



CASCADIA
SCIENTIFIC

ROAD CONDITION MONITORING WORKFLOW

- Data Collection
- Solutions
- Applications
- Calculating Benefits
- Global Applications
- Super Users
- Change Management
- Setup & Time Requirements

Cascadia Scientific Inc.
Vancouver, Canada



Data Collection

Installation of Cascadia Hardware: 4 hours per truck

Fuel Flow Meters



- Built for Mining
- Temperature and Density Corrected
- >99% Consumption accuracy

Controller



- 9 axis Motion Sensing, Pressure Based Altimeter
- Vehicle Network Integration (CDL, PLM, CAN Bus etc.)
- Edge Compute, Store & Forward (7 days of memory)
- Cellular, Wifi, Ethernet

GNSS



- Geo-location accurate to less than 3 meters
- Integrated Antenna design for maximum reliability
- Geo-location data made available to any system via CAN Bus

Capture Type	Content	Trigger	Utilization
Heat Map	<ul style="list-style-type: none"> • Point in time snapshot of location, speed, heading, pitch, altitude and time. Lifetime accumulated values for fuel consumption, gear selection, RMS accumulated values for vibration. 	<ul style="list-style-type: none"> • Captured at 10-20 second intervals 	<ul style="list-style-type: none"> • Heat map workflow, ML Terrain Coach
Fast Capture	<p>Fast Capture Data Tags - availability to include more per client request:</p> <ul style="list-style-type: none"> • DateTimeUtc, Consumption, EngineSpeed, Payload, Latitude, Longitude, Heading, Speed, Altitude, BodyAnglePosition, ServiceBreak, DumpBodyUp, ParkingBrakeStatus, ColdModeStatus, RetarderStatus, SelectedGear, HoistLeverPosition 	<ul style="list-style-type: none"> • Captured every 1-2 seconds 	<ul style="list-style-type: none"> • More granular road / operator analysis

Road Condition Monitoring – Technical Solutions



ML Coach offers a comparative view of haul road performance against an evolving modeled baseline, enabling quick identification of road sections with significant changes in consumption, efficiency, cycle times, and vehicle vibration.

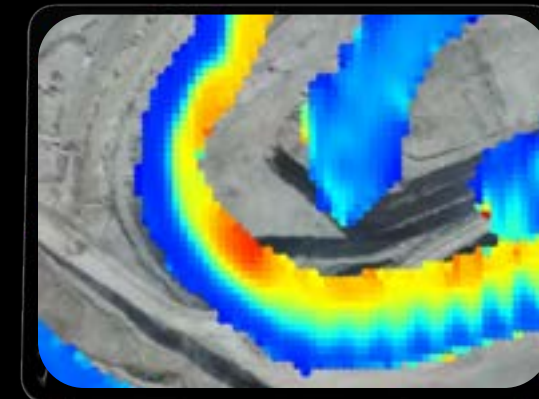
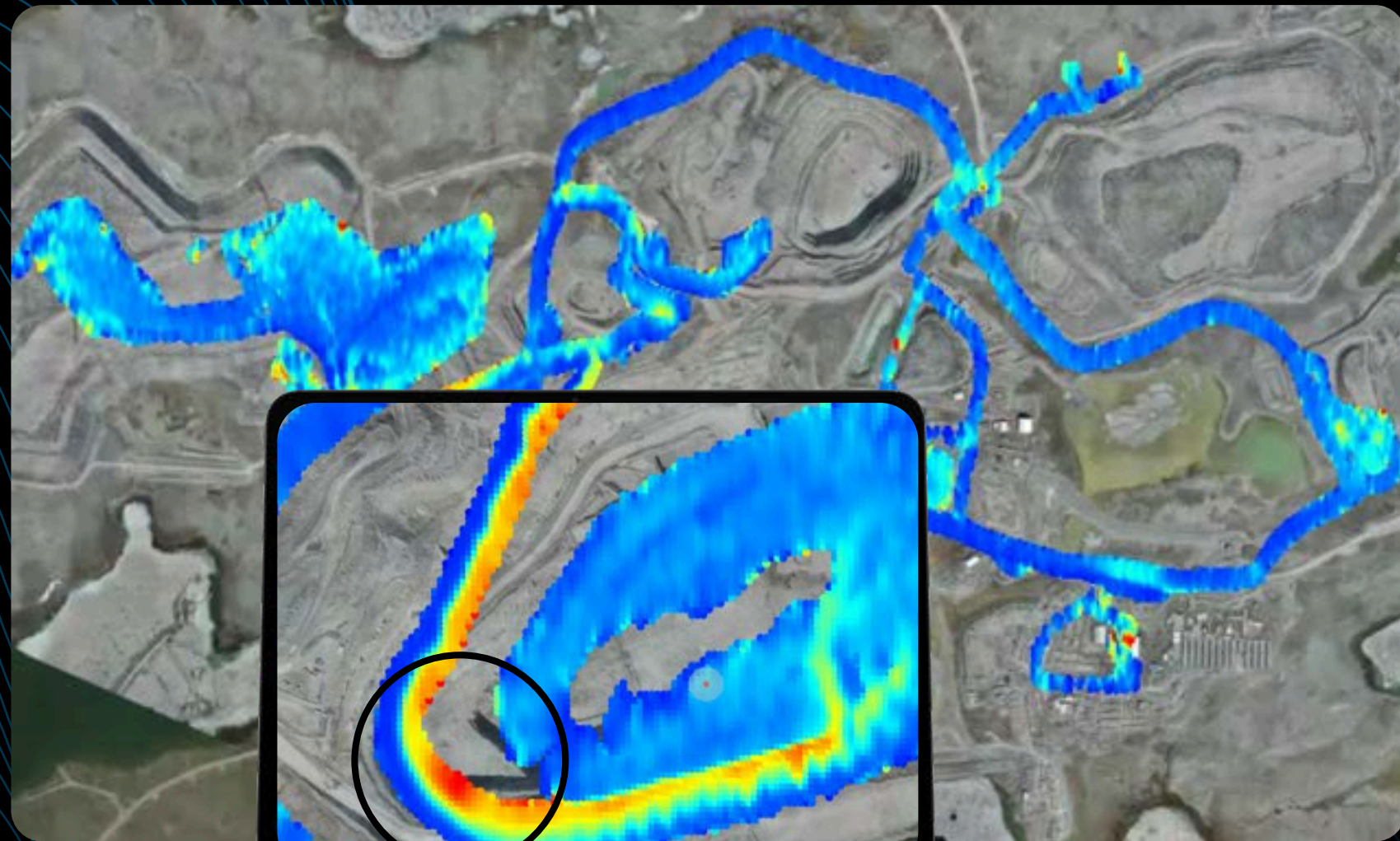


