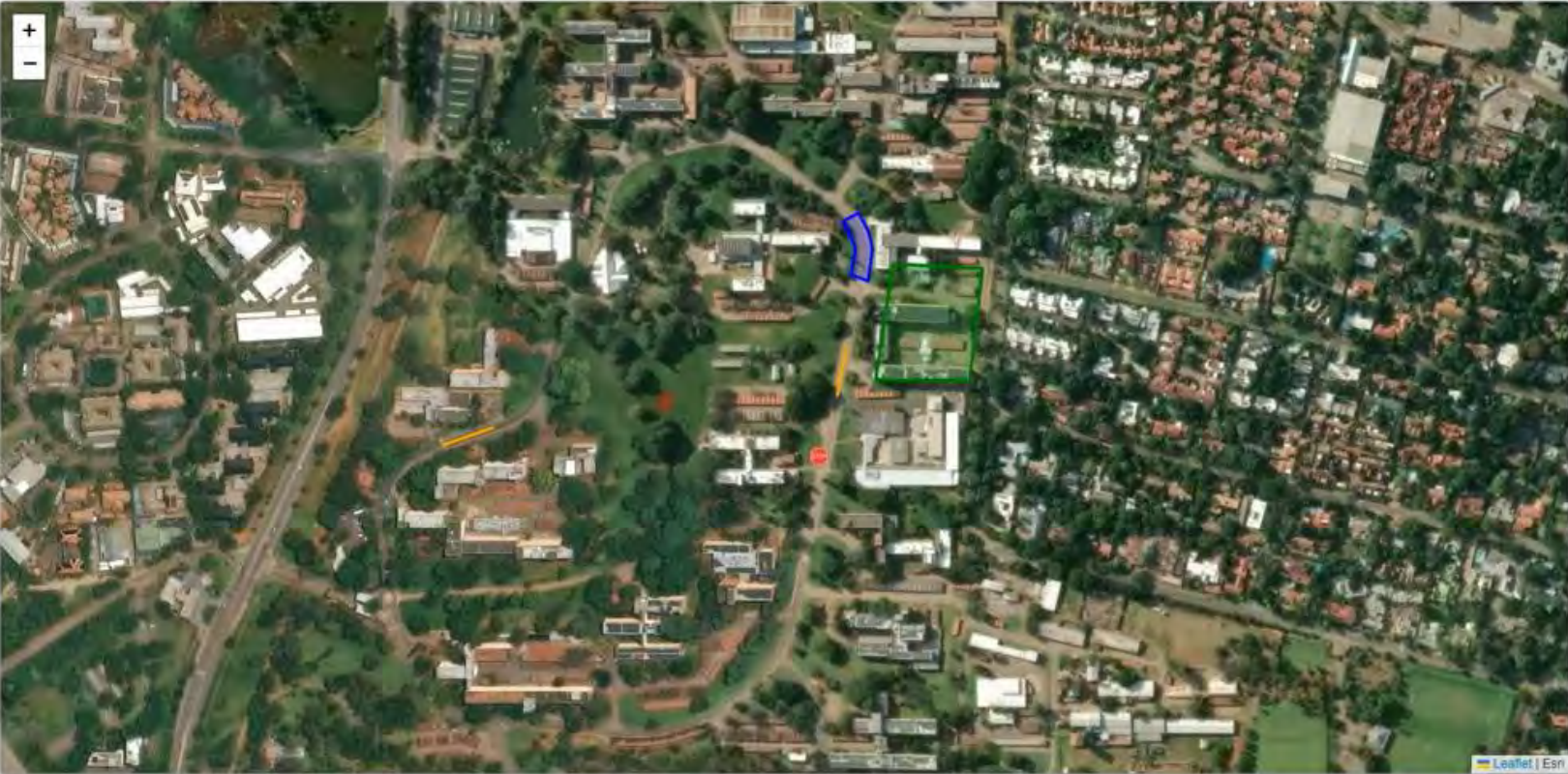
Traffic Management Plan Summary:

- Stop elements: 1
- Berm elements: 2
- Speed elements: 1
- Unloading elements: 1
- Excluding Zones elements: 0

Location: -25.746209, 28.278878

Configure Grid Show Grid

User Access



15:05
2025/10/16

Analysis Manager: List of all analyses created

Analysis manager								New Analysis
Select report start date 		Select report end date 		Select Analysis 	User created 	Search		
Analysis name	Description	User	Start date	End date	Vehicle count	Analysis types	Date processed	Status
Test 3	First on new table	✓	Aug 13, 2024	Aug 16, 2024	6 Vehicles	  	Not processed	unprocessed 
Test 2	Test 20 nd June	✓	May 1, 2022	May 4, 2022	3 Vehicles	  	Not processed	unprocessed 
Test 2	Test 20 nd June	✓	May 1, 2022	May 4, 2022	3 Vehicles	  	Not processed	unprocessed 
Sec test	Test second	✓	Aug 13, 2024	Aug 16, 2024	3 Vehicles	  	Not processed	unprocessed 
Test 2	Test 20 nd June	✓	May 1, 2022	May 4, 2022	3 Vehicles	  	Not processed	unprocessed 
Items per page: 10 1 – 5 of 5								

