Get connected - Step 1 on the journey to electric heavy-duty vehicles

next generation vehicle telemetry

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About Vantage Power

Vantage Power designs and manufactures technologies that connect and electrify powertrains in heavy-duty vehicles. This technology appeals to fleet operators as a retrofit solution for existing vehicles, or to vehicle manufacturers as an OEM solution.

Vantage Power is a high-tech company based in London and to date has designed, manufactured and fielded various electrified powertrain solutions for heavy-duty vehicles, including the production of its own lithium-ion battery systems.

From the outset Vantage Power wanted to introduce cutting-edge vehicle telemetry that would augment their technology, ease the introduction of new products into service and offer their customers new valuable capabilities.

In parallel to the development of new powertrains, Vantage Power created VPVision, a comprehensive telemetry system deeply integrated into the powertrain, vehicle control software and existing vehicle systems.

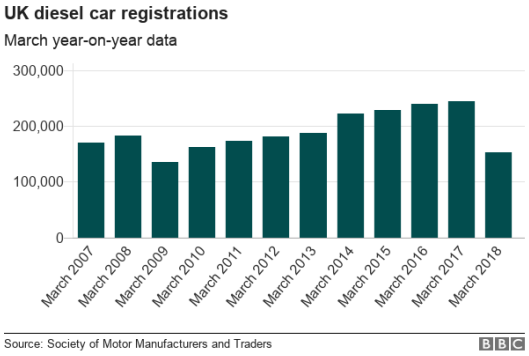
The solution utilises some of the latest Amazon Web Services (AWS) products and acts as an extension by taking the hugely capable cloud platform onto each connected vehicle. This has resulted in numerous technical, operational and financial benefits to Vantage Power and its customers.

VPVision is now offered as a standalone product with complimentary engineering services that enable customers to integrate their own products. Vantage Power find themselves in the highly desirable position of having a comprehensive technical understanding of powertrain components including engines, batteries, control systems, electric generators and motors, as well as bridging the gap to leverage AWS's latest cloud services. This has led to streaming data connections, big data analytics, machine learning and edge computing being employed on heavy-duty vehicles and delivering massive value in new and novel ways.

The challenge

The challenge presented today is no less than preventing millions of premature deaths and saving the planet. If you're to believe ~99% of health and environmental experts, the impact of transitioning to a low carbon economy and reducing harmful emissions is enormous. For the transportation sector this primarily means the electrification of vehicles.

As the demand for electric cars and light-duty commercial vehicles are growing, sales of fossil fuel variants, specifically diesel following the diesel-gate emissions scandal, is starting to decrease. The uptake in the heavy-duty vehicle sector, where reliability and cost are paramount, have predictably been more conservative, leaving some to be guided by legislation before making the change - but these legislation changes are happening now and coming into force.



For instance, by 2025 London and major cities around the world have promised to only buy zero-emission buses. Leading up to this, all vehicles in London's bus fleet will be upgraded to Euro VI standard by 2020, and all vehicles operating in the Ultra-Low Emission Zone will be either hybrid or fully electric. It doesn't just stop there, legislation will often demand hard proof to demonstrate requirements are being met, in many cases this can only be achieved through data collection and reporting. Traditionally dynamometer testing has been used to prove through life compliance, but it's falling out of favour due shortcomings in this approach that have been so dramatically exposed through the diesel-gate scandal.

The first part of the challenge is *legislation* compliance, but this will come in many flavours and deadlines.

The forebearer to electric powertrains is the internal combustion engine which has been established and fine-tuned over 100+ years to achieve its current worldwide adoption. But for electric vehicles, the transition and deployment is likely to be demanded in a much shorter timeframe – so the technology, operation and maintenance will have to mature much faster in comparison.

This rapid deployment is difficult, especially for battery manufacturers who are being asked to provide warranties for up to 10 years+ on what is essentially an unproven product. Lab tests can be conducted where batteries are put through their paces in accelerated lifecycle tests, but no testing is fully representative of a real-world deployment, and there is always a level of uncertainty when deploying a battery into service.

The second challenge is *time-to-market* – balancing legislative deadlines and staying ahead of the competition against the risk of fielding an immature product.

Reliability and cost are pretty high on the agenda for most heavy-duty vehicle operators. Newly developed electric powertrains and batteries are frequently deployed for extended periods when there isn't a great deal of historical performance data to reference and uncertainty resides over how

the battery will behave. Furthermore, the majority of expertise within the industries' support base and supply chain revolves around diesel engines.

In the process of electrifying heavy-duty vehicles, technical issues will occur and they'll have an impact on operations which can result in financial penalties. These technical issues will need to be responded to quickly, efficiently and with a solid solution that will last the course.