SmartRView offers a historical analysis of haul roads with an intuitive visual tool to identify root problems, forecast changes, and calculate benefits from road intervention work.

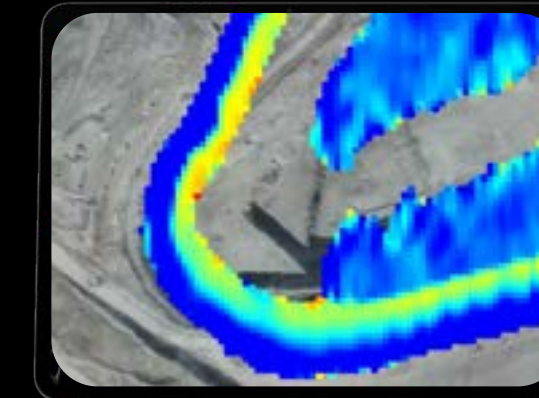


Road Condition Monitoring Workflow

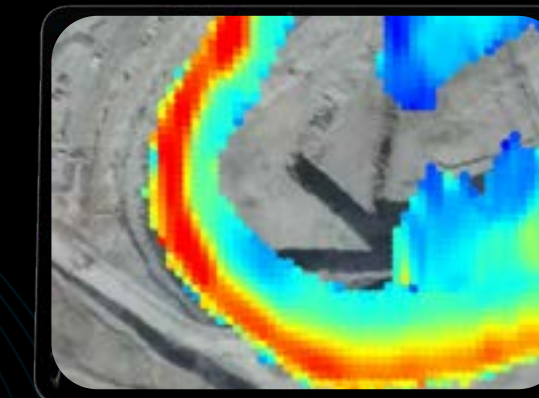
1 Step 1: Zero-in on a Hotspot



Fuel Intensity



Grade

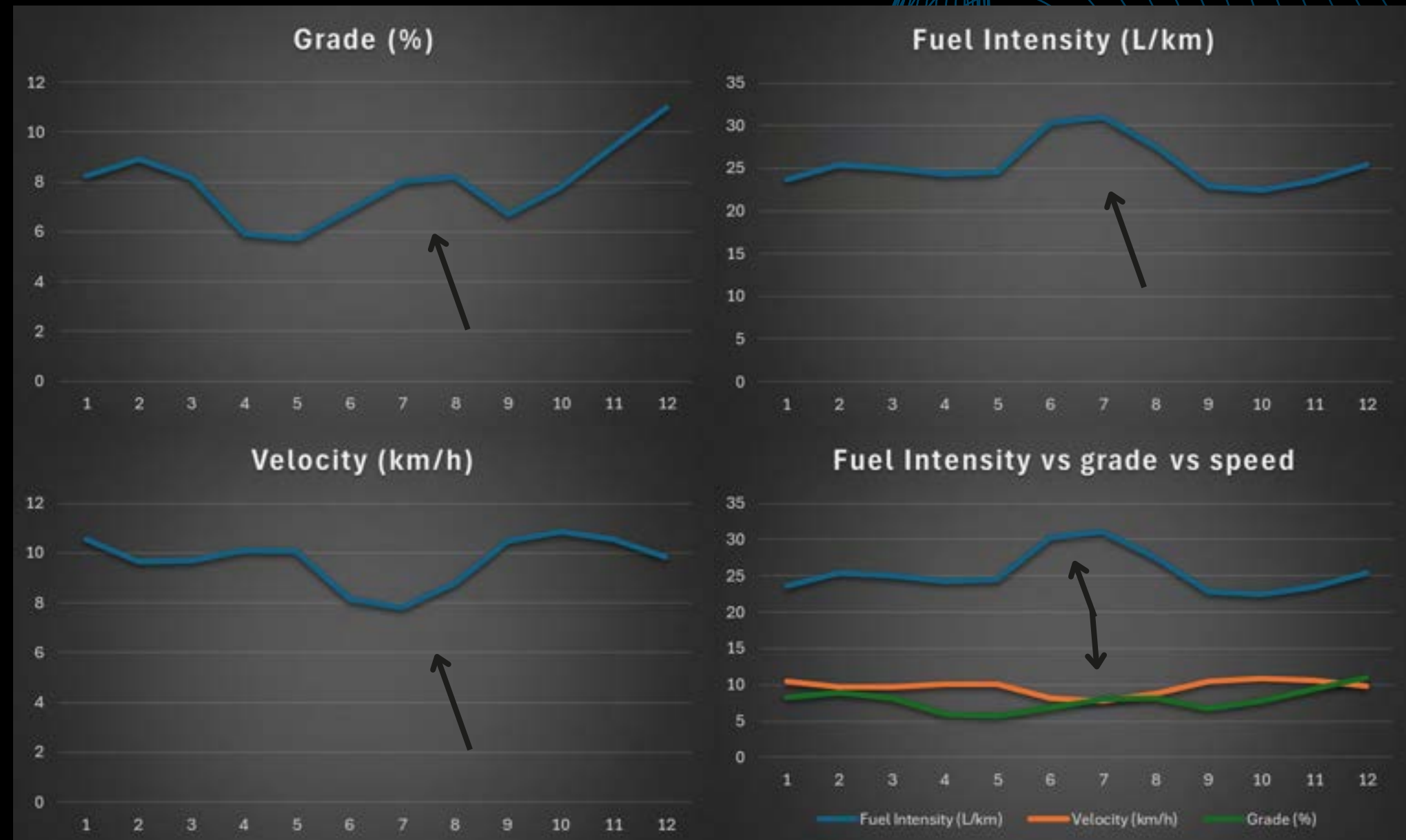
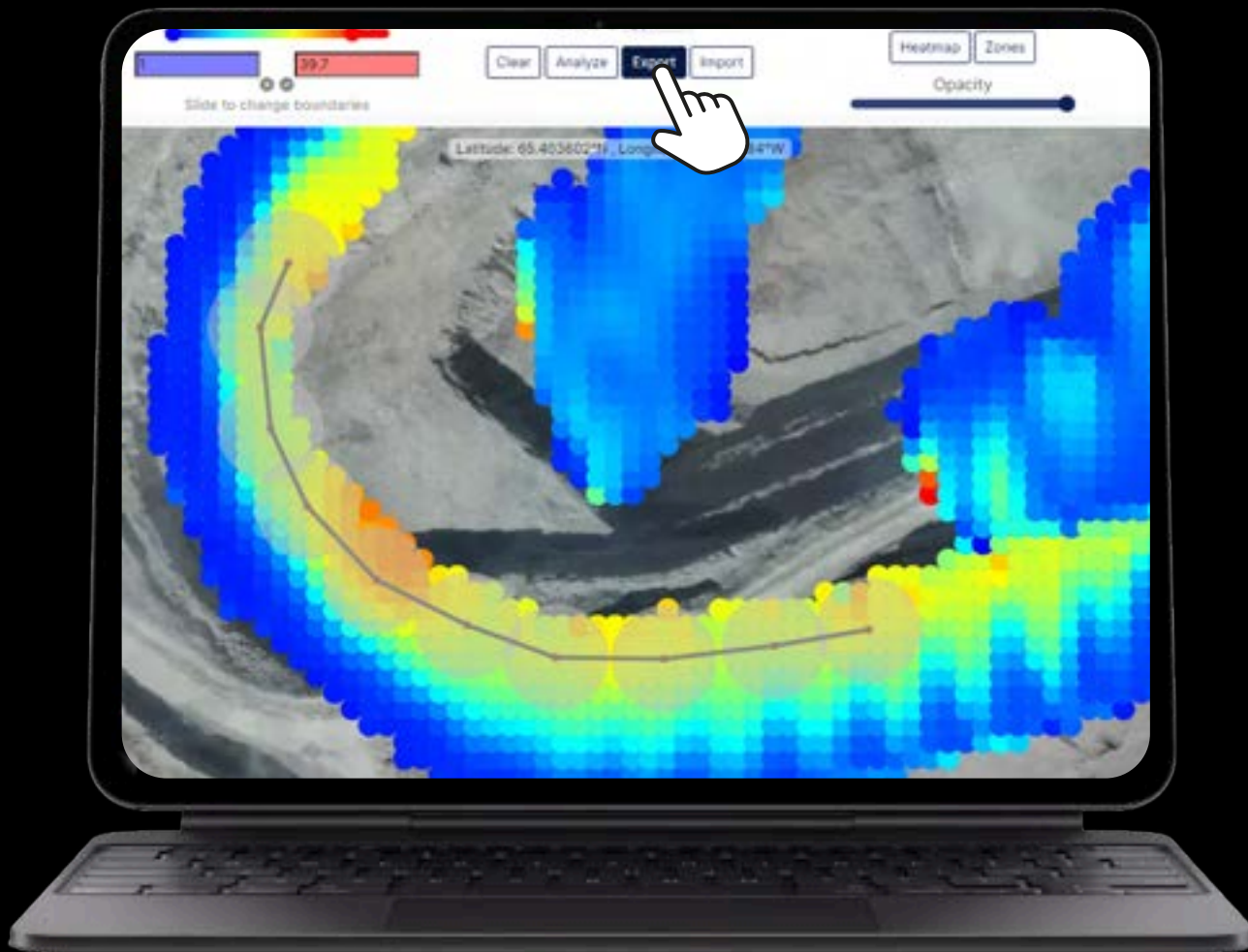