Analysis generation: Configure scope of analysis

Create analysis

Analysis name
Analysis Name*
Compliance Review

Define date range to evaluate
Date range:
Start date*
24/10/2025
End date*
24/10/2025

Description:
Review TMP compliance

Select site to evaluate as well as TMP and specific vehicles
Select Site:
Sites*
Fab data site
Select Analysis Types:
Throughput
Compliance
Average braking
Fatigue
V2V Interaction
Average speed
Vehicle movement
Harsh Driving
Select TMP:
Select TMP
First TMP - 2025-10-17

Select specific or all vehicles
Vehicle selection:
Select Vehicles
Summary:

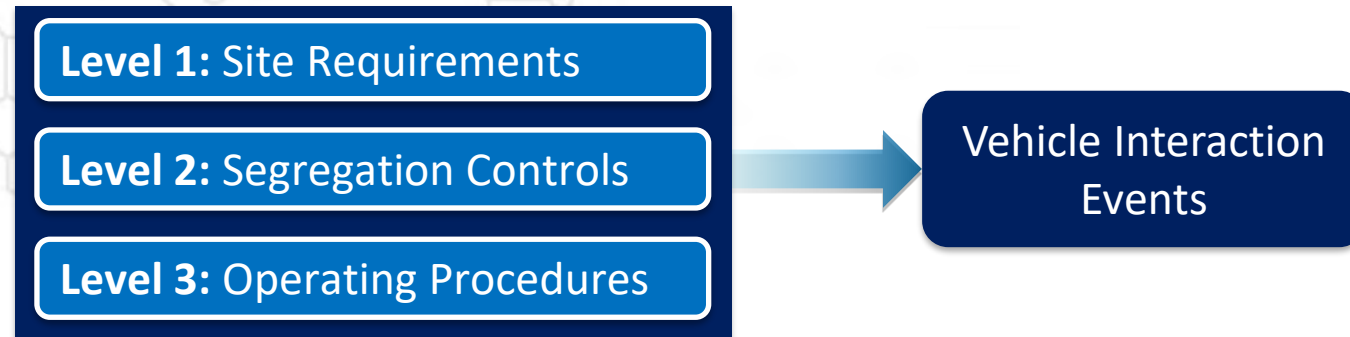
Type	Number
LDV	20

Analyses types to run on the data
Select TMP to evaluate

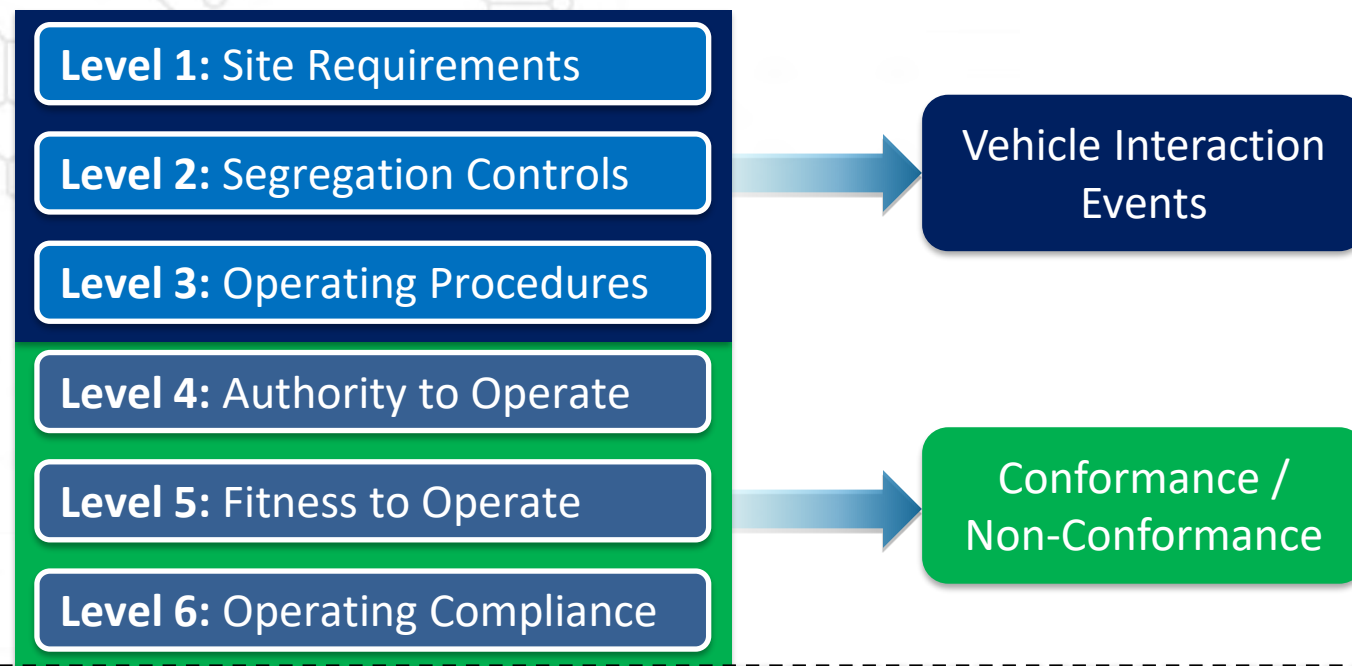
Cancel

Run

EMESRT Level 1 - 6: Vehicle Interaction Events



EMESRT Level 1 - 6 : Conformance/Non-Conformance

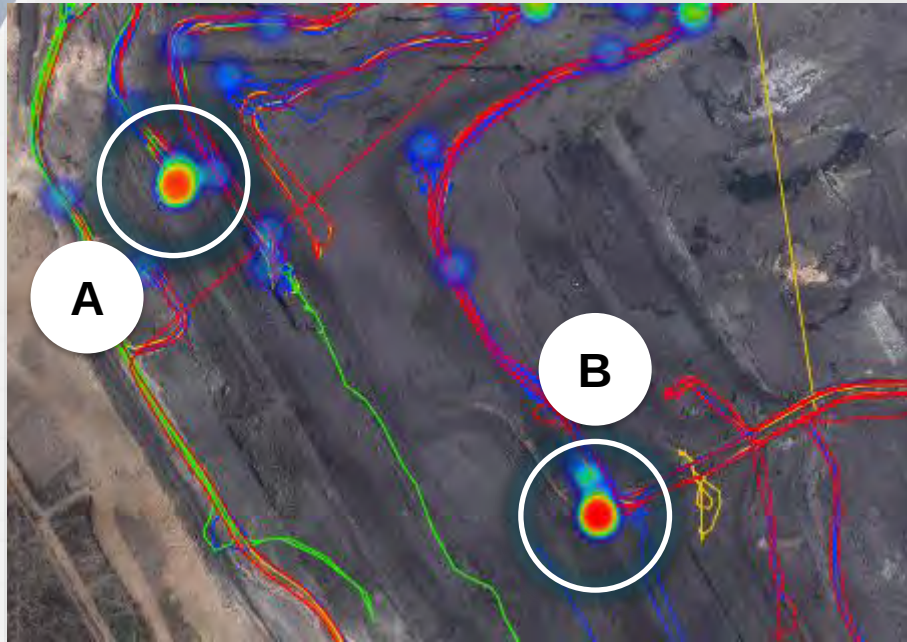


Vehicle Interaction Events: Heatmaps

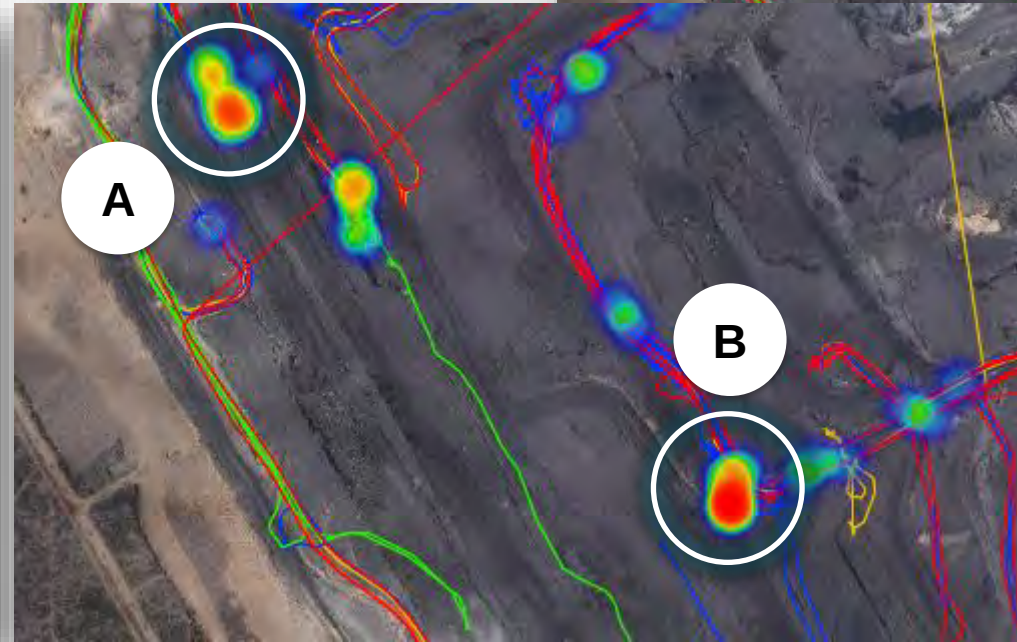
Inference of **Vehicle Interaction Events** using only the **GPS data**

