SmartRView

CASCADIA SCIENTIFIC

Business Improvement through In-Service Fuel Measurement

FOREWARD

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For the foreseeable future, the extraction of resources critical to global prosperity will remain a fuel and carbon intensive activity. The costs arising from diesel fuel consumption are multifaceted and bourn, to some extent, by each of us. As such, the rewards of unlocking improved diesel efficiency are compelling. These include environmental sustainability, improved profitability, and energy security. Striving to maximize the value from each ounce of fuel must therefore be among the goals of every organization serving our sector.

Some time ago, we came to recognize that an accurate accounting of fuel consumption as it relates to mining intensity was uniquely absent among operators of high-horsepower diesel equipment. Moreover, mining equipment operators have more "levers to pull" than their marine, power-gen and rail counterparts in the face of inefficient processes.

It is our belief that the first step towards improved diesel efficiency is establishing an empirical relationship between fuel consumption and mining activity. For this reason, we set out to produce the tools, analysis and services to support this very objective.

Each drop of diesel fuel has both a caloric and informative value. The latter of which is seldom extracted and even less often exploited.

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Part 1- Product Overview

SmartRView

Blutip's SmartRView fuel and data analytics platform is a subscription-based service designed for operators of mobile mining equipment. Differentiated by high-accuracy in service fuel measurement, SmartRView produces unique and actionable insights enabling efficiency gains, increased profitability, and reduced engine emissions. With no reliance on existing mine infrastructure, and the included support of Cascadia Scientific analysts; SmartRView supports end-to-end business improvement efforts in the areas of operational efficiency, maintenance strategy, procurement and mine planning.

SmartRView subscribers can reduce the cost per ton(ounce) of production through reduced fuel use, increased productivity, lower maintenance costs, increased machine availability, better informed procurement, and improved forecasting.

Product Origin

Cascadia Scientific first entered the mining space with a fuel-injection remapping service. To demonstrate and quantify the related efficiency gains, Cascadia Scientific engineers purchased, ruggedized and deployed fuel measurement and data collection equipment. The combination of high-precision real-time fuel measurement data, haul truck operational metrics and detailed statistical analysis allowed Cascadia Scientific to successfully quantify attributable savings in the range of 2 - 5%.

While the approach was reasonable for deployments of limited time and scale, the undertaking was extremely expensive, and equipment would typically fail within 6-months of commissioning. Despite this, customers and third-party vendors, most notably large petrochemical companies, began to engage Cascadia Scientific to perform similar efficiency impact assessments of their products (Premium diesels, Synthetic lubricants etc.).

It was in response to these customer requests that Cascadia Scientific developed SmartRView, and the technology evolved from a sales support tool, to an independent product offering.

Developement was accomplished with care and attention paid to each of the following concerns:

- **Ruggedization**
  The fuel meters, electronics and accessories were redesigned to endure the severity of the mining environment. These efforts yielded further improvements in areas of in-field serviceability and remote diagnostics.

- **Vehicle Network Integration**
  In addition to High accuracy fuel data, the collection of equipment, production and diagnostic information was required to successfully enable the intended set of use cases.

- **Cost reduction**
  Cascadia Scientific partnered with a flow meter manufacturer and leveraged in house expertise to drive down cost while maintaining accuracy and improving reliability.

- **Cloud Connectivity**
  Data needs to be sampled at key moments of mining activity and then uploaded for analysis and presentation. A modular architecture allows Cascadia Scientific to leverage cellular, ethernet or Wi-Fi networks for cloud connectivity.

- **Development of the Web Portal**
  Once collected, fuel consumption, production and efficiency data can be interrogated by customers within the Cascadia Scientific web portal. The portal, discussed at length in later sections, supports hierarchical access to equipment analysis, operator performance and statistical modeling. Every aspect of the portal has been designed to support a growing set of business improvement initiatives.

DID YOU KNOW?

Every other high horsepower diesel industry utilizes In-service fuel measurement to drive business improvement

Why not mining?

Benefits of In-Service Fuel Measurement

Most, if not all, mine production and maintenance support tools serve access to engine control module (ECM) fuel-use estimates. These estimates are produced by combustion models developed in the lab by the manufacturers. These models generally relate injector lift times to atomized fuel flow under varied engine conditions. Unfortunately, the accuracy and repeatability of these estimates are not sufficient to support any number of business improvement use cases.