Speed

Road Condition Monitoring Workflow

2 Step 2 - Hot Spot Investigation

Trace the haul path to extract related data and evaluate the root cause

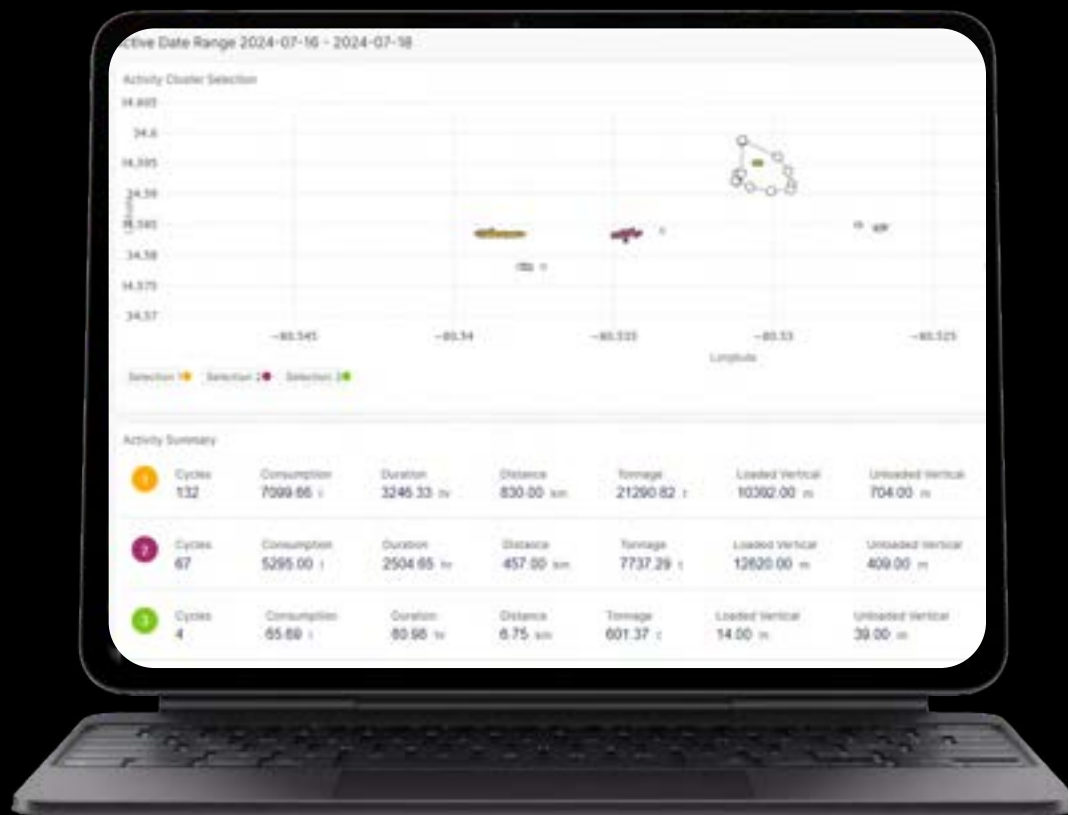




Road Condition Monitoring Workflow

3 Step 3 - Forecast Anticipated Gains

Based on measured truck data, Cascadia creates and updates grade profiles showing speeds and fuel consumption for different road grades. This helps predict how changes in road design will affect fuel use and vehicle speeds, supporting the justification for repairing any road segment.



Grade Bucket [%]	Calculated_Speed [mi/h]	Flow_By_Distance [gal/mi]	Flow_Intensity [gal/h]	Net_Vertical_Speed [mi/h]
-10	12.6122	1.2166	6.9966	-1.2565
-9	12.6039	1.6273	7.6737	-1.1321
-8	12.6017	1.6786	8.2601	-1.0092
-7	11.9307	2.1662	10.2452	-0.8393
-6	11.3944	2.8560	13.6620	-0.6863
-5	10.6969	3.1629	16.7561	-0.5348
-4	11.2108	2.9914	20.1519	-0.4457
-3	12.0969	2.6570	22.0750	-0.3572
-2	12.9792	2.4899	25.7067	-0.2528
-1	16.2462	1.9443	29.5500	-0.1655
0	9.4859	4.7336	31.3005	0.0002
1	17.5072	3.3858	56.7872	0.1812
2	13.0328	4.9939	59.2459	0.2517
3	11.5544	6.3942	66.5140	0.3474
4	11.6024	7.5472	77.4692	0.4631
5	11.2036	8.5943	86.1248	0.5622
6	9.8555	10.1621	91.3239	0.5921
7	8.9441	11.2498	94.9186	0.6280
8	8.2027	12.2328	96.5661	0.6563
9	7.7587	12.9240	97.0606	0.6968
10	7.3843	13.6386	97.7200	0.7366

