National Motor Vehicle Theft Reduction Council

Stored Vehicle Data

A review and assessment

September 2021

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Informing Australia on vehicle crime.

Report outline

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1. Executive Summary

About This Report

Increasingly, it is being recognised that data stored by connected modern vehicles may be of significant value for law enforcement and vehicle crash investigators to better understand what happened, where it occurred, and who was involved. However, despite the obvious benefits, use of the technology in Australia is still in its infancy.

An independent assessment of what data is available and its utility for crime and insurance investigations will assist stakeholders to make an informed decision on the value of investing in related technology and training.

This report is designed to provide insight on data generated by vehicles, particularly with respect to what data can be retrieved, how it is accessed and what usefulness it has for investigators. It provides for present-day practices but also discusses the future and the role that both IAG and the NMVTRC can play in helping to shape it.

The report begins by explaining concepts such as on-board diagnostics and 'bus systems', as well as simplifying some of the technical jargon associated with this subject, especially in reference to mechanical, electrical, and computing terminologies.

We then provide an overview of the numerous devices that can assist in the data extraction process, compare some of them, and explore some of the implications surrounding future data privacy policies, legalities, and the lack thereof. ECU chip tuning is also covered and can be found in the appendix.

Background

Vehicles produce masses of diagnostic data to monitor and regulate vehicle behaviour. This data is generated by numerous control units stationed all over and inside the vehicle, in some cases, they can number over one hundred. This data can help determine speed, direction, pressures, and temperatures, and are often inputs for driver assistance systems.

Specific and highly important data is recorded and stored in an event data recorder (EDR) whenever a significant event occurs, usually resulting in an accident. A German-based company, Bosch, is currently the leader in producing toolkits that can access, retrieve and interpret this data into something meaningful and easy for a person to understand.

Late model cars also process large quantities of data outside of traditional vehicle diagnostics. This modern data includes Global Positioning Systems (GPS), connected devices (phones, tablets, etc), and vehicle activity logs not captured by the EDR. Although this data is being captured, accessing, retrieving, and interpreting it can be a complex task.

A US-based company, Berla, is currently the leader in the field of producing toolkits that can do just that. The relatively expensive toolkits may discourage investigators or agencies from being able to justify the benefit, which is one of the aims of the project to determine. This is an area the report will encompass in the next iteration as we have not been able to physically test any toolkits yet, however the plan for this is outlined later in the report.

ECU chip tuning may also be of interest to investigators. It can severely affect the power and handling of a vehicle and may help determine what contributed to an accident. Detection of ECU tuning is still in its infancy, but some European countries are using it to test a vehicle's emissions compliance. In this document, we explore how it might hinder crash investigations.

Some of these aftermarket products do not intercommunicate with the vehicle's existing systems or allow for accurate diagnostics and troubleshooting. They have not been tested for road use, are not compliant with manufacturer's specifications, and could mean that there is an underlying problem with the vehicle that remains undetected.

We aim that by the end of the final report, the reader will gain a better understanding of the range of stored vehicle data available, potential uses for it, a perspective of usefulness in terms of cost-benefit analysis, and increased awareness and preparedness of present and future trends.

Key Learnings (June 2021 update)

The main focus of the data that is retrieved by the tool is in relation to acceleration and braking forces, and the changes in velocity that are being applied to the vehicle. There is other valuable information as well, such as seat belt status, seat track positions and ignition cycles, but the real focus is about vehicle movement and delta-v.

The data provides for the enablement of crash reconstruction and fraud detection and can be analysed in conjunction with any physical damage to the vehicle to determine what happened in an incident. Strong analytical skills need to be applied to the data to deliver the most accurate findings.

Testing of vehicles provided us with some valuable insight about the variance in what data is collected and displayed, depending on make and model. The same set of government-mandated data exist across the board, but manufacturers can opt to include additional data which accounts for the variance.

One idea for a future project is to construct a database of which vehicle makes and models collect that extra data, which could be valuable to an investigation, and encourage manufacturers that only provide the minimum stipulated, to do the same.

Another idea is to collaborate with Bosch to produce a toolkit that interprets the extra data that gets captures (but not shown in the CDR report) for investigation-specific purposes, for example, if it is possible to capture whether driver-assistance systems were functioning correctly at the time of an accident.

This project has allowed us to understand the components of the vehicle better, and learned how software is applied to allow for increased understanding when an accident or collision occurs. The Bosch CDR toolkit can be useful to police and insurance investigations in helping to reconstruct a scene from five seconds prior to the incident with a variety of reliable data sets.

2. OBD and Bus Systems

2.1 OBD Past

On-board diagnostics, or OBD, refers to a vehicle's ability to perform self-diagnostics and generate meaningful data to inform an owner or repair technician of issues or potential problems. Think of it as a status report for all the major sub-systems within a vehicle, accessible at any given time.

OBD took off in the 1980s as vehicles begun to use more computer systems and sensors. The first systems developed were used for emissions control purposes. The problem with early designs was a lack of any standardisation among manufacturers, meaning all different makes and models required an assortment of adapters in order to work, or in some cases, expensive dealer scan tools.

By the late 1980s, the Society of Automotive Engineers (SAE) proposed a standard diagnostic connector and set of standard test signals, but it wasn't until the mid-1990s that it is incorporated into a new specification, called OBD-II. This specification was made mandatory in the US in 1996, the EU followed suit in 2001 (for petrol vehicles) and 2004 (for diesels), with Australia and New Zealand joining in 2006.

As of 2008, all cars sold in the US are required to use the ISO-15765-4 signalling standard, which is a variant of the Controller Area Network (CAN) bus. The term "bus" is in reference to the type of topology the network is modelled after, like how a bus route is a closed circuit, or loop, and the bus follows the same path over and over. This is the same way messages are sent in a bus-type network topology.

2.2 OBD Present

In Japan, they use JOBD for vehicles sold in Japan, and whilst no standard is mandatory, they add OBD-II support for vehicles being shipped to countries that require it.

In the EU, they use the European on-board diagnostics standard (EOBD), which is equivalent to OBD-II. It uses the same SAE J1962 diagnostic link connector and signal protocols.

ADR (Australian Design Rule) 79/01 is the Australian equivalent of the OBD-II standard, applicable from 2006. This standard was supplemented by ADR 79/02 which imposed tighter emissions restrictions, from 2008 for new models, and 2010 for all models. It implements the same SAE J1962 diagnostic link connector and signal protocols as the OBD-II standard.

OBD-II provides access to ECU data which makes troubleshooting a far easier process. OBD-II specifies the diagnostic connector, its pinout, the signalling protocols, and the messaging format. It also provides a list of diagnostic trouble codes (DTCs) which contain 1 letter and 4 numbers, and are divided into the following categories:

B - Body Code

C - Chassis Code

P - Powertrain Code

U - Network Code

The SAE J1979 standard defines the process for requesting diagnostic data and a list of standard parameters available from the ECU, known as parameter identification numbers (PIDs).

Lists of available PIDs, their definitions, and formulas for converting raw output to meaningful data can be found online and not deemed necessary for inclusion into the report at this stage. It is important to note that manufacturers are not required to implement all PIDs listed in J1979 and are permitted to include proprietary PIDs that are not listed. The benefit of this kind of request-and-retrieve system is that it provides access to real time performance and DTCs.

There are five signalling protocols allowed with OBD-II, with the Bosch-developed CAN protocol (ISO-15765) the most widely adopted. The need to discuss them all in depth is not within the scope of this report.

2.3 OBD Future

There has been discussion of a plan for OBD-III, although nothing has been formalised by any regulatory body or manufacturer at the time of printing.

One such inclusion could be by using a small radio transmitter, vehicles would be able to communicate directly to regulatory agencies or manufacturers. An example of how this technology could work would be like driving through an electronic toll booth, but instead of a microtransaction taking place, the VIN and any fault codes present at the time would be transmitted.

A possibility is that OBD-III becomes completely wireless, which removes the plug and places tighter controls on who can interface with the vehicle, and in what capacity. In this system, non-cosmetic differences between vehicle variants, for example the difference between a base model and the top-spec model, can be applied via over-the-air updates. In effect, this allows a manufacturer or dealership to turn on or off features through the cloud, some of which already occurs today. The problem is, what if the update was malicious or harmful? Hundreds of thousands of lives could be at risk at once.

Whilst this may be a cost-effective solution for regulators, and especially of fleet managers, it has the potential to raise serious questions from motorists who may feel that constant monitoring is a form of surveillance or an invasion of privacy. Privacy is to be at the forefront of conversations when it comes to the implementation of systems that are to be applied en masse (more on that later).

With government policy tracking towards reduced emissions and a reduction in carbon footprint, this type of monitoring system could also help reduce the amount of pollution produced by road vehicles. As soon as a vehicle is detected by the system of exceeding emissions limitations, the owner or operator is notified that their vehicle in non-compliant and needs to be fixed within a period. Not only will this help to reduce carbon emissions, but it will also improve air quality, especially in high density areas.

A caveat to this tracking ability is the reporting of driving behaviour to insurance companies or law enforcement agencies. Speeding, heavy braking and cornering forces all have the potential to be recorded and where maximum values are exceeded, could be flagged and sent to these agencies for review or action. Further to this, tighter controls on vehicle behaviour could be enforced, for example, the limiting of a vehicle to travel a certain speed in a particular area or environment. Fines could be handed out to drivers that speed and insurance polies can increase based on driving behaviour. Whether or not this is a good or bad thing is yet to be debated and decided upon by our society.

One benefit to the consumer could come in the form of a financial cost saving if vehicle registrations and car servicing can be tied into this system. It could significantly affect the need and pricing of these services as the health of the vehicle is under constant monitoring. Maintenance checks would be performed by the system itself and so servicing and repairs can occur as-needed, rather than as-recommended by the service guide. This is a tailor-made solution applicable to each individual vehicle, which becomes vastly more efficient over time.

The success and implementation of such a system would depend on correctly balancing the cost savings to motorists, and, the rights of governments or private enterprises to track, monitor and modify the consumer's vehicle. For Australia, the National Transport Commission (NTC) has started in 2017 the development of an end-to-end regulatory framework for connected and automated vehicles that will address the use-cases and challenges outlined above. A section at the end of this reports will delve a little deeper into these details and outline the opportunities and chances to participate into this process for the NMVTRC.

2.4 Bus Systems

Bus systems are differing methods for communication, in our case, intra-vehicle communication. To help understand the relationship between a bus and OBD-II, think of OBD-II as a language and the bus as a telephone. Some popular bus systems are explained in the section below.

Controller Area Network (CAN)

CAN was developed by Bosch in 1983 and officially released in 1986. It became ISO 11898 in 1993 and has gone through several revisions. It is one of the five OBD-II communications standards.

It has the combined benefits of being low cost, simple, robust, centralised and efficient. CAN frames are processed on priority and are well shielded from electromagnetic interference, making it a great choice for safety-critical applications.

CAN does not offer support for security features or encryption, which leaves networks open to man-in-the-middle interceptions. In some cases, passwords are used for some safety-critical functions, such as modifying firmware, or programming keys, but have a limited number of seed/key pairs and are not very robust.

OBD-II is an example of CAN utilisation within modern vehicles. CAN has found usage outside of vehicles and has been implemented in agricultural machinery, aviation equipment, elevators, escalators, medical instruments, e-bikes, model railway sets, and EV batteries.

FlexRay

FlexRay is a communications protocol, designed in the mid-2000s, to be a faster and more reliable automotive computing system than the popular CAN bus system. It addresses some of CAN's limitations by upping the speed from 1Mbps to 10Mbps, while the payload size goes from 8 bytes to 254 bytes.

But with the increase in speed and reliability came an increase in costs, this being one of the reasons why it still hasn't been widely adopted.

One of the key features of FlexRay is the ability to have two independent data channels, thereby increasing fault-tolerance significantly. This means that it can be utilised outside of the traditional "bus" topology and can be used in a "star" topology, which gives it unique applications. The increased bandwidth also makes for very good use in safety-critical areas of the vehicle.

It was developed by the FlexRay Consortium, which consisted of car manufacturers BMW, Volkswagen, Daimler and General Motors, as well as Bosch, NXP, and Freescale. Although the Consortium was disbanded in 2009, FlexRay has since become a set of ISO standards (17458-1-5).

Today there are a small range of (mostly German) vehicles that have used or continued to use FlexRay.

Local Interconnect Network (LIN)

LIN is a network protocol used primarily for communication between components.

The LIN Consortium was founded in the late 1990s by Audi, BMW, Mercedes-Benz, Volkswagen and Volvo, with the first fully implemented version arriving in the early 2000s. It has since been made into a set of standards (17987).

It is low cost and operates at speeds up to 20Kbps. This makes it useful for non-critical applications where bandwidth is not important and allows for cost savings. Modern uses include operation of lights, sunroof, indicators, wipers, cruise control, radio, climate control, occupant sensors, electric windows, and door locks.

Ethernet

With speeds of up to 1Gbps, and cheaper to implement than FlexRay, Ethernet is looking as a decent option within the future of vehicle communications. The downside is a lower fault-tolerance but provides a good level of quality to bandwidth intensive, non-critical applications. It is also somewhat simpler to implement (complexity).

An example of this is BroadR-Reach, developed by Broadcom Limited and supported by the OPEN Alliance SIG (comprised in part by Broadcom, BMW, Hyundai, Harman, and NXP). OPEN is an acronym for open-pair-ether-net. OPEN Alliance encouraged the use of automotive Ethernet by establishing BroadR-Reach as an open standard for members in 2011.

It is known today as 100BASE-T1 since standardisation by the IEEE (Institute of Electrical and Electronics Engineers).

Data generated by autonomous vehicles (AVs) is set to skyrocket over the next decade, especially in the realm of vehicle-to-everything (V2X) environments, and bringing with it a need to handle large amounts of data (estimates vary but current test vehicles produce between 10 and 150 TB of data per day).

A big downside to increased connectivity is an increase in cyber security threats. As the industry begins to shift towards automotive ethernet (in whatever capacity that is), it must be diligent in its approach and involve well thought-out strategies at all layers – architecture, protocols and applications.

It is a time of tremendous opportunity, but failure to plan and implement effective security strategies correctly could have catastrophic consequences in the not-too-distant future.

3. Main Components

3.1 Modules

Engine Control Unit (ECU)

The ECU is the controlling unit for a vehicle's internal combustion engine (ICE). It has the responsibility of monitoring and maintaining optimal performance by communicating with a range of sensors and adjusting actuators to regulate engine behaviours such as idle speed, air-fuel ratios, and variable valve timing (VVT).

In many cases after engine modification have taken place, the stock ECU will need to be remapped or replaced, especially in the cases where a turbocharger or supercharger had been added, but also for exhaust, transmission, spark plugs, and fuel injection upgrades or additions.

The ECU is found in a multitude of locations. This can range from behind the passenger side dashboard, under the wipers, behind the centre console, in the engine bay, near the fuse box, behind the glovebox, near the battery, under the passenger footwell carpet, and more. If access is required, it is best to look up the make and model beforehand.

Figure 1: Example of an aftermarket ECU.