The third challenge is controlling *risk* – technical, operational and financial.

Thankfully the era of electrification has coincided with the worldwide availability of cloud computing platforms. This is a game-changer for electric-vehicle and battery OEMs and provides them with an incredibly powerful tool to address the challenges they face in a new technology era. With a well specified, well integrated telemetry platform combined with vehicle and powertrain domain expertise, new capabilities can be built at scale and data from entire fleets can be analysed to obtain new insights.

As cities get smarter, vehicles will be required to operate intelligently within their environment. The provision and consumption of energy is becoming increasingly important and the charging and second-life use of batteries needs to be smart. For all those reasons and more, OEMs need to be able to innovate quicker and without restriction. But typical obstacles to innovation remain, including:

- The product is deployed and there's a reluctance to change
- Maybe the idea is complex and will be too costly to test and validate
- The on-vehicle ECUs might not be sufficiently capable to run the required analysis
- Or the data needed does not reside on-vehicle and cannot be easily obtained

Not to mention, product development usually stops before a vehicle or powertrain leaves the factory gates because making a change in-service is too difficult or risky – with a capable cloud telemetry platform this is no longer the case.

The fourth challenge is to maximise the opportunities a cloud telemetry platform enables to *innovate* – using the platform to enhance your product offering and stay at the forefront of technology, even on an in-service product.

With the ability to comply with legislation and reporting requirements, bring new technology to the market faster, innovate even after the product has been deployed and doing this whilst balancing risk – an OEM is presented with many opportunities to deliver new valuable services to customers.

By changing the value proposition and looking to automated services in the aftermarket, OEMs can modify existing business models with the potential to become more competitive upfront and after sale.

Lastly, the final challenge is to exploit the possibilities provided by a cloud based telemetry platform to improve or create new *value streams* – to be price competitive and generate revenue.

Addressing the challenges - How can a cloud based telemetry system help?

The five challenges to successfully navigate the transition to electric heavy-duty vehicles are:

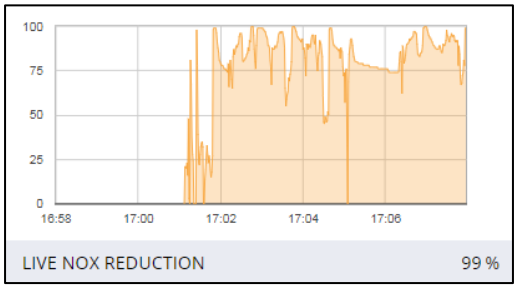
1. Compliance to legislation,
2. Quicker time-to-market,
3. Balancing the risk presented by less mature technologies,
4. Innovating,
5. Improving or creating value streams.

To address these challenges, Vantage Power's own AWS based telemetry platform VPVision has been deployed on its in-house heavy-duty powertrains. VPVision has also been implemented as a standalone product that is fitted to other vehicle systems and OEM products.

To demonstrate how the combination of VPVision and Vantage Powers battery, powertrain and vehicle-specific domain expertise can tackle the challenges, examples of existing applications and benefits are listed below:

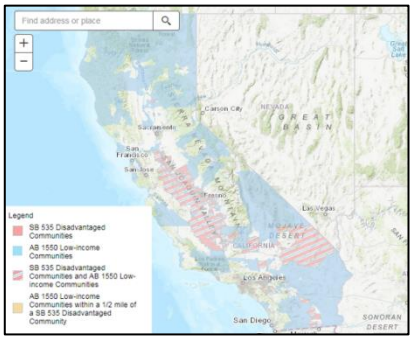
1.) Compliance to legislation

Legislation tends to come in various forms, different countries and regions introduce rules which can have broad implications across the powertrain and vehicle. Every new VPVision implementation comes with a comprehensive integration service, ensuring the right data can be obtained and interpreted. The platform spanning VPVisions back-end architecture and the on-vehicle equipment is incredibly flexible, ensuring that data can be processed and provided as required. Two examples include:



Example 1: Exhaust Gas aftertreatment systems are required to stream live nitrogen oxide (NOx) reduction data in compliance with the Transport for London (TfL) NOx abatement programme. By using the AWS IoT protocol, data collected by sensors at the tailpipe are presented on the VPVision web browser reliably within seconds of each reading, providing both a live read out and aggregated performance data.

Example 2: Geo-fenced performance reporting is used to comply with Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) to accelerate the update of cleaner vehicles in California. Detailed daily, quarterly and yearly performance reports from a large fleet of vehicles can be easily generated using AWS S3, demonstrating how vehicles performed in different geo-fenced areas of California.