**Vehicle
Interaction Events**

GPS Data



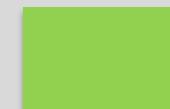
**Simulated Heatmap
(Detection Radius 5m)**



**Simulated Heatmap
(Detection Radius 10m)**



High Number
TMM
Interactions



Low Number
TMM Interactions

Non-Conformance Events: Visualise detections

Conformance /
Non-Conformance

Conformance Events using only the GPS data



The background is a deep blue gradient. It is decorated with intricate, glowing white and light blue circuit-like patterns that resemble a printed circuit board (PCB). These patterns are most prominent on the left side, where they form a dense, vertical structure. On the right side, there are more sparse, horizontal circuit lines. A large, bold, teal-colored diagonal line runs from the top right towards the center. Another similar, but slightly darker and more translucent, diagonal line runs from the bottom left towards the center. The word "Reporting" is centered in the middle of the image, between these two diagonal lines.

Reporting

Reporting: Configurable outputs and analyses to display

Report setup

Select date range

Vehicles

Analysis results to include:

Average braking

Average speed

Vehicle movement

Compliance events

V2V Interaction

Throughput

Configure report

Save edit

Publish report



Comments and observations

Incident Details

Date	Vehicle ID	Violations	Compliance	Sector
2022-10-09	495	2	50	C3
2022-10-12	592	8	50	B5
2022-10-12	605	40	44.44	B5,A6,A2

Items per page: 10 0 of 0

Appendix A - Vehicles considered for report

The following list of vehicles were considered for this report

Vehicle ID	Vehicle Type
495	EH3500 ACIII
592	Hilux Double Cab
605	Hilux Double Cab LDV2
1193	G140
1188	30T