Cook Motorsports Performance Package. Retrieved from https://cdn-ds.com/media/sz_43682/Backgrounds/tcu.png

Body Control Module (BCM)

The BCM is a term applied to an ECU that controls a variety of different electronic accessories, such as lights, wipers, electric windows, electric mirrors, climate control, central locking system, immobiliser and more. The BCM can be thought of as the brain that controls parts the body by sending and receiving signals via the nerves (the CAN bus).

It communicates with the other various computers using the CAN bus network and handles the inter-communication that occurs between ECUs throughout the vehicle, acting as a kind of gateway. Importantly, it also controls the battery management system so there is an order of precedence and the flow of power is regulated.

The BCM is typically located under the dashboard. Access is gained after removing the outer trim. As each vehicle is different, it is always best practice to consult the owner's manual beforehand.

Figure 2: Example BCM from a Holden Commodore.

Body Control Module VZ sedan. Retrieved from https://www.speedspares.net/assets/alt_3/92176587.jpg?20171030164406

Airbag Control Module (ACM)

The ACM is not just responsible for deploying airbags, in fact it monitors a variety of different sensors around the vehicle including accelerometers, gyroscopes, impact sensors, pressure sensors, wheel speed sensors, brake sensors and seat occupancy sensors.

Data is constantly being recorded and stored in non-volatile memory (NVM), meaning if power is lost, a copy of the memory remains intact. It is this data is what is being accessed during the process of crash data retrieval (CDR). The report will explore the stored data in greater depth in later sections.

Generally, the ACM is found underneath the driver's seat and data can be obtained by direct connection to the module, however, in most instances the easier option is via the OBD port.

It is confusingly known by many different names and acronyms, such as Restraint Control Module (RCM), Powertrain Control Module (PCM), Sensing Diagnostic Module (SDM), Occupant Restraint Control (ORC), Airbag Control Unit (ACU), Advanced Crash Safety Module (ACSM), Centre Air Bag Sensor (CABS), and more.

Figure 3: Example ACM from a BMW.

BMW 1 Series Airbag Control Module. Retrieved from https://eurocarupgrades.com.au/media/catalog/product/cache/1/image/9ec63c2d20e0991af854747bc528d670/a/i/airbag_module_bmw_65.77-9240083-02_31924008301z_2_.jpg

3.2 EDR Standards in the US and Europe

United States

The National Highway Traffic Safety Administration (NHTSA) announced their intent to standardize EDRs in 2004, with a ruling finalised in 2006.

Since EDR installation was already occurring voluntarily, the ruling did not make it a requirement for manufacturers to install EDRs for North American vehicles, but warned that if the trend did not continue, they would revisit the decision.

It did however provide a minimum standard for at least 15 types of crash data that EDRs would be required to record. Included in this was pre-crash speed, engine throttle, brake use, changes in velocity (Delta-V), seat belt use (driver only), ignition cycle data, airbag status and airbag deployment times.

In addition, the NHTSA also set the standards for 30 other types of data for manufacturers that were voluntarily configuring EDRs. As an example, if a manufacturer configured an EDR to record engine RPMs (which is outside of the standard 15), then the EDR would have to record 5 seconds of pre-crash data in half-second increments.

The NHTSA also made the requirement that all data be able to survive a 30 mph (48 kph) crash and still be measured with defined precision. It also stated that all manufacturers make their EDR data publicly available "to ensure the commercial availability of the tools necessary to enable crash investigators to retrieve data from the EDR".

By 2009, only General Motors, Ford and Daimler Chrysler had released their EDR data to be publicly read, with the date for compliance set for the following year. In 2014, it was working on an update to give manufacturers until 2014, but it was never issued.

European Union

EDRs will soon be mandatory in the EU as a package of increased safety measures in the General Safety Regulation (GSR), approved by European Parliament in 2019. The new EU regulation will require an EDR to record more parameters than the current US regulation. The requirements for EDRs are mainly aimed to collect data for research, rather than for crash reconstruction purposes.

EDR requirements assume the data shortly before, during and immediately after a collision shall include the vehicle's speed, braking, position and tilt of the vehicle on the road, the state and time lapse of all safety systems, automatic 112-based eCall in-vehicle system (000 emergency call in Australia), brake activation and input parameters of accident avoidance systems, with high level of accuracy and ensured survivability of data.

The new regulation will also require all new vehicles to be fitted with Advanced Driver Assistance Systems (ADAS). These ADAS regulations will apply to Light Commercial Vehicles (LCV), such as cars and vans, and Heavy Vehicles (HV), such as trucks and buses, in the following ways.

- Advanced emergency braking (AEB) systems, LCV only.
- Alcohol interlock installation facilitation, LCV and HV.
- Drowsiness and attention detection systems, LCV and HV.
- Distraction recognition and prevention systems, LCV and HV.
- Event data recorder (EDR) systems, LCV and HV.
- Emergency stop signal (ESS) systems, LCV and HV.
- Full-width frontal occupant protection crash test improved seatbelts, LCV only.
- Head impact zone enlargement for pedestrians and cyclists, safety glass in case of a crash LCV only.
- Intelligent speed assistance (ISA), LCV and HV.

- Lane keep assist (LKA), LCV only.
- Pole side-impact occupant protection, LCV only.
- Reverse camera or detection system, LCV and HV.
- Tyre pressure monitoring system (TPMS), HV only.
- Vulnerable road user detection and warning on the front and side of the vehicle, HV only.
- Improved vulnerable road user visibility from the driver's position, HV only.
- New light vehicles, such as cars and vans, have until 2022 to comply (after the entry into force) and all new registrations have until 2024. Heavy vehicles, such as trucks and buses, have until 2026.

EDR vs CDR

An event data recorder (EDR) is a device installed in a vehicle that allows for the recording of data in the event of an accident occurring. They are developed by OEMs and are mandated by governments around the world. Usually they will be found integrated within the Airbag Control Module (ACM).

Depending on the type installed, some EDRs continuously record and overwrite data, while others only begin recording once a specified condition has been met, for instance, a dramatic change in velocity. Sometimes during an accident, the vehicle suffers from complete power loss, meaning the reserve power stored in capacitors will be used to deploy airbags, resulting in no power left to write any data. Modern EDR systems can produce 8-10 pages of crash data information.

Crash Data Retrieval (CDR) is a toolkit or process that enables the extraction of EDR data, which can help provide facts about the state of the vehicle in the seconds surrounding an accident or significant event. They are developed by OEMs or third parties, with a variety of different toolkits existing today, a range of which will be covered in this report.

In terms of looking towards the future, some regulators consider EDRs as a feature for conventional vehicles, whereas autonomous vehicles (AVs) should have Data Storage System for Automated Driving (DSSAD). Currently, EDRs aims to assist in accident analysis alone, while DSSADs could be utilised for research, monitoring, liability, and legal responsibilities.

4. Stored Data Available

4.1 Data Overview

Below is an outline of the types of data available as well as their potential usefulness. This is not an exhaustive list but provides good examples for the purposes of understanding the breadth of the analysis.

Most of this data is seen to be captured as part of the CDR report, as seen in appendices 10.5 and 10.6. The data elements required, plus the date format required (stipulated from the US Code of Federal Regulations 2011) are provided in tables 3 and 4, in section 6.3.

Engine Revolutions

The number of complete revolutions made by the crankshaft every minute (abbreviated to RPM). It is basically a measurement of how fast the engine is operating at a given point in time.

This information can be used to tell you what kind of load the engine was under at a point in time. A very high number over a prolonged period could suggest a mechanical failure, faulty sensor or an unknown driver input error.

Throttle Position

The throttle position sensor (TPS) is used to ensure a correct mix of fuel and air and controls the airflow into the intake manifold. A faulty or broken TPS can result in engine misfires or stalling.

This information can be used to tell you whether the car may have had a failure that contributed to an accident.

Wheel Speed

The wheel speed sensor reads the speed of the wheel's rotation, per unit of time. It sends this data to the ECU which then uses that information to calculate the correct amount of force to apply to the anti-lock braking system (ABS). It is also used in other driver assistance systems such as traction control systems (TCS) and electronic stability control systems (ESC).

This information can be used to determine if one or more driver assistance systems were being fed with accurate data, and if faulty readings were the cause or contributor of an accident.

ABS Status

The anti-lock braking system prevents the wheels from locking up during braking, therefore ensuring tractive contact to the road surface is maintained. Usually this will simply be shown as on or off.

This information can be used to determine if the ABS was working at the time of an accident. Failure of this system can often have catastrophic consequences. There have been recent examples of manufacturer recalls regarding ABS, so it would be of value to know if the vehicle involved was unknowingly affected.

Vehicle Identification Number (VIN)

The vehicle identification number (VIN) is a unique identifier for a specific vehicle, as such, no two cars will ever share the same VIN. VINs have been standardised by the ISO since the 1980s.

This information can be used to tell you what make and model the car is, where it was manufactured, standard equipment installed, whether it has been in any serious accidents in the past, and if any money is owing on the vehicle. A lot of useful information can be derived from the VIN alone.

Delta-V Maximum/Over Time

Delta-V is a term used to describe the severity of an accident. It measures the total change in vehicle velocity throughout the duration of a crash. The range of measurements is -100km/h to +100km/h.

This information is typically used to measure impact severity, however Delta-V can be difficult to estimate in many cases, particularly sideswipes and angled side impacts, and often given a wide margin for error.

Recreating the damage on components and comparing results is a much more accurate method to predict the force of an impact.

Drive Mode

Drive mode settings can change the way the vehicle behaves by altering components such as engine, gearbox, suspension and steering. The three most common drive modes are Normal, Eco and Sport.

Eco stands for economy and restricts engine and transmission performance in favour of fuel saving. Sport mode does the opposite, with various makes and models also disabling some driver assistance features.

This information can be used to determine the car's characteristics before a crash event. Information such as how much power was available and which driver assistance settings were disabled, particularly in high performance vehicles, can be of high value in determining contributing factors to a crash.

Gear Selected

This will show which gear the vehicle was in over the elapsed period, namely, P (park), R (reverse), N (neutral) and D (drive, or 1,2,3,4,5,6).

This information can be compared to vehicle speed at the time to determine how much load the engine was under. For example, if a vehicle was doing 80km/h in 5th gear, the engine is under less load than one doing 80km/h in 2nd gear. It can also be useful in determining if a car was stationary at the time of impact.

Seatbelt Status

This will simply show whether the seatbelt was buckled or unbuckled at the recorded time.

This information can be used in several useful ways. The first being to simply check seatbelt status to help assess injury severity. The next way would be to check seatbelt status against occupancy status to further assess injury severity, but also to detect fraudulent claims. Seatbelt bruising post-accident can also be used to assess occupancy positioning.

Occupant Seat Status

This information will show whether the seats in the vehicle were occupied or unoccupied at the recorded time. Depending on the make and model, each of the seats will have a weight-triggered sensor to determine occupancy. In some circumstances, a false positive can be triggered by a pet, heavy bag of groceries or similar.

This information may be used to determine the number of occupants which could assist in police investigations. It may also be used to uncover fraudulent injury claims, in the event the driver was the only person in the vehicle at the time of impact.

Driver Seat Position

Indicates the recorded seat track position. In some makes and models, the driver stores their preferences in a profile (sometimes linked to the key fob) and the adjustments are made automatically by the vehicle upon entry.

This information may be used to determine an approximate height of the driver, based on the seat position relative to the pedals and mirrors. Using mirror position it can also determine road vision. It may also be used to assess if injuries are consistent with the data.

Airbag Deployment Status

This will indicate which (if any) of the airbags deployed (front/side). A deployment summary will show the differences in time and order of each airbag deployed.

This information can be used to help determine the severity and order of impacts in an accident and help to complete the picture in crash reconstructions. It can also be used to indicate a fault in deployment in the case of injury assessment. A recent example of where this can be useful is the Takata airbag recall.

Vehicle Speed

Calculated using a combination of vehicle sensors and formulas but provided by the ECU. Has a range between 0-200km/h. Maximum value will simply show as >200km/h.

This information can be used to determine if speed was a contributing factor in an accident. It can also help to prove fault, identify fraudulent claims, assess crash severity, assess injury severity and help determine any mechanical or electrical faults.

Accelerator Pedal Position

This shows the applied position of the accelerator, represented as a percentage (0-100%).

This information can be used in combination with other data to determine driver actions before a crash, for example, unintended or accidental pedal application, and will also help to uncover if a mechanical or electrical fault was responsible, for example, unresponsive or stuck pedals.

Brake Pedal Position

This shows the applied position of the brake, represented as a percentage (0-100%).

This information can be used in combination with other data to determine driver actions before a crash, for example, unintended or accidental pedal application, and will also help to uncover if a mechanical or electrical fault was responsible, for example, unresponsive or stuck pedals.

Hand Brake Position (also known as Emergency Brake)

Often exists as a hand operated lever near the steering column, although in newer vehicles it is increasingly more common to see it exist as an electric or push button. In short, it connects to a cable that applies brakes to the (usually) rear wheels. If applied while in motion it will lock the brake, reducing traction and becoming much harder for a driver to maintain control over.

This information can be used to tell if the hand brake was applied while in motion, which could become a determining factor in an accident investigation. It can also be used to assess whether the brake was applied in the instances of hill-start collisions, roll-back collisions or to determine if a vehicle was parked at the time of a collision, which could help to prove fault.

ESC Status

Electronic stability control (ESC) improves vehicle stability by monitoring traction loss. When it detects losses in steering control, it automatically applies brakes to individual wheels to help “steer” the vehicle in the intended direction. Some systems also temporarily reduce engine power until control is regained. It became mandatory in all new vehicles in Australia in 2013.

It relies on the data from many sensors in the vehicle, namely, the steering wheel angle sensor, yaw rate sensor, lateral acceleration sensor, wheel speed sensor, longitudinal acceleration sensor, and roll rate sensor.

Due to the effectiveness of this system, this information can be used to determine the stability of a vehicle under the conditions at the time. Many vehicles allow the driver to turn this system off just by pressing a button, so it would be important to assess whether this system was active at the time of an accident. If not, then the likelihood of it being a contributing factor to an accident is high.

It might be important to note that under extreme conditions, such as heavy snow or ice, the ESC can prevent the vehicle from moving and so may be required to be switched off temporarily in order to put the vehicle in motion.

Steering Wheel Angle Sensor

This sensor determines where the driver wants to steer, or their intended direction. It is one of the major components in the ESC and is designed to last for the entire life of the vehicle. The sensor is basic in nature, usually comprised of an LED that measures the steering angle input.

This information can be used to determine if the sensor was faulty and may have provided misinformation to the ESC system. It can also be used to provide an indication if the driver swerved before a collision, which may be useful in assessing staged crashes.

Lateral/Longitudinal Acceleration Sensors

Lateral acceleration sensors measure the sideways direction of a vehicle. It can be experienced as a centrifugal force are acting upon it during cornering where the vehicle is pushed to the outside of a corner. Longitudinal acceleration sensors measure the rate of change in velocity, i.e. front-ways acceleration and deceleration.

Data generated is fed back into driver assistance systems to calculate the actual direction of a vehicle.