Road Condition Monitoring Workflow

4 Step 4 - Road Repair

Before



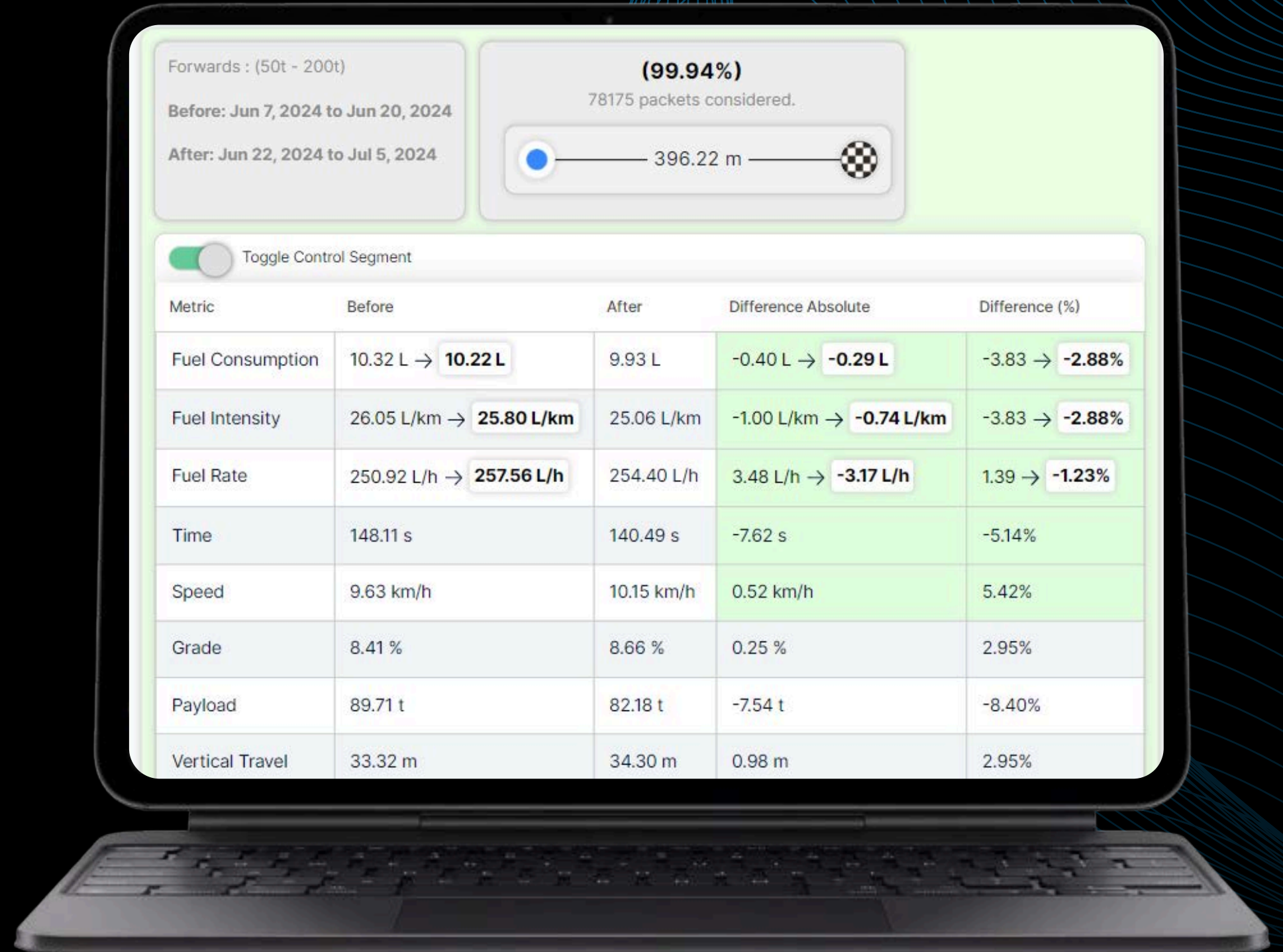
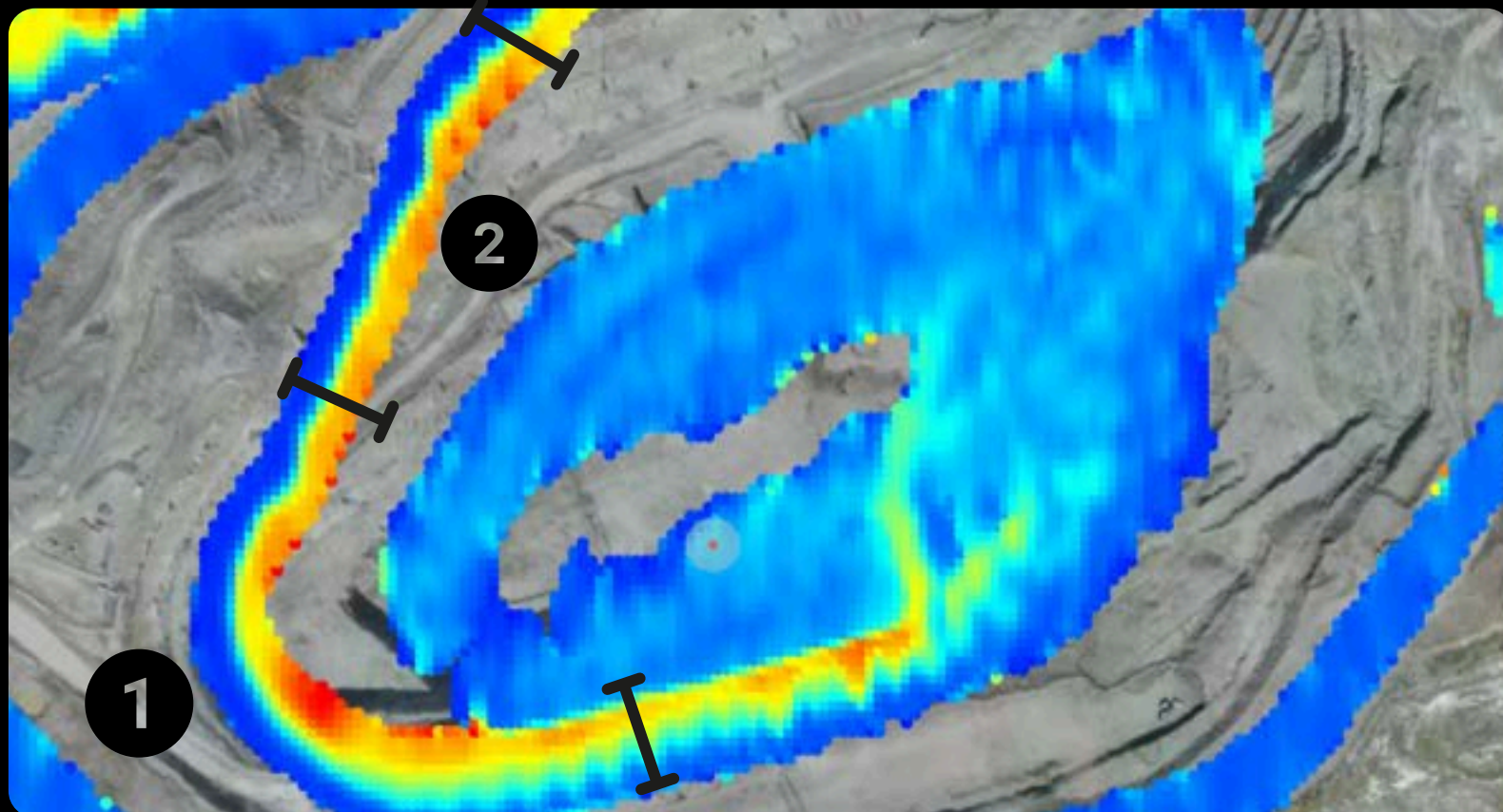
After