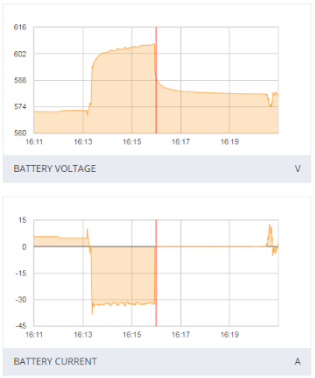


Due to the power and flexibility of the telemetry platform provided by VPVision, customers know that if new complex legislation and reporting is required, their future needs can be accommodated.

2.) Quicker time-to-market

As the industry transitions to electric, if heavy-duty vehicle OEMs are to secure a market position they need to introduce products in a timely manner. Vantage Power developed a brand new hybrid powertrain for double decker buses in London, this included the manufacture of lithium-ion batteries, and in 2017 as part of a pre-production trial it was deployed in to service. The battery pack had been prototyped, lab, track and road tested, although the design was mature, being passed to a new customer and entering service presented new challenges. Time for more testing had passed.

To support the trial, it was important to ensure the continued performance of the battery. Using VPVision, battery performance analysis and failure reporting direct from each vehicle was presented on a web interface, so a detailed status could be obtained at any time without having to visit the vehicle. If a fault did occur, it could be diagnosed before attending the vehicle which helped ensure a rapid and effective response — providing customers with excellent service and minimal down time.



Real-world vehicle utilisation provided valuable data from which edge case scenarios were identified and resolved and further development could be based. Even with the battery in-service product development could continue, and by utilising over-the-air software updates the reliability and performance of the battery was continually improving.

VPVision's live stream and log data ensured a superior level of service and support could be provided, allowing product improvements to be made quicker in response to real-world scenarios, and as a result, a faster time-to-market could be achieved. By using vehicle data in this way, it was possible to enhance and accelerate product development whilst still providing excellent customer support.

As OEMs push to bring new products to market and support the electrification of heavy-duty vehicles, this ability to monitor, learn and improve in-service equipment by making changes to software, hardware or maintenance routines, is critical. Ensuring this is done in combination with an excellent level of customer support is an incredibly powerful capability.

3.) Balancing the risk presented by less mature technologies

Whilst some issues can be fixed through software or hardware changes, there are other issues that cannot be completely resolved. Traditionally, these issues have been managed through vehicle inspection or servicing routines, resulting in a single component being replaced on a set rota or identifying an issue early on to resolve it.

Below are 2 examples of problems where it was not feasible to resolve them by making changes or conducting inspections, instead the risk of failure was managed very effectively using advanced analysis software developed using VPVisions architecture.

Example 1. Heavy-duty vehicle lithium-ion batteries are often constructed of many thousands of individual cells in series which generate high voltage. These cells can suffer a fault known as high self-discharge which is an undesired chemical reaction that reduces the stored charge and can occur for a variety of reasons. If this fault mode is left unresolved it can reduce the performance of the whole pack, effecting the vehicle operation which could result in a safety concern.

To address this problem, VP utilised the existing back-end architecture to develop a cloud-based machine learning model. By analysing billions of datapoints collected from a year of real-world driving, as well as 4 known instances of this problem occurring, the model was trained to detect high self-discharge 1 month earlier than the prior techniques allowed. With an additional months' notice, a targeted service intervention can be scheduled to resolve the issue before more serious faults occur. Highly capable software can perform analysis in the cloud which on-vehicle ECU's are not capable of running, ensuring the technical risks presented by the battery are spotted early and can be controlled.

Example 2. It's not all about the battery. As heavy-duty vehicles transition to electric, mechanical components such as pressure relief valves will continue to be used in cooling circuits, pneumatics and other ancillary systems. Some pressure relief valves are calibrated at the point of manufacture but their set point can drift with time and use. If a set point drifts too close to the operating pressure, it's possible that it will activate more frequently or even start to oscillate. When a relief valve activates, the sudden release of pressure can transmit shock waves through mechanically connected devices leading to accelerated wear and premature failure.

In response to this issue, VPVisions back-end architecture was again used to develop a model that can detect pressure spikes caused by a relief valve activation. By monitoring the frequency and magnitude of the spikes, the severity of the problem was categorised across a fleet and preventative service interventions were scheduled, if necessary. Once developed, the model was pushed to the edge using AWS Greengrass, to be executed on-vehicle, reducing data transmission and compute costs in the cloud. By operating on-vehicle and communicating directly with the vehicle controller, the commanded operating pressure can be lowered automatically, within safe limits, in response to a problem being identified. This means the vehicle can automatically enter a damage limitation mode of operation, reducing the likelihood of a failure before a service intervention is performed.