This information can be used to plot a vehicle's path in both lateral and longitudinal directions, which becomes a very useful tool in crash reconstructions. It may also give clues as to potential causes of an accident or scenario.

Roll/Yaw Rate Sensor

A type of gyroscope that measures a vehicle's angular velocity around its vertical axis. It provides information to the ESC system by helping to determine the slip angle of the vehicle. This is the angle between the direction the wheels are pointing and the actual direction it is travelling, the result of which is the cornering force.

This information can be used to determine if oversteer or understeer played a part in the behaviour of the vehicle before or during an incident. The sensor is also used in the prevention of vehicle rolling, so a broken or faulty sensor can lead to an increase in accident severity.

Odometer Reading

Duplicates of the vehicle's mileage are stored on several ECUs across the vehicular network. This approach has been chosen to prevent odometer manipulation or at to at least increase the difficulties to do so.

Headlight and Indicator Status

In vehicles the overall hours the headlights have been operating is stored, as well as the status. This can help determining whether a vehicle had the lights on at night, was indicating during a turn or if the brake lights lit up.

Connected Device Data

Whenever a device is connected to the vehicle (phone, tablet, computer, USB, etc), a data transfer occurs in which multiple pieces of information are then stored permanently within the vehicle. This can include contacts, call logs, photos, file names, Bluetooth/Wi-Fi identifiers, web browser history, media files, SMS messages, and more.

This data can be used to determine actions of those within the vehicle and is a useful source of information outside of what typical vehicle diagnostics data can tell you.

GPS Pinpoints

Tracking data, such as GPS pinpoints can also be found logged and saved by the head unit (infotainment system). Recent and most frequent places visited, routes, and timestamps of each can give a good indication of events leading up to an incident or may be used to place a vehicle in a location at a given time. This type of data is kept in the embedded filesystem and may be retrievable by a toolkit such as Berla iVe.

Key Fob Data

This information often yields surprising results as to what it captures. VIN, transponder type and ID, HITAG family, key ID, key type, immobiliser type, operating frequency, number of keys coded, mileage, last time in vehicle, fuel level, and exterior/interior colour can be obtained by performing key forensics and analysis.

In addition to the above, the following three types of data are stored in the vehicular network:

Fault/error code: These are identifiers that are stored in the vehicle ECUs once a certain incident has occurred, is occurring repeatedly or a change in a status has occurred. Examples of fault code incidents could be the activation of an airbag, or a reoccurring mismatch between two signals like measured airflow in engine intake manifold against oxygen reading in the exhaust.

Flag: An incident triggers a status flag. This could be events like the vehicle has reached its maximum speed (i.e. 250 km/h) at least once during its lifetime.

Time sequence: A time sequence of a signal is stored in conjunction with an incident. A detailed and incremental time lapse provides for several seconds before and after the event, stored within the EDR.

5. Tools and Products

Overview

To gain access to stored vehicle data, there is a wide range of tools available on the market, starting with simple adaptors that can be connected to the OBD2 port of a vehicle which are paired with an app on a smartphone, over professional workshop equipment like OEM and aftermarket diagnostic tools to highly professional specialised tools designed for crash investigations and forensic purposes.

5.1 OBD Adaptors

There is a variety of OBD2 diagnostic adaptors on the market like Carly or Bluedriver. These adaptors are available for a couple of hundred dollars and can read out and manipulate a limited set of standardised data on vehicles.

The available apps on Apple IOS and Android Google Play store have similar functions and display standardise set of data with some app displaying more than others. The available data varies between makes, models, OBD dongles and mobile apps.

The typical range of data but not limited to:

Table 1: Comparison of different apps

Car Scanner Pro App	Torque Mobile App	Kiwi OBD App
Average fuel consumption	Acceleration (X,Y,Z axis)	Air intake temperature
Average speed	Accelerator pedal position	Engine coolant temperature
Boost	Air fuel ratio	Battery voltage
Engine coolant temperature	Ambient air temperature	Engine rpm
Engine RPM	Trip meter information	Engine power
Distance travelled	Engine coolant temperature	Engine torque
Vehicle acceleration	Engine load	Fuel pressure
OBD module voltage	Engine RPM	Fuel level
DTC Status	Ethanol fuel %	Throttle position
Vehicle speed	GPS data and co-ordinates	Trip meter information
Intake air temperature	Vehicle speed	
Throttle position	Transmission temperature	
Oxygen sensor status	Pitch and roll meter	
Distance travelled since code clear	voltage	

Source: IAG Research Centre research.

The three tested apps can read and clear diagnostic trouble codes similar that of a scan tool however it is dependent on the OBD dongle and mobile app. The app allows for viewing of live data stream and have functionalities focused on fuel efficiency metrics for the driver's convenience. Live data can also be recorded along with capturing freeze frame of a point in time for later viewing.

Although the OBD dongle presents a lot of information for a low cost, it is worth noting that the tested device is for personal use. The ability to view diagnostic trouble codes enables an understanding of the vehicle's status after the event. For example, an engine misfire with the code P0305 will cause a loss in power and affect driveability but will not cause an immediate crash.

The presented data is related to the vehicle's existing status and is not developed for the use of crash data retrieval. If a dongle is connected to the vehicle after the event it will show previous faults and historical data. For the possibility that a dongle would work in a crash or theft scenario, it would need to be installed before the event or fitted to the vehicle from the factory.

5.2 Workshop Diagnostic Tools

Workshop diagnostic tools are designed and required for vehicle maintenance and repairs by OEM and non-OEM workshops. Each vehicle manufacturer operates its own genuine suite of devices tailored to their fleet. Further to that, aftermarket products exist that enable working on a whole range of different vehicles from different brands with one tool. Examples of these are Logicar or Bosch KTS840.

These tools have a wider range of operation than ODB adaptors and are capable of on-board diagnosis and repair, product diagnosis and repair, diagnosis, OBD diagnosis. They come in a price range from several hundred to several thousand dollars and require yearly updates.

The typical range of data (but not limited to):

Table 2: Overview of the range of data

Engine Control Unit	**Transmission Control Module**	**Anti-lock Brake System**	**Supplementary inflatable restraint system**	**Body Control Module**
Accelerator pedal position	Accelerator pedal position	Brake Fluid status	Airbag resistance, drive side	Battery voltage
Ambient air temperature	Brake switch input status	ABS power supply voltage	Driver seatbelt retractor pretensioner status	Brake lamp switch
Clutch pedal position	Clutch actuator status	Lateral acceleration	Driver side seatbelt deployment status	Central lock status
Engine coolant temperature	Engine load	Left front wheel speed input	Ecu operating States	Crash status
Engine oil status	Engine RPM	Left rear wheel speed input	ECU power supply voltage	Hazard warning light status
Engine RPM	Gearbox error Status	Longitudinal acceleration sensor	Number of trouble code set due to diagnostic test	HVAC switch status
Fuel injector phase	Input Shaft Speed	Module supply voltage	Passenger frontal stage deployment status	Vehicle battery estimate temperature

Engine Control Unit	Transmission Control Module	Anti-lock Brake System	Supplementary inflatable restraint system	Body Control Module
Fuel level	Reverse Lamp Control	Right front wheel speed input	Passenger seatbelt retractor pretensioner status	Vehicle battery days in service
Ignition timing advance	Shift Fork Status	Right rear wheel speed input	passenger side seatbelt deployment status	Vehicle battery state of charge
Intake air temperature	Transmission Control Status	Steering wheel angle sensor		
Main ECU voltage supply	Transmission Range status	Vehicle speed		
Malfunction Indicator Lamp	Vehicle speed	Yaw rate		

Source: IAG Research Centre research.

The scan tools allow investigators to determine any faults with a vehicle by examining its current status. For example, a faulty wheel speed sensor can affect the operation of the vehicle's anti-lock brake system hence allowing the conclusion for the cause of the event. Furthermore, the tool can check for any changes made to the vehicle's original configuration so that tampering of the vehicle can be determined. These devices can also produce a report to capture status data of the vehicle which can be stored and viewed at a later stage.

Whilst both the OBD dongle and scan tool have their use cases for investigations, it is worth mentioning that the vehicle's electrical system, especially the ODB port is required to be in working order for these devices to function. The dependency on the OBD connection and the vehicles electrical system can limit investigation and therefore call for the use of direct-to-module options offered by the more expensive crash data toolkits.

5.3 Crash Analytics and Forensic Tools

At the top end of tools for vehicular data extraction and manipulation are devices specifically designed for this purpose. After some research regarding products on the market and their market share, two main products were chosen for further evaluation are the Bosch Crash Data Recorder (CDR) and the Berla iVe toolkits. They both vary significantly in their approach and what kinds of information they will be able to retrieve.

As a general overview, the Bosch CDR toolkit is more akin to retrieving data from a black-box recorder. It can return data from all the major components five seconds before and after an incident. Berla on the other hand, places less emphasis on the ECUs and markets an ability to retrieve information stored in the head unit, or infotainment system.

Each OEM also has a toolkit for vehicle analysis and diagnosis, of which some are available for purchase and use by non-OEM persons. They vary on cost and are very limited to makes and models so are not fit for the purpose of this report and thus excluded.

5.4 Comparison and Assessment

Bosch CDR (June 2021 update)

Features	Since 2000 OEM-authorised and developed Sole distributor in Australia Access is gained via OBD-II or proprietary cable Certificate of completion is available for the Technician Course
Training	Single operator in Australia, based in Queensland (Dave Stocker). 1 and 2-day courses available
Costs	$8,965 for CDR Pro kit with hard case $1,870 for CDR software $117.70 for recommended Ford DLC adapter (F00K108784) * $4,950 for 2-day training for up to 5 people TOTAL: $15,902.70 *more OEM adapters are available for additional costs
Data Available	Number Of Events Time From Event 1 to 2 (seconds) Vehicle Identification Number (VIN) Retrieval Date Retrieval Program Information EDR Report Information Report Requested By Report Date Ignition Cycle At Retrieval Maximum Delta-V Longitudinal/Lateral (km/h) Time to Maximum Delta-V Longitudinal/Lateral (ms) Time to Maximum Delta-V Resultant (ms)

	Ignition Cycle At Event Ignition Cycle Runtime Odometer At Event Time Zero Airbag Warning Lamp Status Vehicle Drive Mode Driver/Passenger Safety Belt Status Driver Seat Position Rear occupant seat status Driver Airbag Deployment 2nd Stage Complete File Recorded Deployment Summary Time Series Data Vehicle Speed Accelerator Pedal (%) Rear Motor Speed (rpm) Service Brake Stability Control ABS Activity Steering Wheel Angle (deg) Lateral/Longitudinal Pre-Crash Acceleration Roll/Yaw Rate Pre-Crash Data Longitudinal/Lateral Delta-V data Serial Numbers Hexadecimal Data
Usefulness	The Bosch CDR toolkit is focused more on control units and therefore has the ability to provide accurate telemetry of the physical world. It would be most useful in reconstruction of crash scenes via computer modelling, or to use the data to corroborate evidence. Once the module is removed the integrity of the data is kept, however, if the module is left attached then it will overwrite existing data if driven. There is nothing to install to the vehicle and reports are generated in a variety of formats, which makes it easy for the user to interpret.
Value	**+** Unparalleled value for crash reconstruction and comparing the data against testimony or eyewitness accounts. **+** Useful for insurance investigations and detecting instances of fraud.

+ Depth and breadth of the data itself and how many sensors are capturing.

+ Data goes through 3 iterations of verification to show there is data integrity built into the software.

+ Raw data can be saved permanently so the integrity is kept. Can be analysed again anytime in the future.

+ Ease of use.

+ Quality of materials and feel.

- Several makes and models are absent from the list of testable vehicles. The value would be greater if more manufacturers and brands could be tested.

- Having been developed by such a large OEM in Bosch, one wonders if the scope of data captured could be greater, or is greater but only a small subsect is visible on the CDR toolkit? Something as simple as a timestamp is not included in the data, but perhaps omitted due to ease of tampering.

Berla iVe

Features

Since 2013

Data is released by OEMs, Berla tests it privately and makes it available through iVe

Access is gained via USB, OBD-II or proprietary cable

Certification available

Training*

**Unable to be fully assessed at this time*

5-day course, covers Ford, GM, BMW, Mercedes, VW and Toyota

Costs*

**A full breakdown of costs will be included in the next version*

Data Available

Connections

Bluetooth Unique Identifiers

Wi-Fi Unique Identifiers

Devices

Phones Unique Identifiers, Contacts, Call Logs, SMS, Media Files

Mass Storage Devices Unique Identifiers, Media Files

Embedded Device Unique Identifiers, Contacts, Call Logs, SMS, Media Files

CD/DVD Unique Identifiers, Media Files

Events: Bluetooth Connections, Doors, Devices, Gear Shifts, Light Status, Media, Odometer Reading, Phone Calls, Message Display, GPS Warnings, Voice, Recording, Traffic Update, Hard Acceleration, Hard Braking, Traction, Events, Driver Distraction, Android Auto enabled, Apple Carplay enabled, Voice Command, Speech Recognition,

	Web Browser History, Emergency Assistance, Ignition Key, Navigation, Power, Seat Belts, Stop/Start Log, System, Time Updates, USB Connections, Voice Command, Voice Recording, Web Browser History, Wi-Fi Connections **Navigation:** Location, Routes, Tracklogs **Key Fob:** VIN, transponder type/ID, HITAG family, key ID, key type, immobiliser type, frequency, number of keys coded, key number, mileage, CryptoKey, last time in vehicle, fuel level, exterior/interior colour System Metadata
Usefulness	Berla iVe best serves as a tool to fill the gaps in the narrative that the Bosch CDR cannot. For example, using GPS data points to track location, route information, or read connected device data (i.e. phones, tablets and laptops). While limited in reconstructing a crash or anything related to the physics of the vehicle, it can add significant value in providing information not available otherwise. This would most likely be of greatest value to law enforcement who can utilise new mobile phone data and timestamps to assist in investigations. It can also pull acceleration/braking data from some models which can be useful in detecting staged crashes or workshop collisions. There is nothing to install to the vehicle and reports are generated in a variety of formats, which makes it easy for the user to interpret.
Value*	**Unable to be fully assessed at this time*

Note

There are separate crash data retrieval kits available for Hyundai, Kia and Tesla. The first two are for the US and Canadian markets only and cost several thousand dollars each, however, Tesla's is priced reasonably at 1200 USD.

Given the difference in vehicle architecture, and the rise in popularity of these vehicles, it could be worthwhile to invest in one of the Tesla kits and compare the findings against the other two toolkits in this report.

6. Summary and Next Steps

6.1 Summary

To summarise, it is very helpful to be able to rely on unbiased and uninfluenced data in any investigation, particularly ones involving serious injury or death. Data retrieval toolkits provide scientific evidence based on measurements and calculations of highly calibrated and accurate instruments.

It is important to note that these toolkits are more helpful to ascertain what the *driver* did, or what the *vehicle* did, rather than *who* was driving or *who* was at fault. Sometimes the reliance on data alone may result in a conclusion that does not factor in extenuating circumstances, for example, weather, medical episodes or an assortment of random events beyond the control of the driver.