Road Condition Monitoring Workflow

5 Step 5 - Confirm Benefits

Cascadia Scientific's software lets users calculate the benefits of repaired road segments by comparing data from before and after the repairs. It also includes tools to add control road segments to account for global changes, like weather conditions, so users can focus on the specific effects of the road repairs.



Additional Applications – Truck, Road & Operator Alarms



Alarms: (date, time, location, asset)

- Frame twisting
- Pot holes
- Rocks on the road
- Material Spillage
- Uneven payload distribution
- Aggressive cornering
- Aggressive braking
- Truck “bucking” events
- Diagnostic Trouble Codes (DTCs)



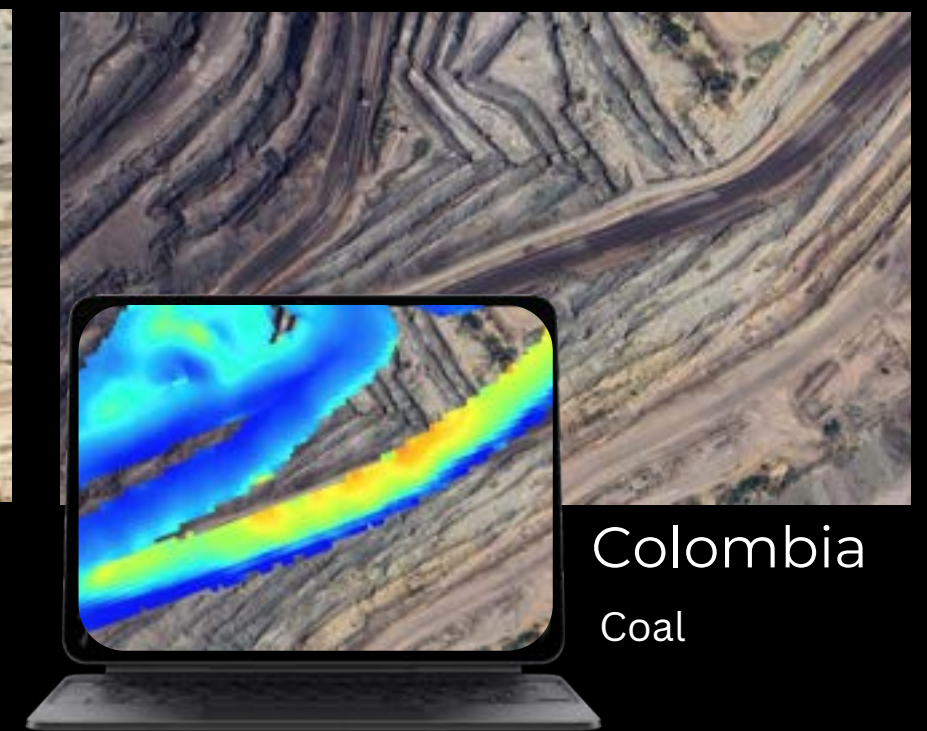
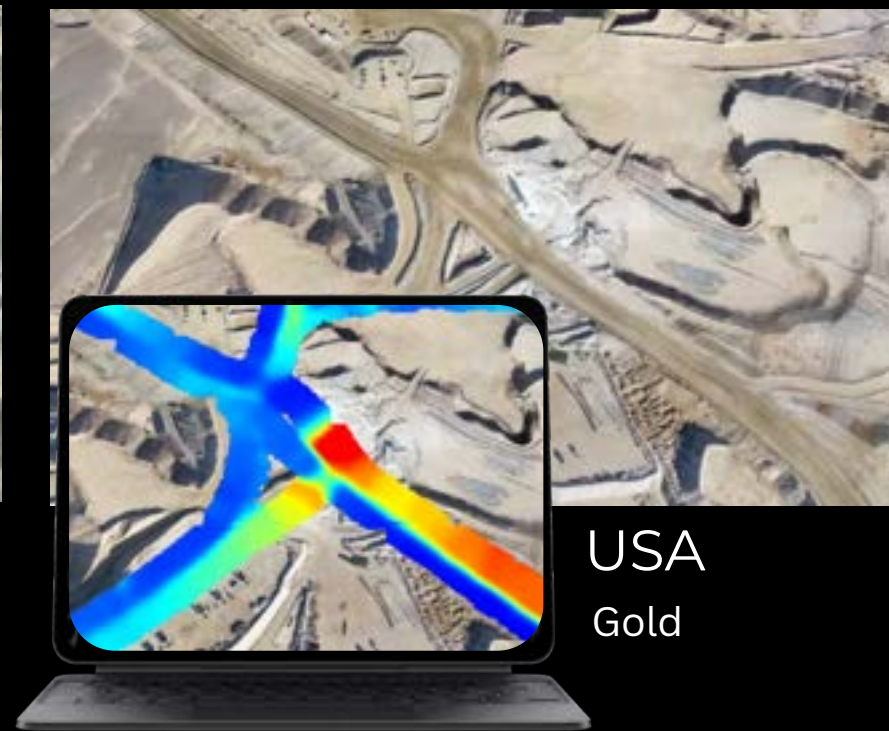
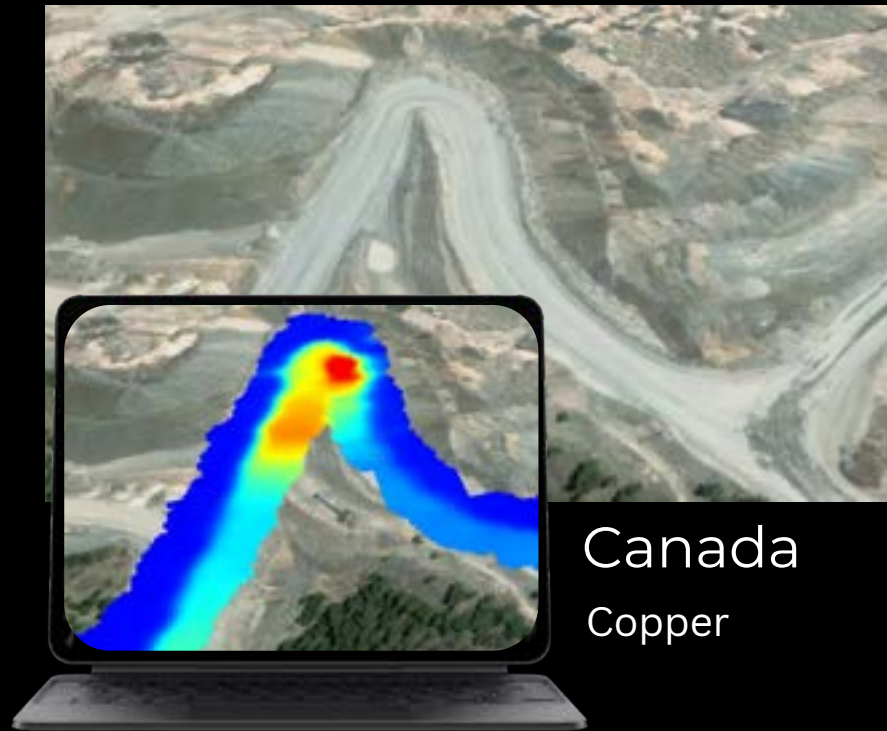
- Operator behaviour alarms
- Idle Heat Map
- Spotting times
- Queing times
- Loading Times

Cascadia Scientific provides custom alarms for roads, trucks, and operators to ensure adherence to operating procedures.