Reporting: Configurable outputs and analyses to display

Select Vehicles

Types

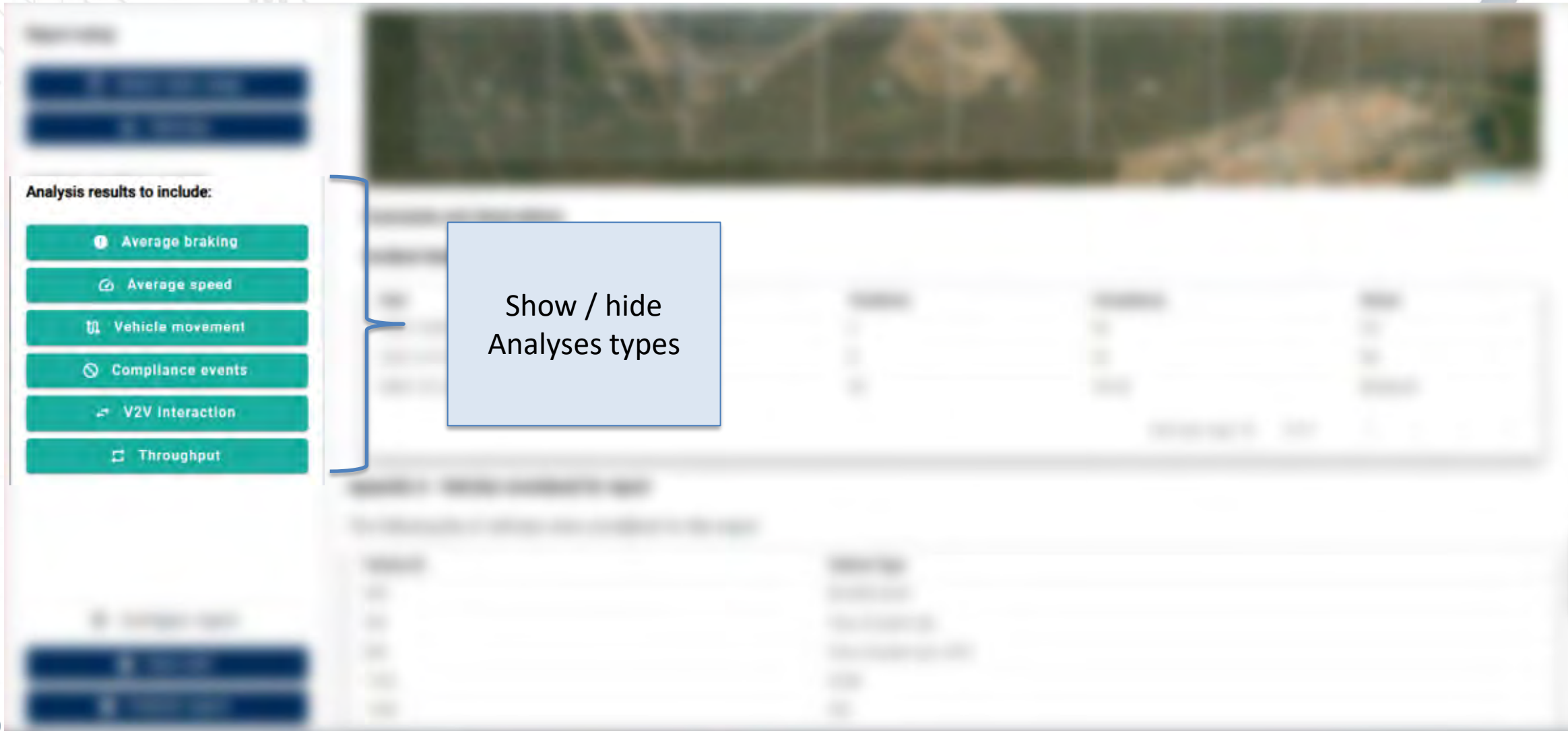
Search vehicles

Select	Vehicle ID	Vehicle Category	Vehicle Model	Analyses
☐	269203	LDV	Bakkie 1	 
☐	269215	LDV	Bakke 2	 