There is a clear need for regulation and reform when it comes to data privacy. Technology continually out-paces laws and legislation which can be problematic, particularly when its citizen's privacy rights are being devalued, overlooked or not considered.

It would be helpful to have a worldwide standard in the eventual release of OBD-III and EDRs. One such concept is the "automotive black box" that is, a data recorder that has a worldwide standard of collectable data and reporting methods, as well as laws that govern the proper use of them.

It could follow similar guidelines set out by the nautical and aerospace industries. The current lack of date, time, and location stamping on EDR logs is slightly disconcerting given the relative ease in being able to implement it, as is the lack of a requirement for this information to be kept at all.

The UNECE is currently developing standards for Data Storage System for Automated Driving (DSSAD) in their WP29 GRVA working groups. For Australia, the National Transport Commission is working on legal frameworks that will deal with these topics and hopefully adopt or interpret the final UNECE regulations into national law. For the NMVTRC, it would be advised to seek contact with the NTC to ensure that requirements from a crime and insurance investigation point of view find their way into this national Australian framework.

Most modern vehicles already have clocks and calendars built into their systems, the navigation system provides for real-time location data, and the SIM card installed could further provide this kind of data.

Transparency of information within the automotive sector, accessibility to training and the choice of training options for police and insurance investigators will help to promote better road safety and more efficient use of our law enforcement's limited resources through simpler and faster vehicle processing in accidents or vehicle-related crimes.

Hopefully the research we have undertaken will assist in providing guidance to useful tools and techniques and to help make our communities safer.

6.2 Bosch CDR (June 2021 update)

In March 2021, IAG Research Centre undertook the necessary training for the Bosch CDR toolkit.

Dave Stocker, the Bosch training representative, was extremely helpful and knowledgeable and provided printed training manuals and resources. He began by explaining the two things we were going to learn. The first was how to safely obtain data from the vehicle, which can be done in a variety of ways and depends on the condition of the vehicle, if it has power, etc. The second was how to interpret that data from the automatically generated Bosch CDR report.

We have included two sample reports in sections 10.1 and 10.2 of this document, to provide some context around what data you get, in what format that appears, and to show where human conclusions need to be made from the data.

He also emphasised to take careful note of the limitations of the data, and any exceptions that can adversely affect the conclusion. The data relies on precise scientific instruments that can easily become inaccurate from simple things that might be overlooked, for example, tyre pressures or diameters, so it is imperative this is always in the forefront of our reasoning.

Once trained, vehicles can be assessed and a CDR report generated in about ten minutes. It then takes some additional time to compare the results of the data in the report to the physical damage to the vehicle to corroborate the evidence.

The findings have allowed us to explore the idea of developing a similar product that can gather the important information but with the added benefits of portability and cost effectiveness, something like a plug-and-play OBD-II dongle that will retrieve data automatically upon connection.

One idea in how to implement this involved approaching Bosch directly and seeing if there was any interest in co-developing a product, based on the backbone of the CDR toolkit. At the time of writing, we have not pursued that pathway yet.

We are currently working on a project with some University of Technology Sydney students, whereby CAN signals and communications are being researched. Our hope is that the results of this collaboration, which are due at the end of 2021, could feed into the idea of developing our own vehicle data-retrieval solution.

In summary, the Bosch CDR toolkit is very useful for aspects relating to crash and fraud investigations, and we have confidence in the integrity of the data and in the reliability of the accuracy of the reports generated. It is worth noting however, that careful consideration needs to be applied regarding the limitations of individual makes and models, as the data captured can vary.

The main drawback was that many manufacturers are absent from the list of compatible vehicles, for example, Chinese and Korean brands. This would require separate purchases for additional toolkits to be able to gather the same set of information that the Bosch CDR does, else those brands remain untestable.

For the price of the equipment and training combined, the Bosch CDR toolkit offers a market-leading solution for crash investigations and is currently utilised in court proceedings. It also provides for a decent avenue to explore insurance-related investigations, such as suspected fraud.

6.3 Points of interest in CDR reports (June 2021 update)

Data not captured

For a variety of reasons, some data may not be captured or may not show up on graphs. This omission can be presented differently, with some showing as a 0, NA, SNA, 255, or simply left blank.

This does not indicate an issue with sensors or a fault in the processing by the CDR, and a reminder to always read through the data definitions or cross-reference if uncertain.

Differences in systems (comparing the Mitsubishi CDR report to Lexus')

Each manufacturer seems to do things slightly differently, and the information provided can even depend on models within the same manufacturer. Looking at the two samples CDR reports, we can compare and highlight some differences between a Mitsubishi ASX and a Lexus ES200H.

Firstly, there is a notable difference in the number of data definitions that the ES200H provides. It serves to give better oversight to the data within the report and also highlights the limitations of that data.

There is also a difference to how much data is provided, and how it is presented. The ASX had a single table for "Pre-crash -5 to 0 seconds", consisting of just five data points (speed indicated, accelerator pedal %, service brake status, engine RPM, and steering input).

Compare this to the ES200H which had four tables and twenty-two data points (vehicle speed, accelerator pedal %, engine throttle %, fuel injection quantity, engine RPM, motor RPM, service brake status, ABS control status, BOS control status, brake oil pressure, longitudinal acceleration, yaw rate, steering input, shift position, sequential shift range, cruise control status, VSC control status, READY signal, drive mode powertrain, drive mode snow, driver mode EV, and driver mode select signal) and you begin to see a disparity in results.

On the flip side, the ASX had a graph and table each for longitudinal delta-v, longitudinal acceleration, lateral delta-v, lateral acceleration, roll angle and vertical acceleration, whereas the ES200H only had a table and graph for longitudinal and lateral crash pulse.

It just goes to show how much the data varies, and how it is presented between two makes and models, and that this variance grows as you begin to explore more vehicles. Sample CDR reports from overseas markets also highlight this variance and are due in part to the differences in government regulations as those mentioned in section 3.2 of this report.

Mandatory data

The Code of Federal Regulations (CFR) 2011 Title 49 Volume 6 Section 563.6 of the United States Federal Motor Vehicle Safety Standards sets out the minimum requirements for vehicles, and states the following:

“Each vehicle equipped with an EDR must meet the requirements specified in §563.7 for data elements, §563.8 for data format, §563.9 for data capture, §563.10 for crash test performance and survivability, and §563.11 for information in owner’s manual.”

The following are the 15 mandatory data elements, for a more comprehensive list of the specific data elements, refer to table 3 in Appendix 10.3.

Data Element
Delta-v longitudinal
Maximum delta-v, longitudinal
Time, maximum delta-v
Speed, vehicle indicated
Engine throttle, % full (or accelerator pedal, % full)
Service brake, on/off
Ignition cycle, at crash
Ignition cycle, at download
Safety belt status, driver
Frontal air bag warning lamp, on/off
Frontal air bag deployment, time to deploy, in the case of a single-stage air bag, or time to first-stage deployment in the case of a multi-stage air bag, driver
Frontal air bag deployment, time to deploy, in the case of a single-stage air bag, or time to first-stage deployment in the case of a multi-stage air bag, right front passenger*
Multi-event, number of events (1, 2)
Time from event 1 to 2
Complete file recorded, yes/no

It is also worth mentioning § 563.12 of the Code, which states:

“Each manufacturer of a motor vehicle equipped with an EDR shall ensure by licensing agreement or other means that a tool(s) is commercially available that is capable of accessing and retrieving the data stored in the EDR that are required by this part. The tool(s) shall be commercially available not later than 90 days after the first sale of the motor vehicle for purposes other than resale.”

This means that every vehicle sold (at least in the US) will have a commercially available tool that can be used to read and retrieve the data. However, there is nothing written about the affordability of such tool, or the utility and ease of use, which may be factors in obtaining the data as well.

Hexadecimal data

One interesting take away is provided within the CDR report (see Appendix of this report).

“All data that has been specified for imaging is shown in the hexadecimal data section of this report. However, not all of this data is translated by the CDR tool. The imaged ECU may contain additional data that is not retrievable by the CDR tool.”

This raises some questions as to what extra data is being captured but not interpreted because of the limitations of the tool. We are particularly interested in knowing the status of some of the driver-assistance systems and whether or not they switch themselves off at a particular point or after a certain threshold has been met in an accident or collision.

Imaging date and crash date

It is important to note that the imaging date and crash date are not retrieved from the device and are manually entered by the user. This needs to be highlighted, especially if evidence is being provided in a court setting or relied on as fact. The dates could have been entered incorrectly at the time of scanning unknowingly.

Ignition cycles

Ignition cycles at time of crash and at time of CDR scan can be used to determine if the vehicle was started, or possibly moved, from the time of accident. There may be some other factor to consider, such as tow trucks, etc, but it still provides for an important piece of evidence in both police and insurance investigations.

6.4 Berla iVe (June 2021 update)

Training for the Berla toolkit was originally forecast for July 2021, however, with the ongoing pandemic still severely affecting many areas of the world (and travel), the organiser has postponed this event until mid-2022.

Being mindful of the above, this part of the report is incomplete pending completion of the training and subsequent physical testing in our workshop, likely towards the end of 2022.

6.5 Note on the future operations of the NMVTRC (June 2021 update)

In May 2021, the NMVTRC announced that the Insurance Council of Australia's (ICA) has decided that it will not be renewing its agreement with the NMVTRC, which expires on 30 June 2021. The NMVTRC's assessment is that it is not sustainable to continue operations beyond 30 September 2021.

The focus remains on the completion of a small number of high-priority projects that will deliver outcomes of value to the NMVTRC's stakeholders in that timeframe. With this in mind, we are still committed to presenting the NMVTRC with all the project objectives and deliverables to the highest standard before this date.

The final piece that requires finalising, the Berla toolkit review, training and workshop testing will therefore be added to this report and presented to the new custodians of the NMVTRC archives for review and acceptance. Further communication around this will take place at a later date.

7. Data Privacy

Even though vehicles equipped with connectivity technology are still quite rare on Australian roads and Advanced Driver Assistance Systems higher than SAE Level 2 not legally operable in Australia, there is momentum for the quick introduction of these technologies into the market.

These systems, be it connected or automated, will create a massive amount of vehicle-related data which can be used in subsequent processes for various purposes. Unlike today, where most of the data is stored locally on a vehicle or just used in time to operate systems, the generated vehicle data of the future will be distributed and accumulated across various systems, even outside the vehicles themselves.

The United Nations Economic Commission for Europe (UNECE) is currently developing global standards regarding minimal requirements for Data Storage Systems for Automated Driving (DSSAD, or "black box") in their WP29 GRVA working groups that will provide a framework for future data recording for crash, forensics and investigation purposes.

In Australia, the National Transport Commission (NTC) has been working intensively since 2017 to develop an end-to-end regulation to support the safe commercial deployment and operation of automated vehicles at all levels of automation in Australia. There have been two pieces created so far dealing with stored data in conjunction with driving and operating vehicles, as well as access and privacy to this data:

August 2019: Policy Paper regarding Regulating government access to C-ITS and automated vehicle data

May 2020: Discussion Paper regarding Government access to vehicle-generated data discussion paper

Both papers address (among other aspects) the key topics of data ownership, data privacy and data access in conjunction with vehicle generated data.

In the first piece, the NTC has identified certain types of data that will come with privacy issues which haven't been sufficiently addressed by the Australian information access framework.

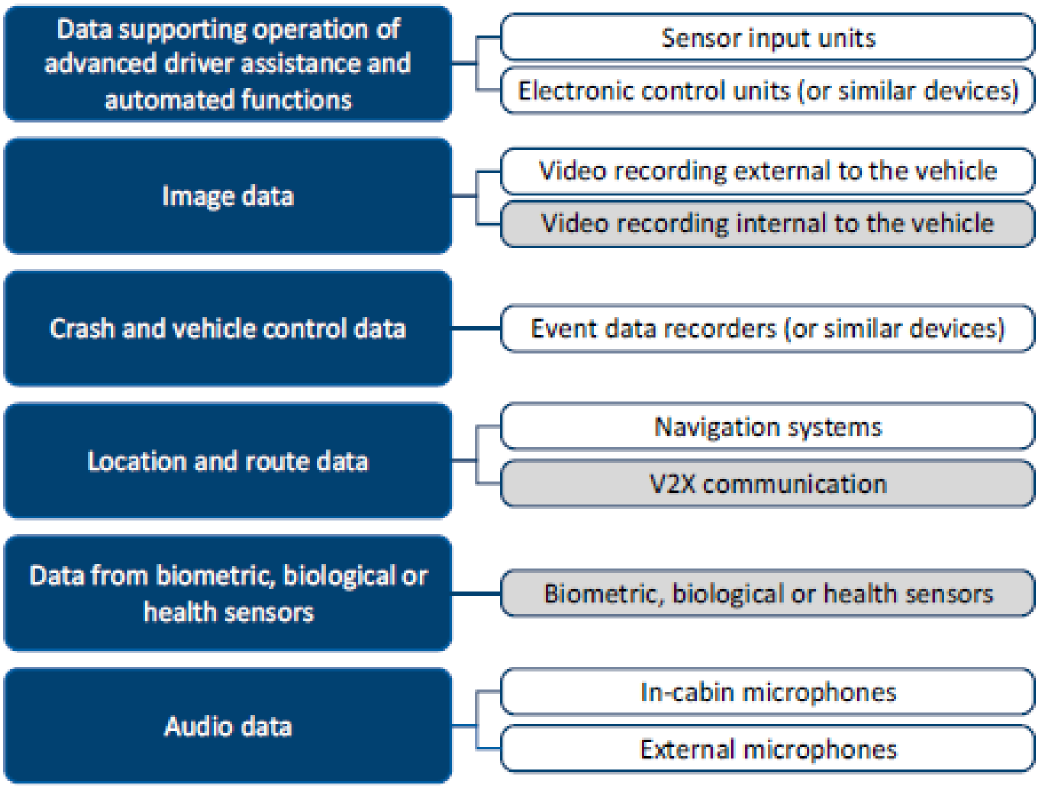

Figure 4: Overview of technology in vehicles.

NTC Discussion Paper. Retrieved from https://www.ntc.gov.au/transport-reform/ntc-projects/regulating-government-access-c-its-and-av-data

The concerns outlined by the NTC are mainly addressing the fit for purpose-ness of data access and the inconsistencies of legal frameworks in the government agencies across states and territories. Based on these considerations, the NTC proposed an approach to develop and agree on broad principles on limiting government collection, use and disclosure of vehicle related data. It developed a set of guiding principles for the development of laws to regulate government access to automated vehicle data:

The laws and aligned standards for C-ITS and automated vehicles should:

1. Balance the benefits of government access to C-ITS and automated vehicle data with additional privacy protections to appropriately limit the collection, use and disclosure of C-ITS and automated vehicle data.

2. Be consistent with, and informed by, existing and emerging Australian and international privacy and data access frameworks.

3. Embed access powers and privacy protections for C-ITS and automated vehicle data in legislation.

4. Clearly define C-ITS and automated vehicle data in inclusive and technology neutral terms.

5. Align government entities' approach to managing C-ITS and automated vehicle data with the objectives underlying existing concepts of personal information.