SmartRView Fuel meters, measuring the difference in flow to and from the engine, yield accuracy and repeatability that outperform ECM fuel use models by as much as 10X (1000%). The meters, having been calibrated across the expected flow range, yield a maximum error of 0.1% and combine for consumption measurement accuracy of 99% or better. This measurement accuracy and the related data collection strategies, are key to enabling high value business improvement use case execution.

Fuel consumption measurement accuracy of 99% or better

Mining Data Integration

Accurate fuel measurement alone is not enough to inform mining business improvement initiatives. For this reason, SmartRView combines in-service fuel measurement with several key mining metrics.

- **Pressure based altimetry**
  used to establish haul cycle gross (loaded) vertical travel, a key indicator of mining intensity.

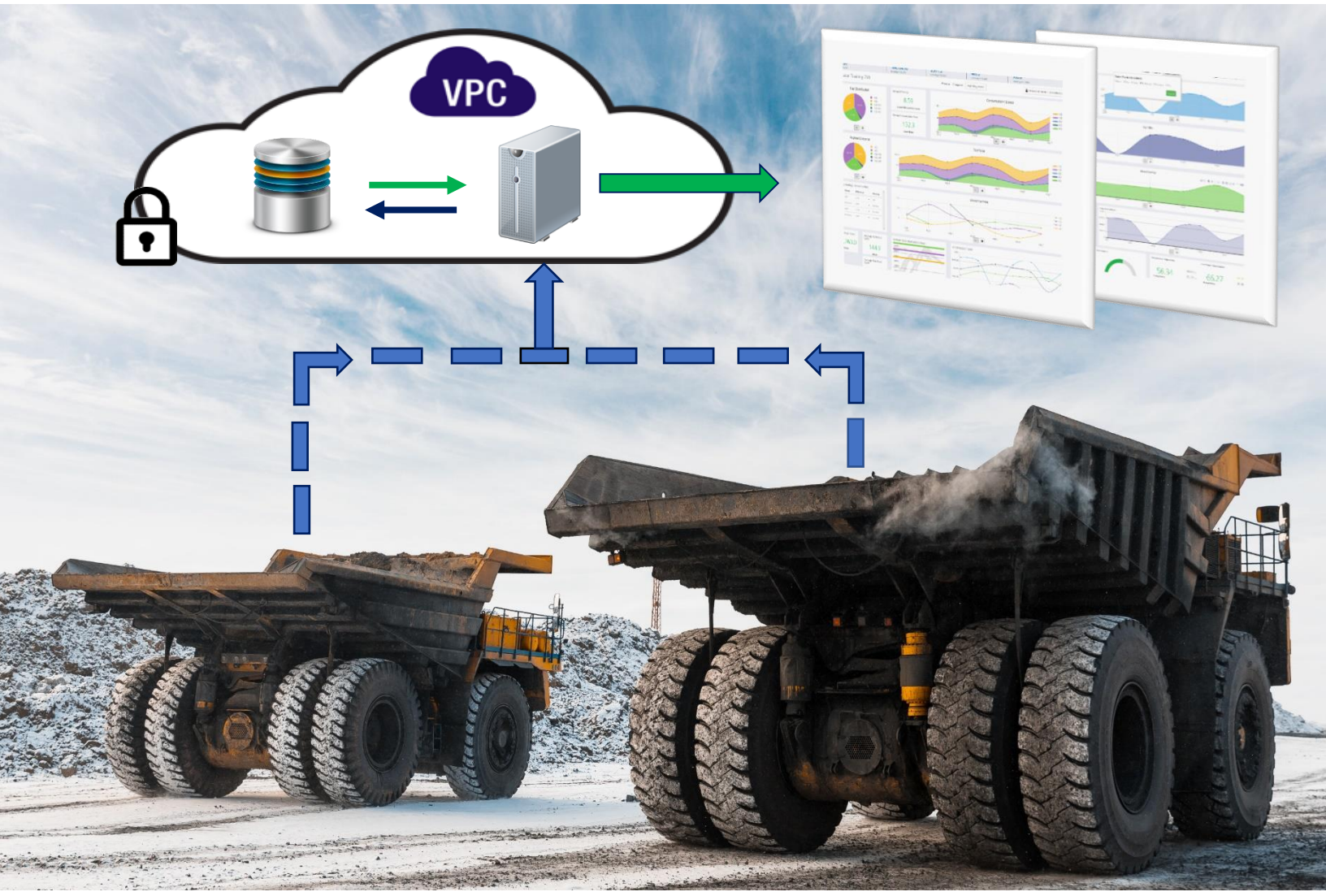
- **Vehicle network integration**
  used to establish haul cycle distance, equipment hours, payload tonnage and specific operator input patterns.