Global Applications



Truck Fleet	830E
Action	Widen Corner
Cycle Efficiency Gain	3.28% Per cycle
Fuel Savings	34,100 Liters Per truck
CO2 Savings	101 Tons Per truck

Truck Fleet	789, 793
Action	Reslope
Cycle Efficiency Gain	0.70% Per cycle
Fuel Savings	6,300 Litres Per truck
CO2 Savings	21 Tons Per truck

Truck Fleet	980E, 930E, 797
Action	Regrade
Cycle Efficiency Gain	1.40% Per cycle
Fuel Savings	16,300 Litres Per truck
CO2 Savings	49 Tons Per truck

Truck Fleet	EH4000, 793, 789, 830E
Action	Regrade
Cycle Efficiency Gain	2.1% Per cycle
Fuel Savings	12,850 Liters Per truck
CO2 Savings	42 Tons Per truck

2023

AVERAGE PER TRUCK SAVINGS, ANNUALLY

\$42k USD

AVG. EMISSIONS REDUCED PER TRUCK, ANNUALLY

163 TONS



Super Users



Colombia

8 Hot spots
\$1.3M USD

5530 Tonnes of CO2e reduced



Peru

5 Hot spots
\$1.8M USD

9100 Tonnes of CO2e reduced



Change Management

TECHNOLOGY

Cascadia creates heat maps of the mine site and alerts operations to problematic road sections

PROCESS

Cascadia and the mine site use heat maps to target haul road repairs. Corrective actions are taken, and Cascadia provides before-and-after analyses to measure repair benefits

PEOPLE

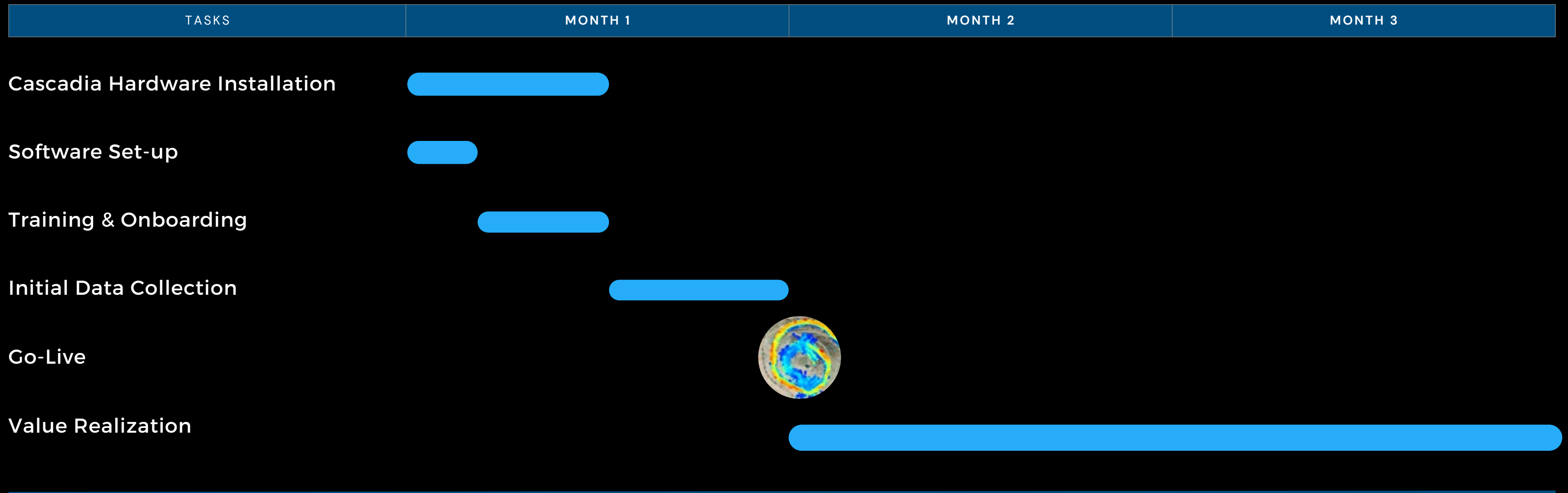
Weekly meetings and site visits are conducted to communicate findings and share results, and improve processes

Task	Time requirement	Task Description	Responsbile
Hardware installation	4 hours per truck	<ul style="list-style-type: none"> • Site inductions and meet & greet • Chaperon Cascadia Technician to maintenance • Support Cascadia technician during installations 	Mine Site & Cascadia
Software Set up	2 hours	<ul style="list-style-type: none"> • Provide copy of Mine plan for ML Terrain Coach 	Cascadia
Software & Training	1 hour per session	<ul style="list-style-type: none"> • Training with Operations, Mine Planning, Engineering, environemntal teams 	Cascadia
Haul Road Condition Monitoring	On-Demand: 15 minutes per occurrence	<ul style="list-style-type: none"> • Build heat map rendering of mine site • Identify areas of high fuel use, vibration, etc • Allocate support equipment to these areas • Forecast new haul roads 	Mine Site & Cascadia
Benefits Calculation	On-Demand: 15 minutes per occurrence	<ul style="list-style-type: none"> • After road repair, benefits report provided to establish benefits and ensure succesful repair 	Cascadia
User Group Meetings	1 Hour	<ul style="list-style-type: none"> • Provides information to support mine operations staff in tactical decision-making and execution 	Mine Site & Cascadia



Setup & Time Requirements

Cascadia Scientific partners with you to manage people, processes, and technology. We use software and analytics to boost your mining operation's productivity, profitability, and sustainability. Our end-to-end support **ensures ROI within 6 months.**





CASCADIA
SCIENTIFIC

MINING DATA

FOR MINING PROFESSIONALS