6. Specify the C-ITS and automated vehicle data covered, the purposes for which the data can be used and the parties to whom the purpose limitations apply while not impeding access to data with a warrant or court order authorising a different use.

7. Recognise the importance of notifying users in plain English about government collection, use, disclosure and storage of C-ITS and automated vehicle data.

8. Recognise that meaningful informed consent is important but provide avenues for government entities to balance individuals' expectations of privacy in alternative ways where obtaining such consent is not possible.

9. Recognise the difficulty of irreversibly de-identifying C-ITS and automated vehicle data in many circumstances.

10. Support data security.

11. Allow for regular review of privacy protections for C-ITS and automated vehicle data.

This yet-to-be-developed framework will regulate the future access to vehicular data and will need to be considered in any processes that use the technology outlined in this report for investigation purposes. In the future, vehicle data must be considered either *private* or *sensible* data and therefore, government authorities and insurance investigators will need to take different legal steps to gain direct access to different detail levels of data.

The second discussion paper of the NTC addresses (among other topics) the current state of data ownership in Australia. Unlike in other jurisdictions, the ownership of vehicle generated data is not completely determined. With the various stakeholders involved, this could be either the driver of the vehicle, the owner, the vehicle manufacturer or the mobility service operator.

All these parties might have a different view on their willingness to share this data and if the data is stored cloud based, this might even be done so in other jurisdictions across the globe. Current Australian information access regulations do not yet cover these cases and will need to be adapted in the future.

Taking all this into consideration, an involvement of the NMVTRC in the proceedings of the NTC around the regulatory framework regarding connected and automated vehicles is strongly advised to ensure respective requirements of law enforcement, crime investigation agencies are appropriately considered as well as the private insurance sector.

Australia Definition of Ownership

A complicated and often-considered “grey” area. It is one that has many opinions, but no finite and useable definition. It will also vary in accordance to what country, state and local laws and legislations are in effect.

There are currently equal claims from both government, manufacturer and vehicle owner as to who the owner of the data is, but the common ground is that during an active investigation, law enforcement, manufacturers and insurance companies should be complicit and assist each other where possible.

An interesting case study that occurred in 2005 in NSW saw a young, female, P-plate driver convicted of “dangerous driving causing death/occasioning grievous bodily harm". Evidence from the vehicle EDR showed that the car was being driven in excess of the posted speed limit. An injunction against the use of this evidence, obtained by the owner of the car (the parents of the defendant), was overturned by the Supreme Court.

United States Definition of Ownership

The federal Driver Privacy Act of 2015 was enacted on December 4, 2015. It stated that the owner or lessee of a motor vehicle is the owner of the data collected by the EDR.

In order to access that data, an investigator would need to (1) be authorized by a court or judicial or administrative authority, subject to the standards for admission into evidence; (2) obtain the written, electronic or recorded audio consent of the vehicle owner or lessee; (3) be conducting an investigation or inspection authorized by federal law; (4) demonstrate it is necessary to facilitate medical care in response to a car accident; or (5) be conducting traffic safety research, so long as the personal information of the owner/lessee is not disclosed.

European Union Definition of Ownership

The new EU regulation requires to respect the General Data Protection Regulation 2016/679 (GDPR), doesn’t allow the storing of the last 4 digits of the VIN, but doesn’t specify the ownership or use.

8. Glossary

Accelerometer

An instrument that measures the acceleration of a body or object.

Airbag Control Module (ACM)

The module responsible for controlling the airbags, monitoring vehicle sensor data and storing of information in an accessible file.

Advanced Driver Assistance Systems (ADAS)

Electronic assistance systems designed to help a vehicle operator with driving, parking and awareness.

Autonomous Electronic Braking (AEB)

An electronic feature designed to assist a driver in the event of an imminent crash by applying the maximum braking force without human intervention.

Alcohol Interlock

An electronic breath analysis device linked directly to the ignition system of a vehicle. Drivers must provide a clean sample of breath before the vehicle will start.

Autonomous Vehicle (AV)

A vehicle capable of sensing its environment and operating without human intervention.

Body Control Module (BCM)

An electronic control unit responsible for operating and monitoring various vehicle components and accessories.

Brake Override System (BOS)

A technology that cuts engine power in the event of simultaneous application of both the brake and accelerator pedals. The system reduces engine power, it does not stall or turn off.

Bus

A subsystem used to connect computer components, such as control units and sensors, and transfer data between them.

Byte

The standard unit of digital information, or data. It is the smallest addressable unit of memory.

Controller Area Network (CAN bus)

A vehicle bus standard that allows for intercommunication among controllers and devices, without the need for a central computer.

Crash Data Retrieval (CDR)

The retrieval of crash data from the vehicles EDR.

Delta-V

The unit of measurement for crash severity, defined as the total change in vehicle velocity.

Diagnostic Link Connector (DLC)

The multi-pin connection port used to interface a scan tool to determine fault codes, read live data streams and access the on-board diagnostics.

Distraction Recognition System

Infrared facial recognition technology that issues alerts when it detects driver distraction, for example, when holding a phone, texting, eating, yawning or micro-sleeping.

Drowsiness Detection System

A car safety technology that helps prevent accidents caused by driver fatigue. Some methods used by various systems include steering pattern monitoring, vehicle-in-lane monitoring, and facial recognition.

Data Storage System for Automated Driving (DSSAD)

A system that monitors and records data of a vehicle fitted with an automated driving system. Basically an updated version of an EDR but specifically catering for when the automated driving system is in control of the vehicle or requesting takeover.

Diagnostic Trouble Code (DTC)

A five-digit code that represents a specific problem or issue within a vehicle. These are displayed on a scan tool when it's connected to the ODB port.

eCall

An in-vehicle system that alerts emergency services to the exact location of an accident. It allows the occupant to communicate directly with the operator via voice and uses the 112-emergency number. It was made mandatory for all new cars sold in the EU from 2018.

Electronic Stability Control (ESC)

A software-controlled technology that improves vehicle stability by detecting loss of traction and automatically applying the brakes to help steer the vehicle in the direction the driver intends to go.

Engine Control Unit (ECU)

The module responsible for monitoring and optimising vehicle operation, performance, and engine management.

Event Data Recorder (EDR)

A device that records vehicle information, sensor data and occupant information for a specified time before, during and after triggering an event, typically a collision.

Emergency Stop Signal (ESS)

An electronic feature designed to prevent collisions by warning following vehicles about a sudden or forceful application of brakes by flashing the hazard lights at fast speeds.

Engine Mapping

A process that alters a vehicle's ECU, usually done so for the purpose of increasing performance.

EOBD

European On-Board Diagnostics.

Ethernet

A method for connecting computers together in a local area network (LAN).

EU

European Union.

Firmware

A type of permanent software programmed directly into read-only memory.

FlexRay

An automotive, time-triggered communications protocol particularly useful in safety-critical applications.

Gateway

A type of network hardware that allows for data to flow from one network to another, i.e. a router.

GB

Gigabytes, equivalent to 1024 MB or a billion bytes.

Gbps

Gigabytes per second.

Global Positioning System (GPS)

A satellite-based radionavigation system used to calculate a geographic location.

Gyroscope

An instrument used to measure orientation or angular velocity.

HV

Heavy vehicle, for example, a truck or bus.

ICE

Internal combustion engine. An engine that generates power by the burning of petrol, oil, diesel or other fuel, with air inside the engine, with the hot gases produced used to push pistons (and more) as they expand.

Intelligent Speed Assistance (ISA)

An electronic assistance system that alerts the driver when they have exceeded the speed limit, based on speed-sign recognition or GPS location data. Some systems increase the resistance of the accelerator when travelling above the speed limit, making it harder to accelerate.

International Standards Organisation (ISO)

An international standard-setting body comprised of representatives from various national standards organisations.

JOBD

Japanese On-Board Diagnostics.

KB

Kilobytes, equivalent to 1024 bytes.

Kbps

Kilobytes per second.

kph

Kilometres per hour.

Lane Keep Assistance (LKA)

An electronic assistance system that alerts drivers via audio, visual and haptic feedback, that their vehicle is crossing over the lane marking without the indicators being activated. Advanced versions will self-correct the steering to guide the vehicle back inside its lane.

LCV

Light commercial vehicle, for example, a car or van.

LIN

A network protocol used for communication between vehicle components. A cheaper alternative that is suitable for non-safety critical functions.

Man-in-the-middle

A term that describes an unauthorised third party being able to intercept and alter data sent between two parties without their knowledge. They believe they are in direct communication but the attacker is actually the one relaying the information between them.

MB

Megabytes, equivalent to 1024 KB or a million bytes.

Mbps

Megabytes per second.

Module

A separate unit of software and/or hardware, that performs a specific function.

mph

Miles per hour.

NHTSA

National Highway Traffic Safety Administration. A US-based federal agency responsible for keeping people safe on America's roadways.

Non-volatile Memory (NVM)

A type of computer memory that stores information even after power has been turned off. Unlike volatile memory, it does not require periodic refreshment of memory data and is often used for long term storage.

NTC

National Transport Commission. An Australian statutory body created to operational and regulatory transport network reform.

On-Board Diagnostics

An term that refers to a vehicle's capability to self-diagnose and report the status of various sub systems.

PID

Process identifier. A unique identification number of a process.

Pinout

A diagram that shows the arrangement of pins on a circuit-board, as well as their functions.

Reverse Camera

A type of video camera attached to the rear of a vehicle, with the purpose of increasing visibility when reversing and alleviating rear blind spot. Often combined with audio triggers that indicate distance-to-object, it was designed to prevent reversing collisions.

RPM

Revolutions per minute.

SAE

Society of Automotive Engineers. A US-based standards developing organisation for engineering professionals and industries.

Service Guide

Also known as a service log book. A guide provided by the manufacturer containing information on specified or recommended service requirements and intervals.

Signal Protocols

A system of rules that allow two or more entities to communicate with each other. The protocol defines the rules, syntax, semantics, and synchronisation of communication.

TB

Terabytes, equivalent to 1024 GB or a trillion bytes.

The Cloud

The storing and accessing of data or programs over the Internet instead of a traditional hard drive.

Tyre Pressure Monitoring System (TPMS)

An electronic system designed to monitor and report real-time tyre air-pressure information.

US

United States.

V2X

Vehicle-to-everything. Describes the communication between a vehicle and any other entity that may affect the vehicle, and vice-versa.

Vehicle Identification Number (VIN)

A unique identifier used by the automotive industry.

Vulnerable Road User Detection

A safety technology that is able to identify vulnerable road users, such as cyclists and pedestrians, and inform the driver so they can make informed driving decisions earlier and adjust driving behaviour accordingly.

Vehicle Stability Control (VSC)

See Electronic Stability Control (ESC).

Variable Valve Timing (VVT)

The process of altering a valve lift event to improve performance, economy or emissions.

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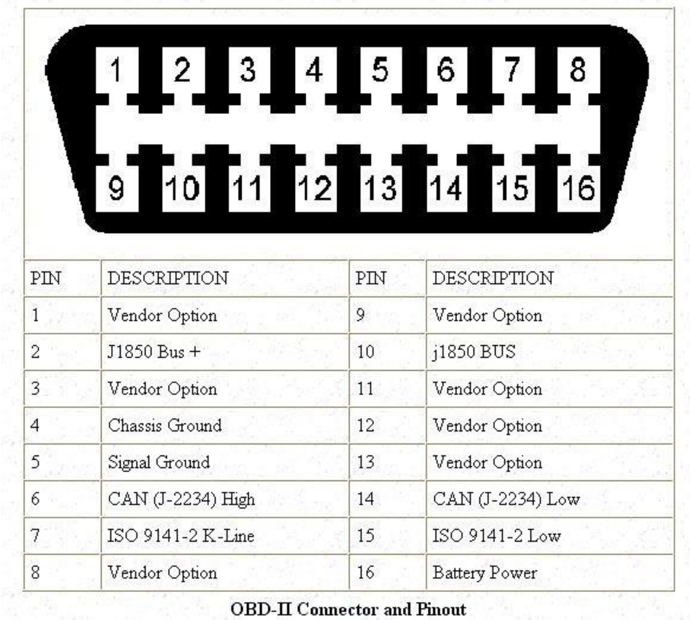
Image of OBD-II pinout. Retrieved April 22, 2020 from https://amynasec.io/blogs/single.php?id=12

10. Appendix

10.1 OBD-II Pinout and Current Standards



PIN	DESCRIPTION	PIN	DESCRIPTION
1	Vendor Option	9	Vendor Option
2	J1850 Bus +	10	j1850 BUS
3	Vendor Option	11	Vendor Option
4	Chassis Ground	12	Vendor Option
5	Signal Ground	13	Vendor Option
6	CAN (J-2234) High	14	CAN (J-2234) Low
7	ISO 9141-2 K-Line	15	ISO 9141-2 Low
8	Vendor Option	16	Battery Power

OBD-II Connector and Pinout

Figure 5: OBD-II pinout.

OBD-II connector and pinout. Retrieved from https://amynasec.io/assets/img/blog/b13.png

Current Standards

<u>Society of Automotive Engineers (SAE) Standards</u>

J1962: defines the physical connector used to interface. One of the most commonly applied standards.

J1979: defines test modes.

J2012: defines diagnostic trouble codes (DTCs) and definitions.

J2178-2: defines definitions for data parameters

J2284-3: defines CAN physical and data link layer

<u>International Standards Organisation (ISO) Standards</u>

ISO 9141: Road Vehicles – Diagnostic Systems (1989)

ISO 11898: Road Vehicles – Controller Area Network (CAN) (2003)

ISO 14230: Road Vehicles – Diagnostic Systems, Keyword Protocol (1999)

ISO 15031: Communication Between Vehicle and External Equipment for Emission-related Diagnostics (2010)

ISO 15765: Road Vehicles – Diagnostics on Controller Area Network (CAN) (2004)

10.2 Use Cases

- Only one vehicle in a collision is able to have data extracted: by using mathematics and modelling, it is still possible to get *both* vehicle's speeds at the point of impact.
- By extracting data at the scene, you can perform analysis on it later in the lab. This could help to speed up crash site procedures and allow traffic to regulate itself sooner.
- Hit while parked claims.
- Who-hit-whom-first claims.
- Testing phone use at time of crash.
- Occupancy verification or dispute.
- Seatbelt status (assessing injury claims).
- Impact severity (assessing injury claims).
- Validate witness testimony.
- Assist in crash reconstructions.
- Help to identify cases of fraud.
- Shorten claims times.
- Some European countries have successfully implemented similar analysis for checking emissions compliance.

10.3 Code of Federal Regulations (US Federal Motor Vehicle Safety Standards 2011)

The Code of Federal Regulations (CFR) 2011 Title 49 Volume 6 Section 563.6 of the United States Federal Motor Vehicle Safety Standards sets out the minimum requirements for vehicles, and states the following:

"Each vehicle equipped with an EDR must meet the requirements specified in §563.7 for data elements, §563.8 for data format, §563.9 for data capture, §563.10 for crash test performance and survivability, and §563.11 for information in owner's manual."