- **9-Axis motion sensing**
  included to detect ramp grades and measure vibration levels to inform decisions around road design and maintenance.

- **Geo Location (GPS)**
  used as a highly available source of date and time. Additionally, geo-location data can be used to restrict analysis to specific areas of the mine.

Data Flow

On haul trucks, data sampling is event triggered, occurring in response to load, dump and alarm detections. In the absence of these events, data capture is triggered by time. Capture triggers vary for other mobile mining equipment but in all cases, the goal to is collect enough information to accurately reconstruct mining activity. Data packets are then delivered to the Cascadia Scientific virtual private cloud leveraging enterprise grade tools for privacy and security. Data packets are imported, analysed and visualized for users who interact with their data through the SmartRView web portal.



The SmartRView Web Portal

The SmartRView web portal, leveraged in collaboration with Cascadia Scientific analysts, is where customers extract value from a SmartRView subscription. Not simply a dashboard, the SmartRView web portal was developed with a singular design objective; Provide access to detailed analysis directly supporting business improvement use case execution. As the set of supported use cases grows, the SmartRView portal will offer new and varied ways to consume and analyse information. The following examples illustrate how this design philosophy has been put into practice:

- Reconstruction of haul-cycles characterized in tonnage, distance over ground, vertical travel, time and fuel-burn quickly lends itself to productivity and efficiency modeling.

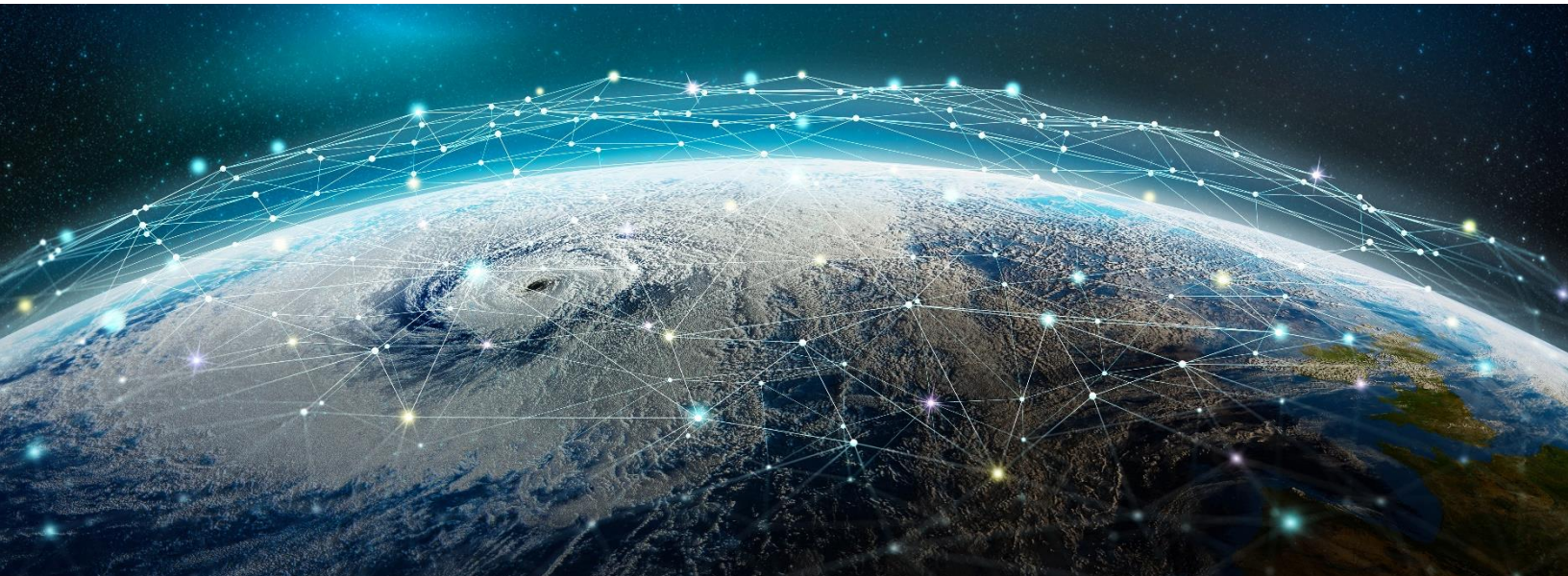
- Linear regression modeling tools generate equations that characterize equipment and operator performance and support production and fuel consumption forecasting per the mine plan.