Items per page: 10 1 - 2 of 2

Finish

Reporting: Configurable outputs and analyses to display



Reporting: Configurable outputs and analyses to display

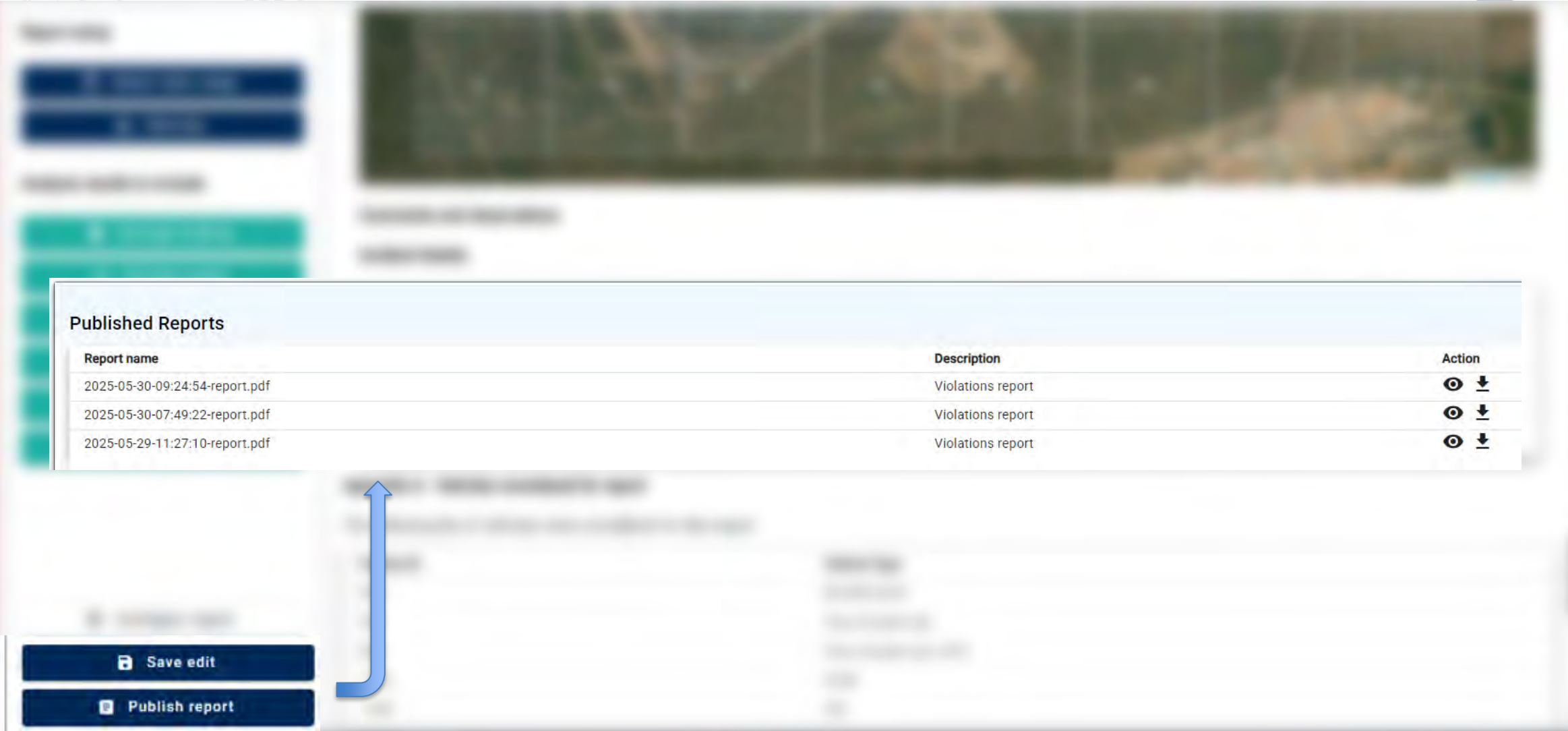
Mine A

☒ Stop Violations configuration	☒ Speed Violations configuration	☒ Berm Violations configuration	☒ Exclusion Violations configuration	☐ Maintenance Violations configuration
Enable elements ☒ Show violation map ☒ Enable heatmap overlay ☒ Enable violation marker ☒ Show incident chart ☒ Show "Comments and observations" ☒ Show incident details	Enable elements ☒ Show violation map ☒ Enable heatmap overlay ☒ Enable violation marker ☒ Show incident chart ☒ Show "Comments and observations" ☒ Show incident details	Enable elements ☒ Show violation map ☒ Enable heatmap overlay ☒ Enable violation marker ☒ Show incident chart ☒ Show "Comments and observations" ☒ Show incident details	Enable elements ☒ Show violation map ☒ Enable heatmap overlay ☒ Enable violation marker ☒ Show incident chart ☒ Show "Comments and observations" ☒ Show incident details	
Comments and observations Enter comments and observations	Comments and observations Enter comments and observations	Comments and observations Enter comments and observations	Comments and observations Enter comments and observations	
☐ Blast Violations configuration	☒ Unload Violations configuration	☒ V2V Interactions configuration	☐ Fatigue Violations configuration	☐ Harsh Violations configuration

Configure report

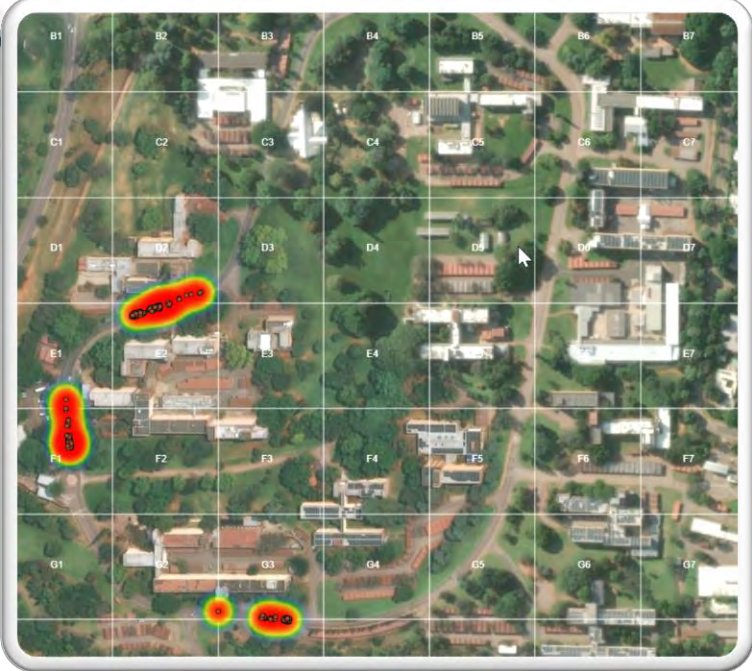
Apply changes **Cancel**

Reporting: Configurable outputs and analyses to display



Published Reports		
Report name	Description	Action
2025-05-30-09:24:54-report.pdf	Violations report	 
2025-05-30-07:49:22-report.pdf	Violations report	 
2025-05-29-11:27:10-report.pdf	Violations report	 

Site Reporting: Summary and details of violations



Comments and observations

Incident Details

Date	Vehicle ID	Violations	Compliance	Sector
2022-05-07	264	3	N/A	F7
2022-05-01	264	3	N/A	F7
2022-05-06	289	6	N/A	A5
2022-05-05	289	9	N/A	A5
2022-05-07	289	6	N/A	A5
2022-05-04	289	6	N/A	A5
2022-05-03	289	6	N/A	E7,A5
2022-05-06	293	3	N/A	A5
2022-05-05	293	6	N/A	A5
2022-05-07	293	6	N/A	A5