The data elements mentioned in §563.7 are captured in table 3 below:

Table 3: Data elements required for all vehicles equipped with an EDR (Event Data Recorder)

Data Element	Recording interval time (relative to time zero)	Data sample rate (samples per second)
Delta-v longitudinal	0-250 milliseconds or 0 to end of event time plus 30 ms (whichever is shorter)	100
Maximum delta-v, longitudinal	0-300 milliseconds or 0 to end of event time plus 30 ms (whichever is shorter)	N/A
Time, maximum delta-v	0-300 milliseconds or 0 to end of event time plus 30 ms (whichever is shorter)	N/A
Speed, vehicle indicated	-5 to 0 seconds	2

Data Element	Recording interval time (relative to time zero)	Data sample rate (samples per second)
Engine throttle, % full (or accelerator pedal, % full)	-5 to 0 seconds	2
Service brake, on/off	-5 to 0 seconds	2
Ignition cycle, at crash	-1 second	N/A
Ignition cycle, at download	At time of download	N/A
Safety belt status, driver	-1 second	N/A
Frontal air bag warning lamp, on/off	-1 second	N/A
Frontal air bag deployment, time to deploy, in the case of a single-stage air bag, or time to first-stage deployment in the case of a multi-stage air bag, driver	Event	N/A
Frontal air bag deployment, time to deploy, in the case of a single-stage air bag, or time to first-stage deployment in the case of a multi-stage air bag, right front passenger*	Event	N/A
Multi-event, number of events (1, 2)	Event	N/A
Time from event 1 to 2	As needed	N/A
Complete file recorded, yes/no	Following other data	N/A

* Note: this is a US regulation which accounts for the front passenger being on the right.

Table 4: Data element format

Data element	Minimum range	Accuracy	Resolution
Lateral acceleration	At option of manufacturer	At option of manufacturer	At option of manufacturer
Longitudinal acceleration	At option of manufacturer	At option of manufacturer	At option of manufacturer
Normal acceleration	At option of manufacturer	At option of manufacturer	At option of manufacturer
Longitudinal delta-v	-100 to +100 km/h	±10%	1 km/h
Lateral delta-v	-100 to +100 km/h	±10%	1 km/h
Maximum delta-v, longitudinal	-100 to +100 km/h	±10%	1 km/h
Maximum delta-v, lateral	-100 to +100 km/h	±10%	1 km/h
Time, maximum delta-v, longitudinal	0-300 ms, or 0 to end of event plus 30 ms*	±3 ms	2.5 ms

Data element	Minimum range	Accuracy	Resolution
Time, maximum delta-v, lateral	0-300 ms, or 0 to end of event plus 30 ms*	±3 ms	2.5 ms
Time, maximum delta-v, resultant	0-300 ms, or 0 to end of event plus 30 ms*	±3 ms	2.5 ms
Vehicle roll angle	-1080 to +1080 degrees	±10%	10 degrees
Speed, vehicle indicated	0-200 km/h	±1 km/h	1 km/h
Engine throttle, % full, or accelerator pedal % full	0-100%	±5%	1%
Engine rpm	0-10,000 rpm	±100 rpm	100 rpm
Service brake	On or off	N/A	On or off
ABS activity	On or off	N/A	On or off
Stability control	On, off or engaged	N/A	On, off or engaged
Steering input	±100%	±5%	1%
Ignition cycle, at crash	0-60,000	±1 cycle	1 cycle
Ignition cycle, at download	0-60,000	±1 cycle	1 cycle
Safety belt status, driver	On or off	N/A	On or off
Safety belt status, front passenger	On or off	N/A	On or off
Frontal air bag warning lamp	On or off	N/A	On or off
Frontal air bag suppression switch status, front passenger	On, off or auto	N/A	On, off or auto
Frontal air bag deployment, time to deploy first-stage, driver	0-250 ms	± 2 ms	1 ms
Frontal air bag deployment, time to deploy first-stage, front passenger	0-250 ms	± 2 ms	1 ms
Frontal air bag deployment, time to nth-stage, driver	0-250 ms	± 2 ms	1 ms
Frontal air bag deployment, time to nth-stage, front passenger	0-250 ms	± 2 ms	1 ms
Frontal air bag deployment, nth-stage disposal, driver	Yes or no	N/A	Yes or no
Frontal air bag deployment, nth-stage disposal, front passenger	Yes or no	N/A	Yes or no

Data element	Minimum range	Accuracy	Resolution
Side air bag deployment, time to deploy, driver	0-250 ms	± 2 ms	1 ms
Side air bag deployment, time to deploy, front passenger	0-250 ms	± 2 ms	1 ms
Side curtain/tube air bag deployment, time to deploy, driver	0-250 ms	± 2 ms	1 ms
Side curtain/tube air bag deployment, time to deploy, front passenger	0-250 ms	± 2 ms	1 ms
Pretensioner deployment, time to fire, driver	0-250 ms	± 2 ms	1 ms
Pretensioner deployment, time to fire, front passenger	0-250 ms	± 2 ms	1 ms
Seat track position switch, foremost, status, driver	Yes or no	N/A	Yes or no
Seat track position switch, foremost, status, front passenger	Yes or no	N/A	Yes or no
Occupant size classification, driver	5^{th} percentile female or larger	N/A	Yes or no
Occupant size classification, front passenger	Child	N/A	Yes or no
Occupant position classification, driver	Out of position	N/A	Yes or no
Occupant position classification, front passenger	Out of position	N/A	Yes or no
Multi-event, number of events	1 or 2	N/A	1 or 2
Time from event 1 to 2	0 to 5.0 seconds	0.1 seconds	0.1 seconds
Complete file recorded	Yes or no	N/A	Yes or no

* Whichever is the shorter of the two.

Source for tables 3 and 4: *CFR 2011 Title 49 Volume 6. Retrieved from https://www.govinfo.gov/content/pkg/CFR-2011-title49-vol6/pdf/CFR-2011-title49-vol6-part563.pdf*

10.4 Additional considerations

Motorcycles, Trucks and Buses

This report has thus far been in reference to cars, but there is still a need to have the same data available for other road users, namely, trucks, buses and motorcycles. Further investigation is required.

OEMs

Because many of the manufacturers and suppliers are different, alternative solutions may need to be investigated. This was not considered to be a part of the intended use of this report but can be added if required.

Hacking

It has not yet been tested if one can hack into and change event data, or the difficulty of doing so.

Autonomous Systems

It is not yet known if it possible to detect if autonomous driver assistance systems are engaged at the time of, or right before an incident occurring.

Tesla

It may be important to know that at least one other manufacturer, Tesla does things differently by developing and using entirely their own systems. This makes things both easier and harder. On the one hand they have one controller module, giving access to almost everything at once. It also records 360-degrees around the vehicle for the entirety of the journey, and the data can be access by the owner via the centre console (it is stored on a USB stick), which makes processing accidents or thefts that much easier.

The thing to watch is if other manufacturers begin to adopt some of these practices themselves as Tesla's market share swells.

Bosch currently sells an EDR for Tesla kit for the US market only.

Present-day Difficulties

The need for updating the current set of standards is being tested with rapidly increasing technologic advancements becoming the new standard in safety and features.

Modern vehicles have become connected to many more sensors and computer systems than even as little as five years ago. Some useful data not accessible by traditional OBD-II extraction methods are:

Cameras: modern vehicles can be found with both internal and external cameras or aftermarket dashcams. Footage obtained before, during and after an accident or crime will be invaluable to investigators.

Microphones: microphones are used in many modern applications within the vehicle, for example, using the Mercedes-Benz voice control system, you simply announce "Hey, Mercedes" and give it a command, much like Google Assistant, Amazon's Alexa or Apple's Siri. This has the implication that it is always listening, and there is potential for previous commands to be stored somewhere in the system.

Phone Data: most consumers are unaware that text messages, call logs, contacts, music and much more are often uploaded to the vehicle simply upon connecting the phone to the port. A metaphorical treasure trove of phone data can be accessed via the head unit (infotainment system). This could tell an investigator a lot about events prior to, during, and after, a crime.

GPS: the global positioning system (GPS) tracks a vehicles movement and relays position information (longitude and latitude) back via cellular networks. Some systems can also report speed, key on/off, and engine data, such as fuel level, oil temperature and RPMs.

Proximity Sensors: many advanced driver assistance systems (ADAS) utilise sensors to determine the vehicle position relative to other road users and objects. This data could be used to help in crash reconstructions, along with data captured by the EDR.

Many would benefit from updating some of the above data to be included as retrievable via OBD-II as a standard. This way, manufacturers, dealers, insurance agencies, and law enforcement agencies, can get easy access to data that may help detect criminal behaviour, or assist in investigations.

10.5 ECU Chip Tuning

An ECU is an essential electronic component that controls the processes of sensor input and controller output. These sensors include air flow input to the engine, air fuel ratio oxygen sensors and temperature measuring sensors. The values are managed by the ECU within a set of predefined parameters to ensure the engine operates to the manufacturer's specifications.

ECU chip tuning is the technique of reprograming the vehicle's ECU parameters to allow for changes in output such as performance increase. The process can include the unlocking of the ECU's software, adding of hardware to the existing ECU or the replacement of entire component. By doing so, adjustments are made to the ignition timing, fuel maps, boost and fuel pressure which in turn can equate to a 30% increase horsepower and 10% increase in fuel economy.

There are three different types of ECU chip tuning being researched and available on the market. These include standalone ECU, piggyback and reflashing with many differences as outlined in table 1. The tuning is not limited to everyday petrol and diesel vehicles but also available for commercial trucks and agricultural vehicles.

The ECU controls a lot of different systems, and most of them are vital to how the engine works. The process of making any changes to the operation of a vehicle will pose a risk due to the fact that the stock parts are chosen with the manufacturer's default settings in mind. The car's standard brakes, tires and suspension are all matched to the car's power output at production, incorrect practices can result in overly dangerous boost in power and hence potentiate accidents.

Whilst there are legal modifications offered by the manufacturer, it however does not affect the vehicle's design. In New South Wales, the Vehicle Standard Information on Light Vehicle Modification is intended to help vehicle owners and modifiers determine what modifications will require certifications as they exceed the state's rules. Certificates for modification is issued by a person accredited as a licensed certifier on the Road and Maritime Services (RMS) Vehicle Safety Compliance Certificate Scheme (VSCCS). Along with certifications, any modifications to the engine and ECU fitted in an ADR emissions complying vehicle must demonstrate that the emissions levels are retained. The testing for emissions is conducted at specific Heavy Vehicle Inspection Stations (HVIS) or a 4 to 5 gas analyser test may be conducted at a vehicle repairer to prove acceptable emissions levels.

Although the modifications will aid in some driving environments such as towing of additional loads, it is crucial that other aspect of the vehicle should be accounted for. For example, an increase in the vehicle's performance will affect the effectiveness of the braking system and when emergency braking is required, the brakes won't have enough stopping-power. In Australia, upgrading brakes is not mandatory when increasing car performance hence posing a serious risk to driver's safety as well as others.

Any modifications to the vehicle will require the notification to the owner's insurance provider, however this is up to the owner's discretion. Currently in Australia, there is no means of detecting alterations to vehicle ECUs without physical assessment. In cases where the vehicle is being assessed, the ECU module can be removed to avoid detection.
The recommendation by Cesvi France (RCAR conference 2018) to overcome this issue is to:

1. Perform checksum verification at ignition cycle to verify the checksum data.
2. Ban the original file extraction from OBD.
3. Encrypt the original file.
4. Apply modification recognition.
5. Ensure password protection.

The increase use of ECU chip tuning and the adoption of illegal modifications poses a greater risk on road safety. The lack of strict assessments and mandatory upgrades after ECU chip tuning is linked to higher risk of accidents.

The ongoing problem with this issue is the lack of awareness and training within the different industries. Introduction of training on state laws for vehicle modification will allow increase knowledge so that detection can be made. The process of inspection would need to be thorough, which again comes with the knowledge attained from further training.

Table 5: Comparison of types of chip tuning

	Standalone ECU	**Piggyback ECU**	**Re-flashing**
Physical differentiation	Standalone replacement ECU located in OEM ECU location.	Piggyback ECU connects between sensor connectors and physical wiring harness	Process of reprogramming OEM ECU, which may require add-on boards or specialist tooling. It can be difficult to identify as everything is fully enclosed.
Functionality	For motorsport/off-road use.	Piggyback ECU acts as a man-in-the-middle to alter OEM signals in order to increase engine performance. It is easy to install and remove and does not trigger	Dependant on Make/Models and ECU's. it has limited parameters and fewer adjustments.

	Standalone ECU	Piggyback ECU	Re-flashing
		engine lights or error codes. It can be connected via Bluetooth and WIFI.	
Stored data	Loss of all OEM stored data as the OEM ECU is removed. Can log engine parameters and additional sensors to SD memory.	Maintains all OEM stored data and functionality	Maintains all OEM stored data and functionality
Pros	Limitless adjustments to parameter and can add extra features to existing vehicle.	Easy to setup and tune. Mobile app functionality for over-the-air updates, viewing of live data stream and logging of engine parameters. Retains OBD diagnostics port functionality and emissions control.	Cost effective.
Cons	Requires custom wiring harness or patch harness to connect to the ECU, tuning specialist, labour intensive and time consuming.	Web-based community and/or dealer support with periodic update to fix bugs and add features.	Requires OEM ECU to be unlock or physically modified. Require laptop and specific software to read/write values. Values are logged on the physical ECU. Limited to adjustments and overall performance.
Cost	~$2000-$6000 plus labour & tuning.	~$1800-$3000 plus labour & tuning.	Under $1000 plus labour & tuning.

Source: IAG Research Centre research.

10.6 Bosch CDR Report 1: Mitsubishi ASX

IMPORTANT NOTICE: Robert Bosch LLC and the manufacturers whose vehicles are accessible using the CDR System urge end users to use the latest production release of the Crash Data Retrieval system software when viewing, printing or exporting any retrieved data from within the CDR program. Using the latest version of the CDR software is the best way to ensure that retrieved data has been translated using the most current information provided by the manufacturers of the vehicles supported by this product.

CDR File Information

User Entered VIN	JMFXTGA2WJU009196
User	s74210
Case Number	NRA123
EDR Data Imaging Date	03/03/2021
Crash Date	01/26/2020
Filename	JMFXTGA2WJU009196_ACM.CDRX
Saved on	Wednesday, March 3 2021 at 16:29:44
Imaged with CDR version	Crash Data Retrieval Tool 21.0.1
Imaged with Software Licensed to (Company Name)	Insurance Australia Group-Research Centre
Reported with CDR version	Crash Data Retrieval Tool 21.0.1
Reported with Software Licensed to (Company Name)	Insurance Australia Group-Research Centre
EDR Device Type	Airbag Control Module
Event(s) recovered	Record 1

Comments

DATE TIME PLACE
CDR900
DLC
MITSUBISHI ASX
YEAR 2018
225/55/R18
TYRE PLACARD 225/55/R18

Data Limitations

General Information:

These limitations are intended to assist you to read EDR data from the airbag control unit. They are not intended to provide specific information regarding the interpretation of this data. Event data should be considered in conjunction with other available physical evidence from the vehicle and scene.