- User-defined equipment and operator groups summarize fleet and roster performance and efficiency, while group nesting offers a convenient means of navigation to sub-groups or specific assets.

- User selectable productivity metrics and units of measure cascade to influence efficiency calculations and rankings.

- Inclusion of loaded vertical travel as a key indicated of mining intensity is used to normalize activity across the mine and beyond.

The portal serves a second vital role as the principal tool for remote monitoring and configuration of SmartRView equipment. The portal enables Cascadia Scientific staff to proactively monitor the health of subscriber deployments and provides customers the ability to manage their equipment configurations. Common scenarios where customers engage this area of the portal include the selection of density tables to reflect winter and summer fuel changeover and when equipment alarms, limits and thresholds are adjusted.



Data Security

As mining embraces digital transformation, each newly connected asset represents an additional attack vector, and each newly digitized insight increases the importance of data persistence and security. These concerns are ignored at the peril of mining companies and service providers alike who are in no way immune from the threats of a constantly evolving cyber landscape.

In developing the SmartRView controller, Cascadia Scientific has sought to limit the potential impact of a successful attack to the interruption of data collection. Additionally, SmartRView hardware and firmware make the complexity of such an attack, if even possible, highly disproportionate to the rewards of success.

Over the air data transmissions are encrypted and individual packets possess minimal intrinsic value. Blutip's cloud infrastructure runs on the Amazon Web Services platform, and benefits from enterprise level security and availability.

The typical SmartRView offering is comprised of cellular, cloud-connected equipment delivering data to a multi-tenant web server and database. Customer interaction occurs by way of encrypted and authenticated access to the SmartRView web portal. Where elements of this architecture are incompatible with a mine's cyber security policy, Cascadia Scientific collaborates with customers to implement solutions to suit.

SmartRView cloud infrastructure runs on the Amazon Web Services platform, and benefits from enterprise level security and availability.

Installation

Maintaining high equipment availability is essential in the modern mine. Downtime that results from the installation or malfunction of equipment can completely undermine its additive value. These concerns were at the forefront when designing the SmartRView installation materials and install procedures.