Reporting: Configurable outputs and analyses to display

SmartMine

localhost4200/report-view

Select Analysis

Select Analyses

Site Select report start date Select report end date Analyses Types Search

Select	Created date	Site	Analysis name	Description	User	Start Date	End Date	Vehicles	Analyses
☐	21/10/2025	Fab data site	Demo 7	Demo analysis 7	✓	26/04/2023	26/04/2023	20 Vehicles	⌵ ⌶
☐	21/10/2025	Fab data site	Demo 6	Demo analysis 6	✓	25/04/2023	25/04/2023	20 Vehicles	⌵ ⌶
☐	21/10/2025	Fab data site	Demo 5	Demo analysis 5	✓	24/04/2023	24/04/2023	20 Vehicles	⌶ ⌵
☐	21/10/2025	Fab data site	Demo 4	Demo analysis 4	✓	23/04/2023	23/04/2023	20 Vehicles	⌵ ⌶
☐	21/10/2025	Fab data site	Demo 3	Demo analysis 3	✓	22/04/2023	22/04/2023	20 Vehicles	⌵ ⌶
☐	21/10/2025	Fab data site	Demo 2	Demo analysis 2	✓	21/04/2023	21/04/2023	20 Vehicles	⌶ ⌵
☐	21/10/2025	Fab data site	Demo 1	Demo analysis 1	✓	20/04/2023	20/04/2023	20 Vehicles	⌶ ⌵ ⌶
☐	21/10/2025	Fab data site	t9	sd	✓	20/04/2023	20/04/2023	20 Vehicles	⌶
☐	20/10/2025	Fab data site	T7	VT	✓	20/04/2023	20/04/2023	20 Vehicles	⌶ ⌵
☐	20/10/2025	Fab data site	t6	ds	✓	21/04/2023	21/04/2023	20 Vehicles	⌵