Recorded Crash Events:

- A non-deployment event is recorded if the change in longitudinal or lateral velocity equals or exceeds 8km/h over a 150ms timeframe or another type of non-reversible deployable restraint device other than a front, side, or side curtain airbag (e.g. seatbelt pretensioner) is commanded to deploy. Except as indicated below, non-deployment events are not locked into memory and can be over-written by subsequent non-deployment or deployment events.
- A deployment event is recorded if front airbag(s), side airbag(s), or side curtain airbag(s) are commanded to deploy. Deployment events are locked into memory and cannot be over-written.

Data:

- Delta V, longitudinal reflects the change in velocity that the airbag control unit experienced in the longitudinal direction during therecorded portion of the event and is not the speed the vehicle was traveling before the event.
- Speed, vehicle indicated data accuracy can be affected by various factors, including but not limited to the following: - Significant changes in tire size from the factory setting - Wheel lockup
- Slip
- Accelerator pedal position, percent full means the ratio of accelerator pedal position compared to the fully depressed position.
- Service brake, on/off means the state of the brake pedal switch.
- Ignition cycle means the number of power cycles applied to the airbag control unit.
- Time to deploy means the elapsed time from crash time zero to the deployment command.
- If airbag or other restraint system is not deployed, time to deploy reports a "0". And if airbag or other restraint system is deployed before cumulative delta-V is reached to Time-Zero thresholds, time to deploy reports a "0".
- Multi-event, number of event reports a "1" in case of single event. In the case of a multiple event, the data from the first event reports a "1". The data from the subsequent event reports a "2".
- Time from event 1 to 2 is reported in 2nd event data in case of a multiple event.
- Complete file recorded reports "Incomp. Record" if power to airbag control unit is lost during an event.
- Acceleration Time-History data is as follows:
    (1) The Time Step (TS) is 10msec.
    (2) The number of the first point (NFP) is 0.
    (3) The number of the last point (NLP) is 25.

- Lateral or Longitudinal acceleration data that exceeds the design range of the sensor is 60G.
- Depending on the vehicle specification, some items may not be recorded. If these items are not recorded, they will be identified in this document.

Data Element Sign Convention:

The following table provides an explanation of the sign notation for data elements that may be included in this CDR report. Directional references to sign notation are from the perspective of the driver when seated in the vehicle facing the direction of forward vehicle travel.

Data Element Name	Positive Sign Notation Indicates
Longitudinal	Forward direction acceleration
Lateral	Left to right direction acceleration
Vertical (Normal)	Downward direction acceleration
Roll	Left to right rotation
Steering Input Angle	Left Turn

Hexadecimal Data:

All data that has been specified for imaging is shown in the hexadecimal data section of this report. However, not all of this data is translated by the CDR tool. The imaged ECU may contain additional data that is not retrievable by the CDR tool.

21003_Mitsubishi_003_r001

System Status at Retrieval

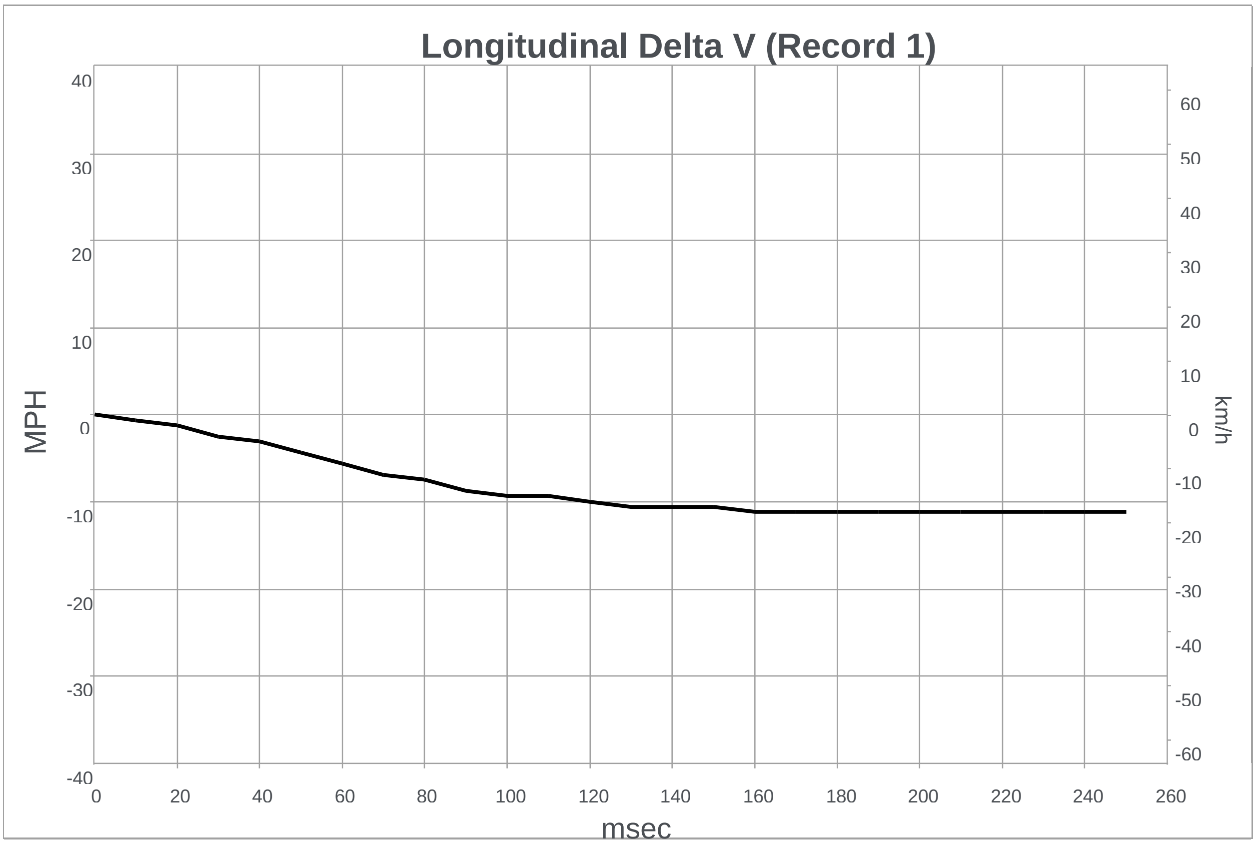
Original VIN	JMFXTGA2WJU009196
Current VIN	JMFXTGA2WJU009196
Diagnostic Variant Code	81 04 73 00
ECU Model Code	KJFA
ECU Century	20
ECU Year	18
ECU Month	04
ECU Day	09
ECU Serial Number	81 30 49 23 30
ECU Part Number	8635A321
Ignition Cycle, Download	3,223

System Status at Event (Record 1)

Ignition Cycle, Crash	3,204
Multi-event, Number of Events (1,2)	1
Time From Event 1 to 2 (ms)	0.0
Complete File Recorded (Yes, No)	Yes
Safety Belt Status, Driver	SNA
Safety Belt Status, Front Right Passenger	SNA
Frontal Air Bag Warning Lamp, On/Off	Off
Frontal Air Bag Suppression Switch Status	None
Seat Track Position Switch Status, Driver	None
Occupant Size Classification, Passenger, Child Size	None
Maximum Delta-V, Longitudinal (MPH [km/h])	-11.2 [-18]
Time, Maximum Delta-V Longitudinal (ms)	260
Maximum Delta-V, Lateral (MPH [km/h])	5.0 [8]
Time, Maximum Delta-V Lateral (ms)	190
Time, Maximum Delta-V, Resultant (ms)	160
Sensor Design Range was Exceeded, Time, Longitudinal Delta-V (ms)	Not Exceeded
Sensor Design Range was Exceeded, Time, Lateral Delta-V (ms)	Not Exceeded

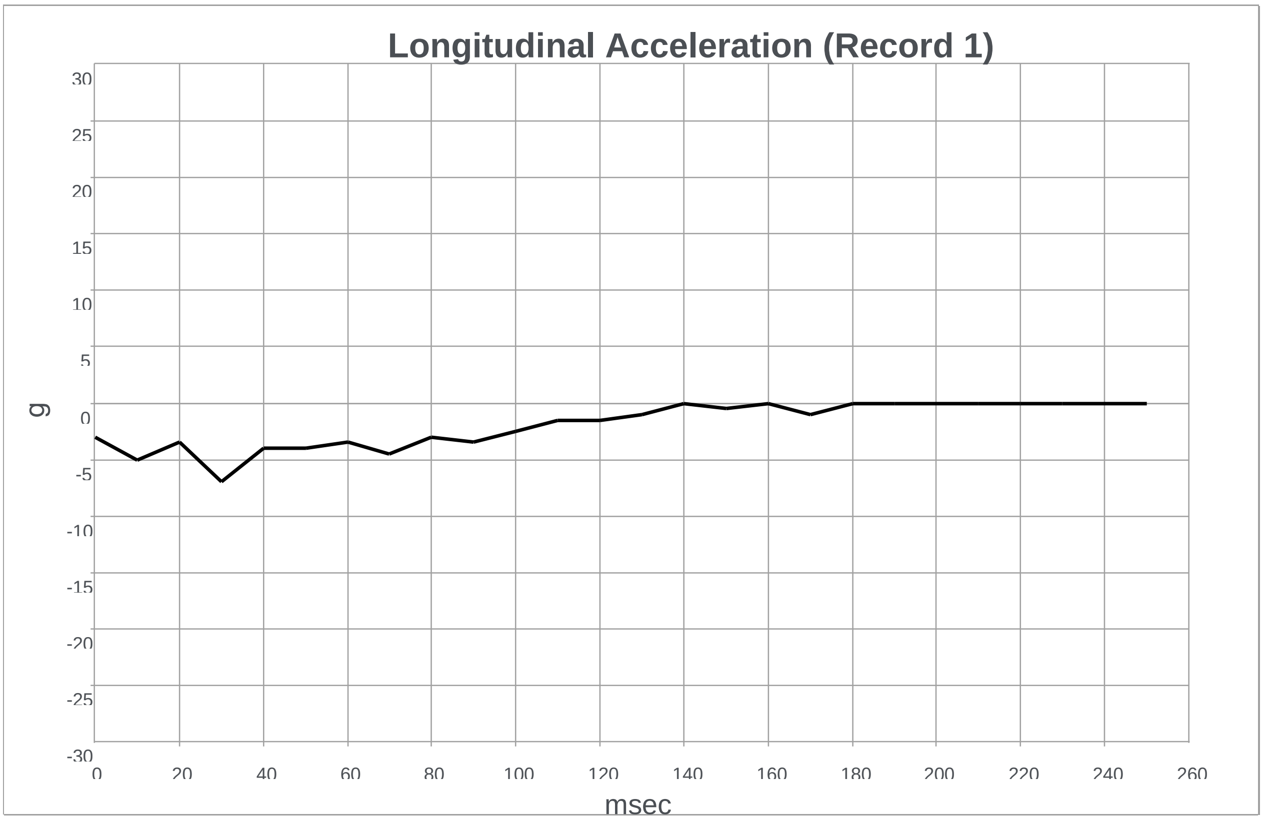
Deployment Command Data (Record 1)

Frontal Airbag Deployment, 2nd Stage Disposal, Driver	Not Disposal
Frontal Airbag Deployment, Time to 1st Stage, Driver (ms)	0.0
Frontal Airbag Deployment, Time to 1st Stage, Passenger (ms)	0.0
Side Airbag Deployment, Time to Deploy, LH (ms)	0.0
Side Airbag Deployment, Time to Deploy, RH (ms)	0.0
Side Curtain Airbag Deployment, Time to Deploy, LH (ms)	0.0
Side Curtain Airbag Deployment, Time to Deploy, RH (ms)	0.0
Pretensioner Deployment, Time to Fire, Driver (ms)	0.0
Pretensioner Deployment, Time to Fire, Passenger (ms)	0.0
Frontal Airbag Deployment, Time to 2nd Stage, Driver (ms)	SNA
Frontal Airbag Deployment, 2nd Stage Disposal, Passenger	Not Disposal
Frontal Airbag Deployment, Time to 2nd Stage, Passenger (ms)	0.0



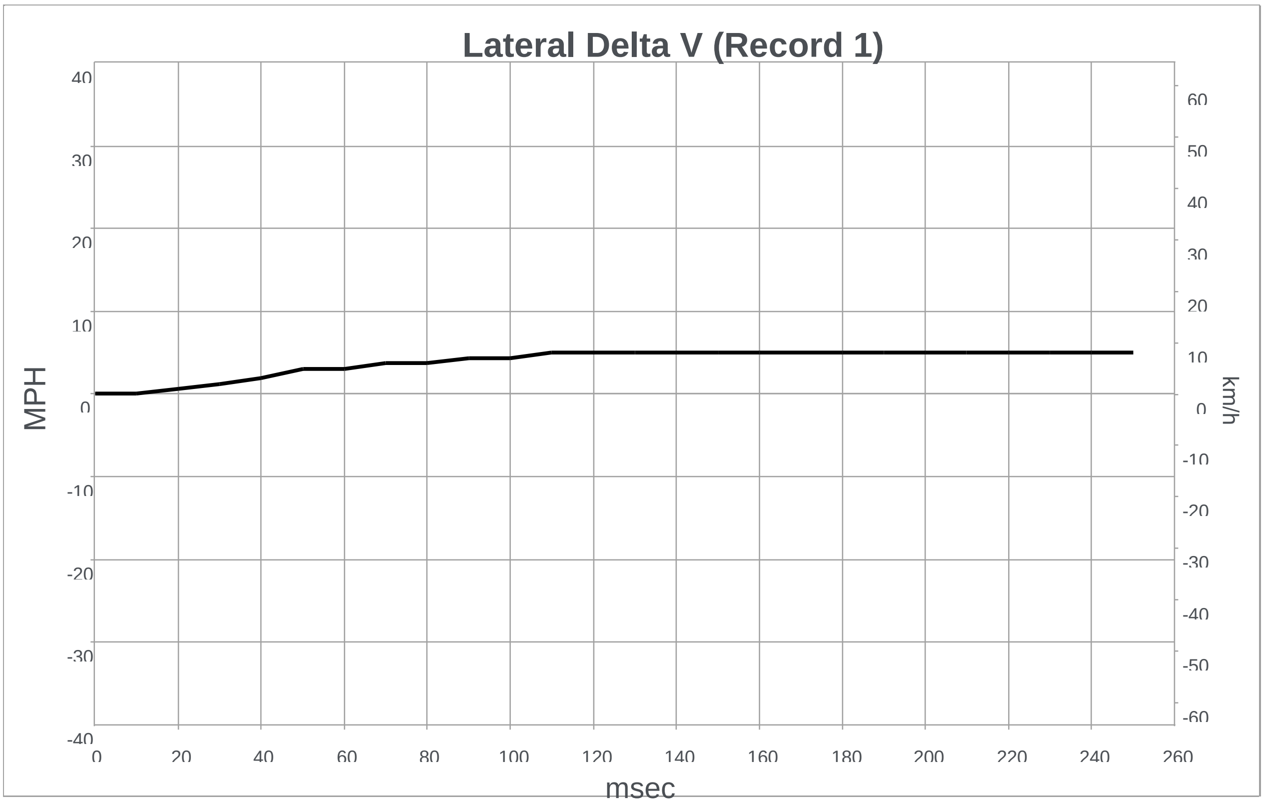
Longitudinal Delta V (Record 1)