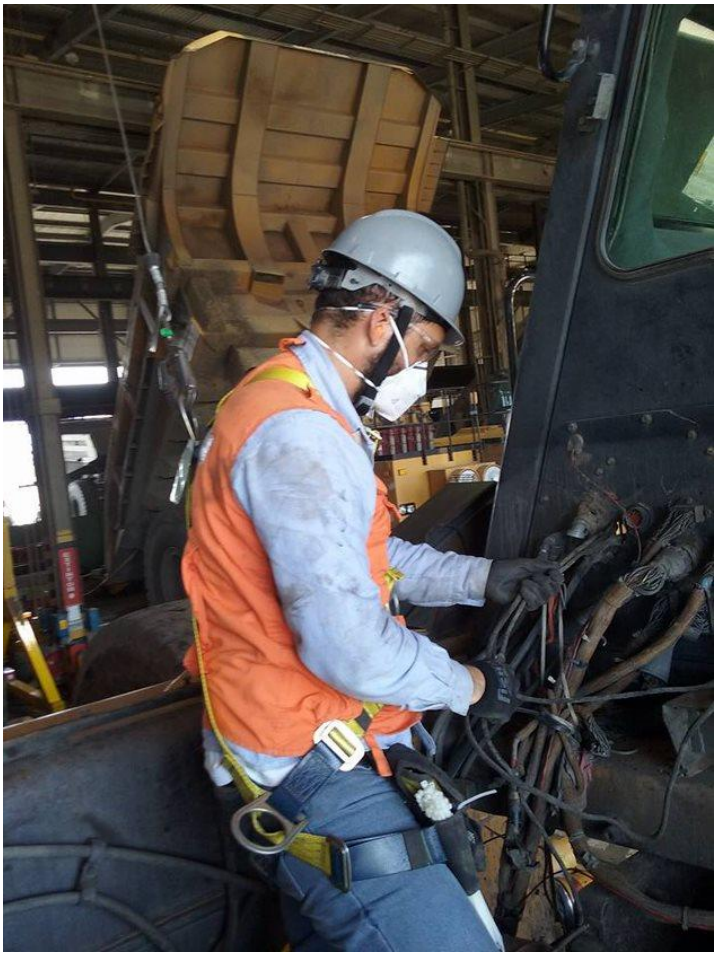
Complete SmartRView installation can be completed in 2 hours

The complete SmartRView installation process can be completed in as little as 2 hours, and where possible, this work is completed during scheduled maintenance or other planned downtime. Ideally, work is completed in a covered workshop with areas of the equipment having been pressure washed prior to the start of installation. When not an option, installations have taken place outdoors in all manner of conditions.

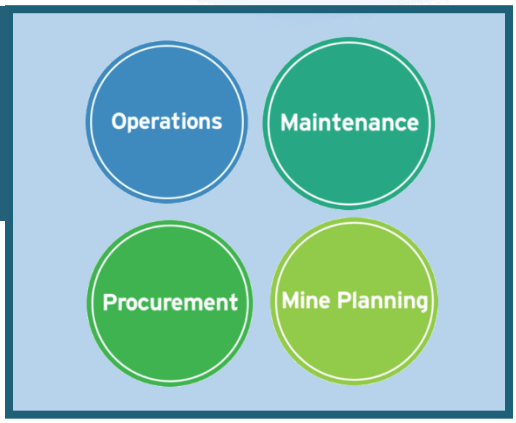
Cascadia Scientific leverages high strength magnets to secure all instrumentation, controllers and antennas, thus eliminating the need to permanently modify and possibly compromise customer owned components. Each magnet has a pull force of 56 lbs, and in the case of Blutip's 1" meter body, 8 of these magnets are employed. All SmartRView components have been designed for installation in areas fully exposed to the mining environment and are rated for temperature extremes, salt spray, and vibration.

Electrical harnesses are constructed from OEM grade GXL wire and protected with a woven loom including a blue trace for easy identification. Connections to power, payload and vehicle network controllers are plug-and-play. No customer harnesses are ever cut.

Fuel System tie-in is the most significant step in the installation process. Fuel fittings are selected to suit site preference, and existing lines are left in place to facilitate rapid removal or relocation of meters. Care is taken to prevent fuel spillage, and to contain or capture any errant drops.



BUSINESS IMPROVEMENT USE CASES



Part 2- Business Improvement Use Cases

With Part 1 having described the SmartRView platform, the remainder of the document presents the business improvement use cases available to all SmartRView subscribers. These opportunities are presented in 4 sections: Operations, Maintenance, Procurement and Mine planning, allowing mining professionals to evaluate the use cases most closely aligned with their business function. Where possible, anonymized customer experiences have been included.

Perhaps your success will be the focus of a future focus case study.

FOCUS CASE STUDY

Operations

SmartRView enables use-cases targeted to improve operational efficiency. Opportunities in this category range from operator performance, to payload targets and haul route speed limits.

Operator Evaluation and Coaching

SmartRView can characterize and rank the performance of your operators in terms of efficiency and productivity. Armed with this information, supervisors can incentivise good behavior and focus remedial training and corrective measures on low-end performers.

Operational Alarms

SmartRView can raise alarms in response to operational loss scenarios which may not represent diagnostic hazards. Further, SmartRView can attribute financial loss amounts to these events. Dozer long-walks, long-idles, dump-body tipping engine over and under speeds events, are all examples of activities impacting efficiency but not captured as machine health events.