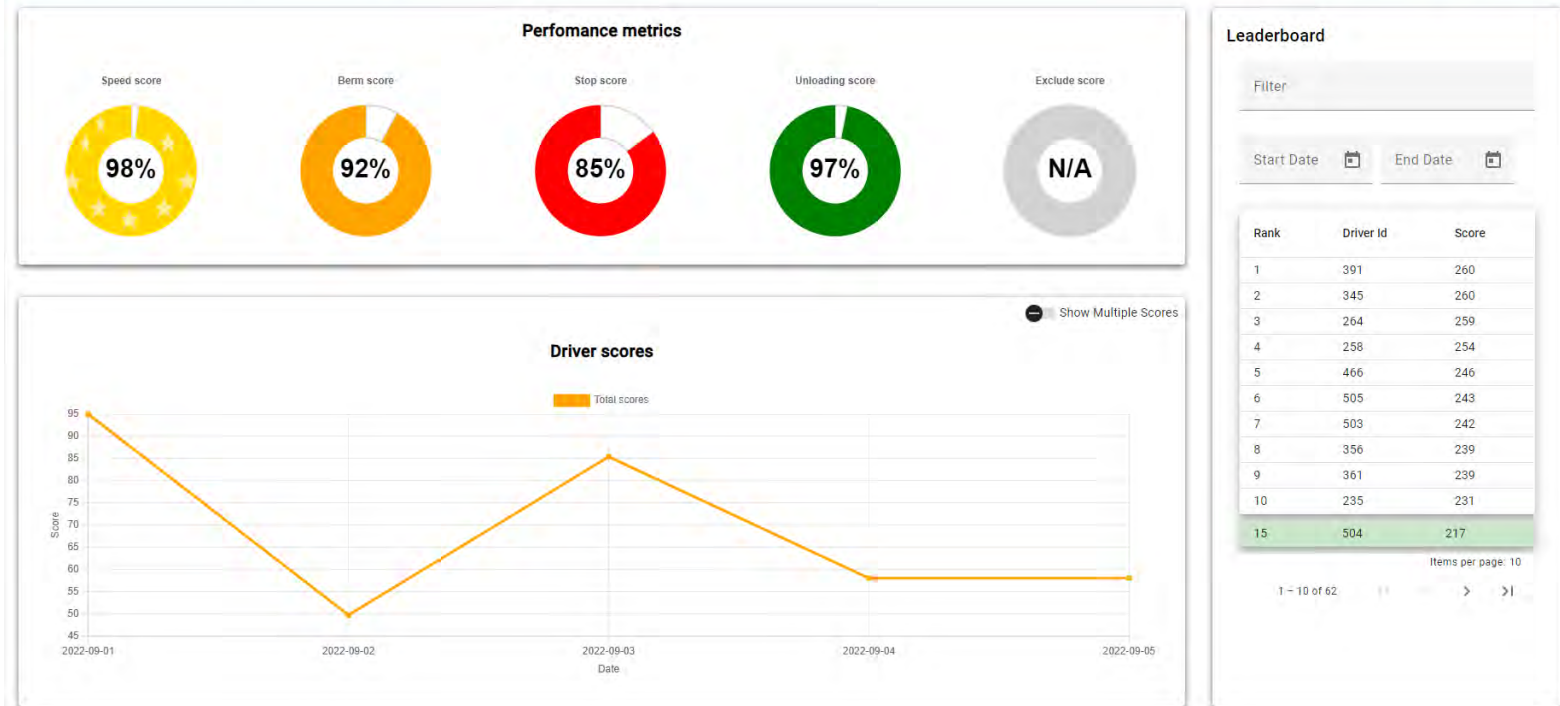
Items per page: 10 1 - 10 of 16

12:07 2025/10/21

Operator Performance: Module Gamified Training tool



Driver Performance Dashboard



Show Performance scores

- Most recent
- Historic data
- See scores relative to other drivers

Identify potential issues

- Training
- TMP issues
- Missing damaged infrastructure



Report review: Dynamic Risk Assessment

Qualitative Analysis

Risk Rating

Impact / Severity

3	4	5
2	3	4
1	2	3

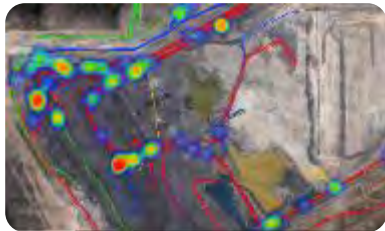
Risk Assessment Table

Update Risk Rating

Traffic Management Plan (TMP) Update



Update **TMP** by means of the TMM Digital Twin Cloud Based Interface



Real-World Data:
Vehicle Logs
Analysis results

Quantitative Analysis

TMM Digital Twin
Data Analytics

Analyse the key events to determine the **risk ratings**

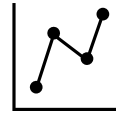
Summary - CSIR TMM Digital Twin Services



On-premise or Cloud-based platform – User interface, Configure TMP and Analysis



TMP Compliance Analysis



- ☐ Speed limit violations
- ☐ Stop signs violations
- ☐ Berm violations
- ☐ Exclusion zone violations
- ☐ Blast and unloading zone violations
- ☐ Follow distance
- ☐ Reversing

Profiling and Tracking



- ☐ Vehicle movement
- ☐ Average speed
- ☐ Average braking
- ☐ Driver performance scores
- ☐ Harsh Driving

Vehicle Interaction Analysis



- ☐ Vehicle-to-vehicle interaction events
- ☐ Software based – without level 7 – 9 equipment



Reporting – dashboard and download reports

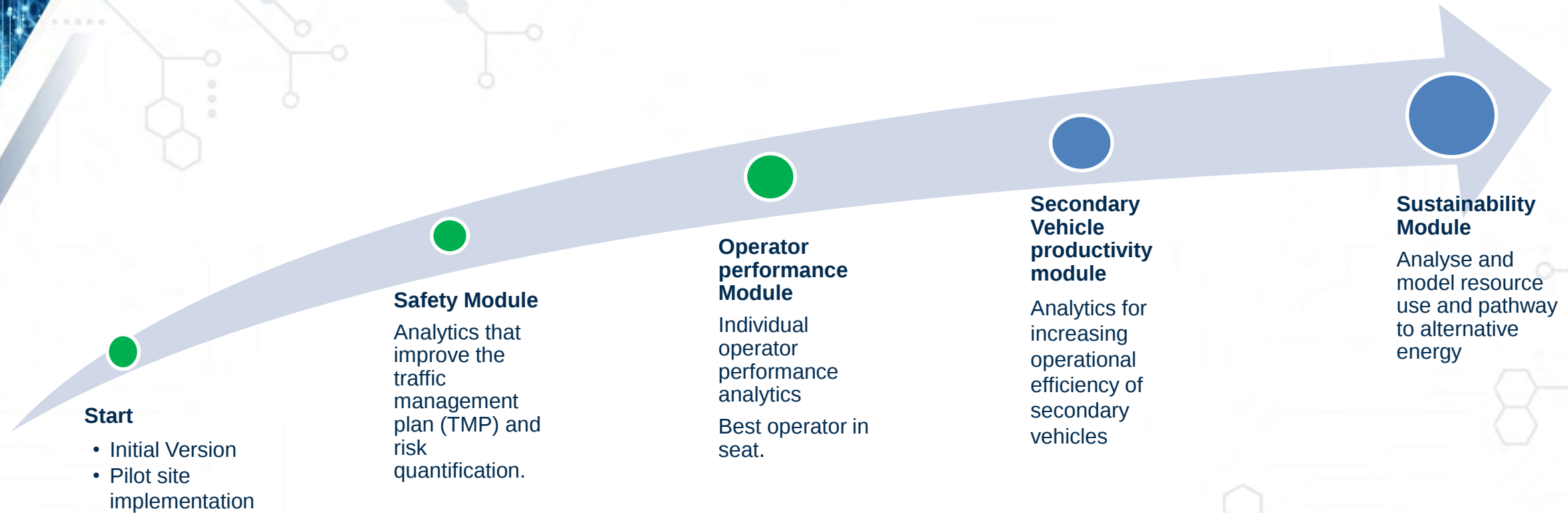
☐ Configurable template

☐ Dynamic filtering

☐ Combine analyses



Roadmap: Future of the platform



Commercialisation: Industry partnership



Hardware/Software
integration



Insights and
visualisation



Enhanced Value
Proposition



The background is a deep blue color with a subtle, intricate pattern of white and light blue circuit board traces. A large, thick white arrow points from the left side towards the right, partially overlapping the circuit pattern. The text "Thank you" is centered in the middle of the image.

Thank you