It's possible to prepare for some technical issues during a product development phase, but not all. If technical problems do occur in-service and cannot be permanently fixed, they can be very effectively managed by using the capabilities provided by VPVision.

The severity and risk presented by different issues can be understood remotely and in real-time for an entire fleet, allowing analysis and any decision making to be automatically triggered for a service intervention, or used to command the vehicles to enter a damage limitation mode, thus enabling

technical risks to be addressed quicker and more accurately – creating a huge advantage when deploying new technologies.

In response to emerging problems, VPVision's architecture provides an ideal mechanism to develop, validate and deploy new analysis techniques which could ultimately become a new vehicle fault code or prognostic alarm. If the analysis to too complex or not well suited for on-vehicle ECU's, its execution can reside in the cloud, or by using AWS Greengrass, it could be deployed directly to the edge.

This capability increases the ability to manage technical risks, meaning that the associated operational risks and financial risks can now be more tightly controlled.

4.) Innovating

VPVision's back-end architecture provides the perfect environment and toolset for stimulating innovation and developing ideas through to deployment. Large quantities of real-world operational data can now be used to simulate the effectiveness of new code, whilst being tested on live data streams from in-service vehicles in parallel. This process can happen virtually, before making a single change to any equipment. Testing code in this manner is representative, ensuring high-quality, and presenting zero risk to the vehicle, substantially reducing cost when compared to orchestrating a specific testing programme.

This process has been used to improve the energy efficiency of in-service vehicles. As an example of Big data analytics, after gathering years' worth of real-world driving data from multiple vehicles, a model was developed to find operational inefficiencies and identify how the vehicle control software could be more energy efficient. As a result, an iterative approach was taken to modify the control laws and measure the efficiency gains by using the historical data to run simulations. Once the required improvement was achieved an over-the-air software update enabled changes to be deployed quickly and cheaply to in-service vehicles, creating a step change in energy efficiency across the fleet.

Following a similar process; to ensure lithium-ion batteries remain in good health it's important to keep them balanced, this requires the battery to be in the correct state, at the required charge and for a sufficient period of time. A model was created to automatically analyse each vehicles schedule and utilisation to identify the ideal time and location for balancing. When each vehicle approached their designated location the mode of operation changes so the target state of charge can be reached by the time the vehicle is parked. With the required conditions met, the balancing will automatically start so that it has the best opportunity to complete before service resumes. This innovation was developed in the cloud and tested on live real-world data, making sure it was optimised and validated before deployment.

The scope to innovate and create changes in the cloud is huge. Whether it's a performance improvement, fault management improvement or a brand new capability, the manner in which code can be developed, tested, deployed and scaled at low risk and low cost is truly immense.

New data and software driven innovations will be required for heavy-duty vehicles to successfully transition to electric and allow them to be become integrated with their environment. In many cases, these innovations will require technical powertrain data and off-vehicle or 3rd party data to be correctly interpreted and used in conjunction. Vantage Powers vehicle specific domain expertise and VPVisions cloud based telemetry platform provides a powerful combination and the perfect environment to see new ideas successfully launched.

5.) Improving or creating value streams

All the examples described in this document represent new opportunities for electric heavy-duty vehicle OEMs:

- Complying with legislation to open up new markets,
- Getting new technology to market faster and developing a superior product based on real-world data,
- Managing technical, operational or financial risk so that warranted products can deliver a more reliable and efficient service,
- Or creating, innovating and augmenting product streams with new services and capabilities.

The opportunity to create value through a capable telemetry platform is substantial. An OEMs existing aftermarket service and support proposition will be able to reduce costs by performing remote diagnostics, automating and identifying warranty infractions, pre-scheduling service interventions, and introducing fault prognostics – these can all be delivered by VPVision today and VP is only scratching the surface.

Whether it's preventing over servicing of vehicles, automating operations, streamlining the supply of replacement parts, improving product performance, over-the-air software updates, extending the operational life of a battery, implementing geo-fenced speed limits - value can be created from data-driven services, allowing OEMs to modify existing business models to become more competitive.

As an OEM makes the leap to electric heavy-duty vehicles, whether they are a vehicle, driveline or component supplier, they need to address the challenges presented. With access to advanced telemetry platforms such as VPVision, and battery, powertrain and vehicle-specific domain expertise offered by Vantage Power, there are highly capable options available today to ensure OEMs can remain competitive on price and technology.

In conclusion, existing products, services and technology roadmaps can benefit greatly from the introduction of artificial intelligence, edge-computing to big data analytics - creating new services and revenue streams for today's world; delivering real-value to keep OEMs at the forefront of technology for years to come.