Operate to Efficiency

Establish optimal targets for haul road speed limits, payload tonnage, refueling intervals and more, based on accurate fuel per ton metrics.

Equipment allocation

Select appropriately sized equipment for specific activities. Park the least economical assets when production is bottlenecked by other factors.

Challenge: Increase haul truck efficiency through improved operator performance

A large Latin American mining operation engaged training consultants to deliver simulator-based coaching. Upon return from training, there was no way to establish the impact of the adjusted behaviors, and no way to evaluate or influence the resulting benefit over time.

SmartRView was installed on several haul trucks to measure haulage efficiency and productivity. A customized feature was developed to establish the level of adherence to the newly learned behaviors. The mine supplied operator rosters and allocation details which enabled SmartRView to report on individual operator performance. This was done by stitching together periods of operation across multiple shifts and multiple trucks.

Results:

The data was compelling and showed a significant and measurable improvement in operator efficiency upon return from training. SmartRView is used to evaluate operator efficiency and provides operator rankings normalized by equipment. These rankings inform operator recognition and re-training priorities.

FOCUS CASE STUDY

Maintenance

Challenge: Reduce cost and downtime related to premature maintenance

A Canadian oil sands operation ran a preventive maintenance strategy driven by days in service. Members of the maintenance team suspected that this approach, while straight forward to implement, was resulting in significant pre-mature maintenance.

SmartRView was installed on haul trucks and dozers reporting on mining activity and fuel burn.

Results:

Over a 2-month period, the standard deviation in daily fuel burn was 26% of the mean and the highest consuming day saw 3.5 times the fuel burned as the lowest. The variation in fuel burn across maintenance intervals was 24% illuminating a clear opportunity for cost savings. Fuel burn also dramatically outperformed engine hours which accumulate steadily regardless of the intensity of work. This evidence strongly supports the economic justification of fuel-based maintenance scheduling.

SmartRView enables use-cases targeted to improve maintenance strategy. Opportunities in this category use fuel consumption as a powerful proxy for total engine output and equipment health.

Maintain to fuel burn

Total fuel burn, as accurately measured by SmartRView, is a direct indication of total engine output and a strong predictor of remaining lubricant life and component wear. A refined maintenance strategy including total fuel burn can reduce unnecessary maintenance while avoiding unplanned failures. Consider the benefit of eliminating a single unnecessary preventive maintenance event per asset per year.

Maintain to efficiency

Prioritize or pre-empt maintenance scheduling for equipment that operates outside of desired efficiency limits. Focussed attention of the least efficient assets can significantly raise average fleet efficiency.

Fuel System Conditioned Based Maintenance

SmartRView fuel meters provide feed and return flow rates and temperatures. This information can provide early diagnosis of failing or aged fuel system components and can uncover situations of degraded fuel injector and ECM cooling.

FOCUS CASE STUDY

Procurement

SmartRView enables use-cases targeted to improve procurement process. Opportunities in this category include head to head product comparison and in-service validation of vendor efficiency claims.

Petrochemical Evaluation

SmartRView powered mining trials have been conducted on behalf of 2 of the worlds leading petrochemical producers and distributors. Petrochemical evaluations typically run for 5 months and determine the specific impact of premium fuels and lubricants on equipment efficiency.

Mobile Mining Equipment Evaluation

Over the life of a mobile mining asset, total fuel burn is often measured in the tens-of-millions of litres. A choice made in equipment size, manufacturer or configuration will impact profitability decades into the future. SmartRView uniquely informs the purchasing process by allowing customers to accurately establish equipment efficiency in their own operation.

Fleet Rationalization

As equipment ages, decision must be made related to the decommissioning, sale, or repurposing of equipment. SmartRView offers the capacity to inform these decisions through an accurate accounting of production and efficiency of an aged fleet.

Challenge: Establish the efficiency impacts directly attributable to premium fuels and lubricants

The decision to accept a higher price per volume for petrochemicals is most commonly based on the promise of increased efficiency and reduced maintenance costs.

SmartRView has been leveraged as an independent and impartial tool for in-service mining trials performed in partnership with global mining companies and fuel distributors. Most commonly involving a fleet of 8-10 haul trucks the study unfolds in 3 stages. First a baseline is established across the instrumented fleet. In the second stage, half of the fleet is re-configured with the premium lubricant or fuel and operation continues while the impacts stabilize. In stage 3, the attributable benefits of the petrochemical are established by comparing the relative change in performance between the 2 fleets in stages 1 and 3.

Results:

In every case the mining company makes a procurement decision armed with data to support personalized cost-benefit analysis. These techniques can be extended to any change under consideration on diesel burning equipment.

FOCUS CASE STUDY

Mine Planning

CASCADIA SCIENTIFIC

Challenge: Predict operating costs and productivity associated with mine evolution

SmartRView captures data from mining trucks which is analyzed to produce haul cycle aligned observations. Each cycle is characterized in-terms of fuel use, payload, (un)loaded distance over ground, (un)loaded vertical travel, cycle time, average ramp grade and more. These characterisations are used to train linear regression models which predict cycle properties as a function of others.

Mine planners then run the models based on the planned evolution of the mine. The most common examples include

predicting fuel use by running the models with cycle distance and pit depth informed by the mine plan

Predicting cycle length, and therefore production by running the models with cycle distance and pit depth informed by the mine plan

Results:

With model-based predictions for fuel use, and production, mine planners can improve forecasting and budgeting associated with mine expansion.

SmartRView enables use-cases targeted to improve mine planning. Thousands of haul cycle observations are used to build linear models with strong predictive accuracy.

Forecast operating costs

SmartRView captures data to characterize and evaluate mining activity. Each observation can be used to build and refine predictive linear models. Once the models have been established, mine planners can run the models by setting variables related to haul distance, vertical travel and tonnage as prescribed by the planned mine evolution.

Plan to efficiency

SmartRView can be used to determine the optimal ramp angle based on targeted payload and equipment in use. Optimize the plan by striking the appropriate balance between productivity and efficiency.

Optimize haul route maintenance

SmartRView controllers are equipped with vibration sensors and GPS. Understanding the relationship between road surface conditions and efficiency allows for targeted mine road maintenance.

Summary

Business improvement opportunities enabled by high accuracy fuel measurement and analytics in mining are substantial and immediate. Cascadia Scientific is committed to the development and evolution of these tools and the success of our subscriber base. We are actively seeking engagement with professionals who recognize the fundamental importance of these insights and are prepared to be a force for data driven change in their organizations. There is powerful data locked inside your fuel, don't *just* burn it**.**

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SmartRView

Technical Specifications

Materials & Design:

- Glass-filled thermoplastic resin enclosure for reliability and durability
- UL 94V-0 rated circuit boards & wiring (Self-extinguishing)
- GXL silicone-based wiring, copper stranded
- Stainless steel hardware
- Magnetically mounted
- Plug and Play harnessing comprised of GXL silicone wiring, braided nylon sheathing, and Deutsch connectors
- Seamless integration with no splicing of existing OEM harnesses

Ruggedization:

- IP67 rated – Dust tight, water immersion capable
- Salt fog/salt spray approved - SAEJ1455
- Temperature rated from -40C through +65C ambient operating – SAEJ1455
- Storage temps from -40C through +85C non-operating – SAEJ1455
- Relative humidity levels of 0-99%, Condensing – SAEJ1455
- Vibration tested to 6g – As per SAEJ1455 & MIL810F
- Shock (Mechanical) tested to 20g – As per MIL810F
- Pressure wash testing

Connectivity:

- CAN BUS
- CAT Data Link
- Komatsu PLM
- Hitachi CAN
- RS232, RS485
- MODBUS RTU
- GPRS - Penta-Band HSPA, LTE
- EGPRS / WCDMA / HSDPA / HSUPA protocol stack
- GPS

I/O and Sensor Package:

- 9 axis motion sensor (pitch, roll, yaw)
- 3 axis 16bit gyroscope
- 3 axis 14bit accelerometer
- 3 axis magnetometer
- Altimeter
- Relay control outputs (with expansion module)
- Digital and Analogue I/O (with expansion module)

Certifications:

- FCC Part 15, Subpart B, Class A – Unintentional Radiators