Time (msec)	Delta-V, Longitudinal (MPH [km/h])
0	0.0 [0]
10	-0.6 [-1]
20	-1.2 [-2]
30	-2.5 [-4]
40	-3.1 [-5]
50	-4.3 [-7]
60	-5.6 [-9]
70	-6.8 [-11]
80	-7.5 [-12]
90	-8.7 [-14]
100	-9.3 [-15]
110	-9.3 [-15]
120	-9.9 [-16]
130	-10.6 [-17]
140	-10.6 [-17]
150	-10.6 [-17]
160	-11.2 [-18]
170	-11.2 [-18]
180	-11.2 [-18]
190	-11.2 [-18]
200	-11.2 [-18]
210	-11.2 [-18]
220	-11.2 [-18]
230	-11.2 [-18]
240	-11.2 [-18]
250	-11.2 [-18]


Longitudinal Acceleration (Record 1)
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
g
0
20
40
60
80
100
120
140
160
180
200
220
240
260
msec

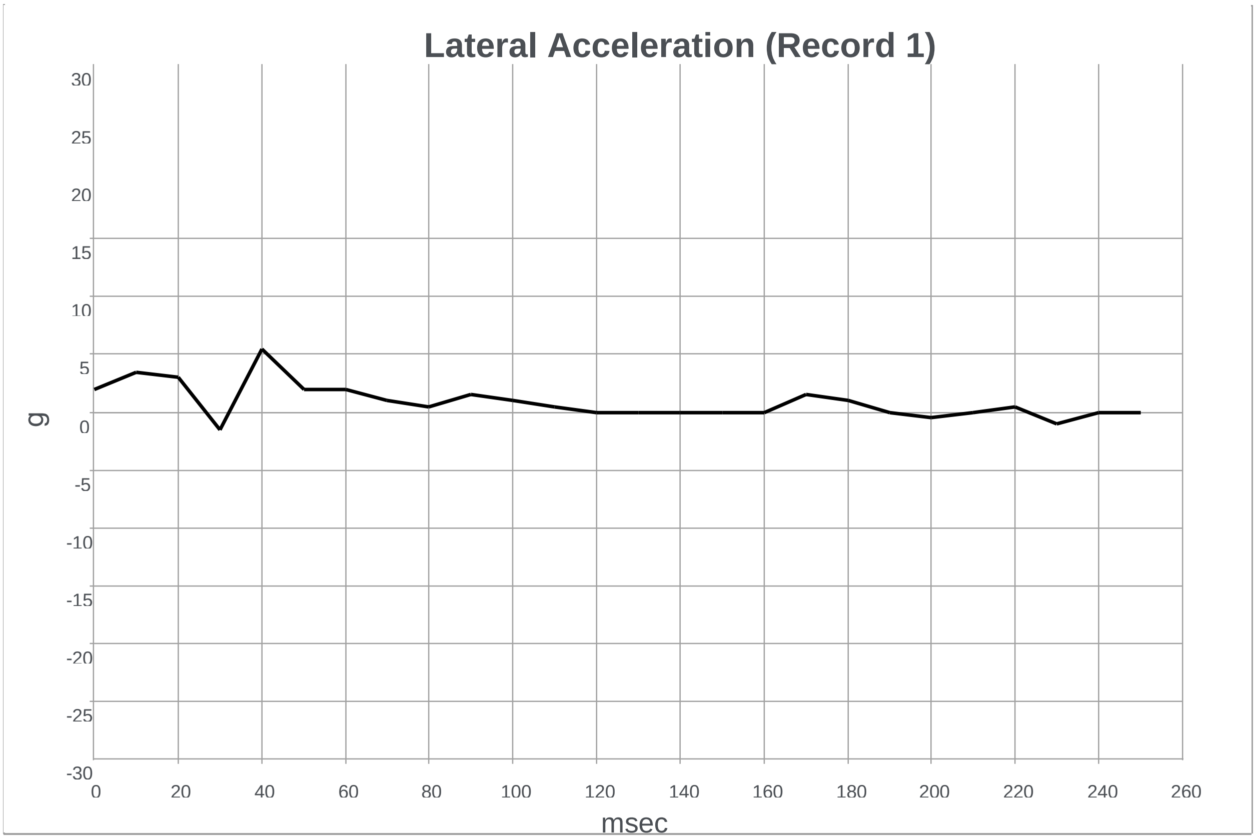
Longitudinal Acceleration (Record 1)

Time (msec)	Longitudinal Acceleration (g)
0	-3.0
10	-5.0
20	-3.5
30	-7.0
40	-4.0
50	-4.0
60	-3.5
70	-4.5
80	-3.0
90	-3.5
100	-2.5
110	-1.5
120	-1.5
130	-1.0
140	0.0
150	-0.5
160	0.0
170	-1.0
180	0.0
190	0.0
200	0.0
210	0.0
220	0.0
230	0.0
240	0.0
250	0.0



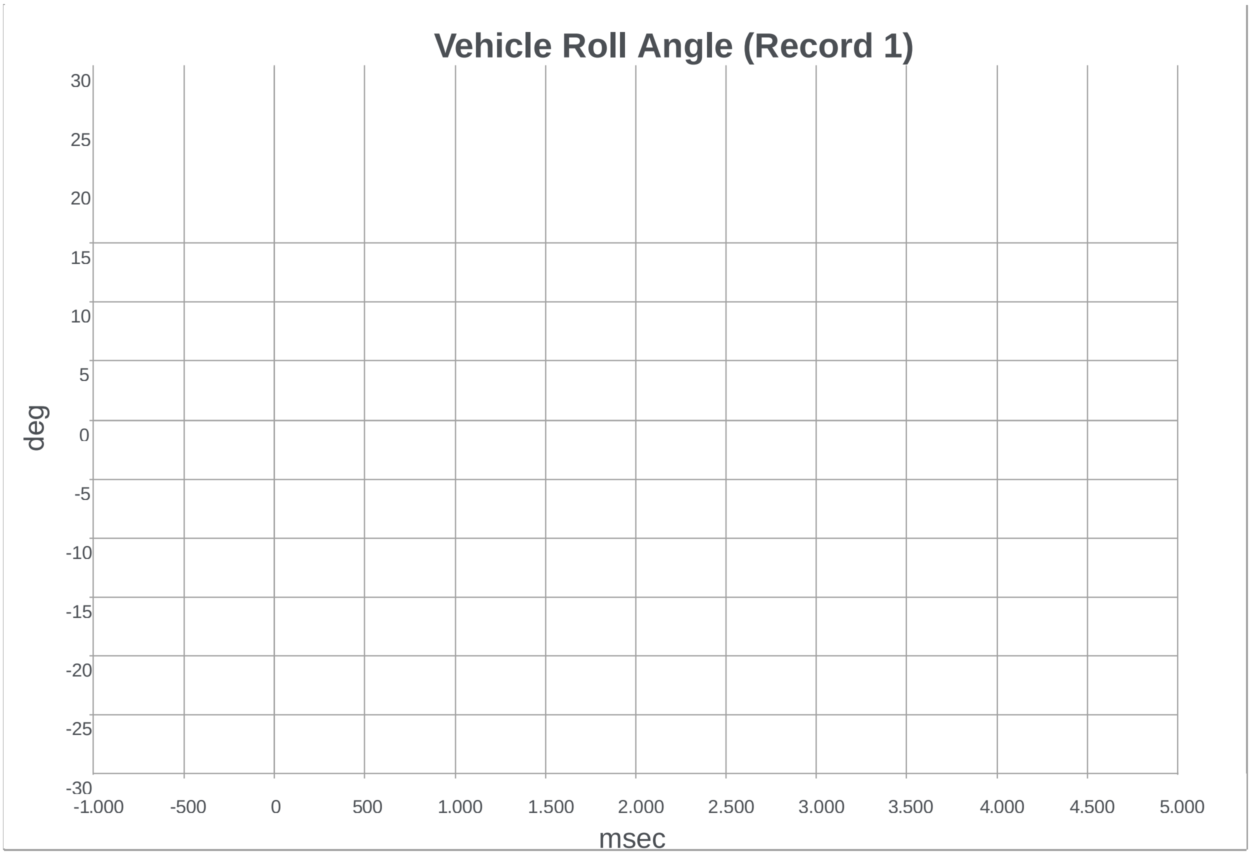
Lateral Delta V (Record 1)

Time (msec)	Delta-V, Lateral (MPH [km/h])
0	0.0 [0]
10	0.0 [0]
20	0.6 [1]
30	1.2 [2]
40	1.9 [3]
50	3.1 [5]
60	3.1 [5]
70	3.7 [6]
80	3.7 [6]
90	4.3 [7]
100	4.3 [7]
110	5.0 [8]
120	5.0 [8]
130	5.0 [8]
140	5.0 [8]
150	5.0 [8]
160	5.0 [8]
170	5.0 [8]
180	5.0 [8]
190	5.0 [8]
200	5.0 [8]
210	5.0 [8]
220	5.0 [8]
230	5.0 [8]
240	5.0 [8]
250	5.0 [8]


Lateral Acceleration (Record 1)
g
msec
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
0
20
40
60
80
100
120
140
160
180
200
220
240
260

Lateral Acceleration (Record 1)

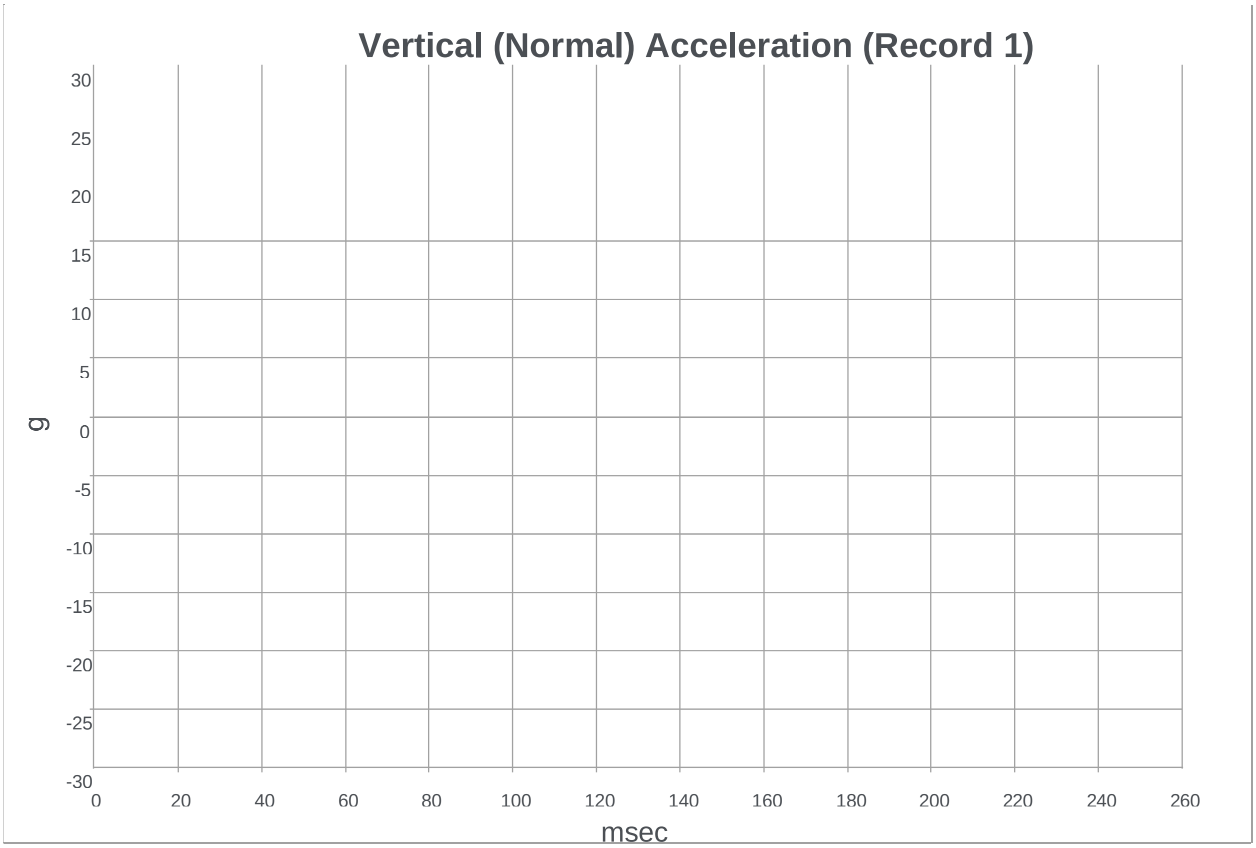
Time (msec)	Lateral Acceleration (g)
0	2.0
10	3.5
20	3.0
30	-1.5
40	5.5
50	2.0
60	2.0
70	1.0
80	0.5
90	1.5
100	1.0
110	0.5
120	0.0
130	0.0
140	0.0
150	0.0
160	0.0
170	1.5
180	1.0
190	0.0
200	-0.5
210	0.0
220	0.5
230	-1.0
240	0.0
250	0.0


Vehicle Roll Angle (Record 1)
deg
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-1.000
-500
0
500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
4.500
5.000
msec

Vehicle Roll Angle (Record 1)

Time (msec)	Vehicle Roll Angle (deg)
-1000	SNA
-900	SNA
-800	SNA
-700	SNA
-600	SNA
-500	SNA
-400	SNA
-300	SNA
-200	SNA
-100	SNA
0	SNA
100	SNA
200	SNA
300	SNA
400	SNA
500	SNA
600	SNA
700	SNA
800	SNA
900	SNA
1000	SNA
1100	SNA
1200	SNA
1300	SNA
1400	SNA
1500	SNA
1600	SNA
1700	SNA
1800	SNA
1900	SNA
2000	SNA
2100	SNA
2200	SNA
2300	SNA
2400	SNA
2500	SNA
2600	SNA
2700	SNA
2800	SNA

Time (msec)	Vehicle Roll Angle (deg)
2900	SNA
3000	SNA
3100	SNA
3200	SNA
3300	SNA
3400	SNA
3500	SNA
3600	SNA
3700	SNA
3800	SNA
3900	SNA
4000	SNA
4100	SNA
4200	SNA
4300	SNA
4400	SNA
4500	SNA
4600	SNA
4700	SNA
4800	SNA
4900	SNA
5000	SNA


Vertical (Normal) Acceleration (Record 1)
g
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
0
20
40
60
80
100
120
140
160
180
200
220
240
260
msec

Vertical (Normal) Acceleration (Record 1)

Time (msec)	Vertical (Normal) Acceleration (g)
0	SNA
10	SNA
20	SNA
30	SNA
40	SNA
50	SNA
60	SNA
70	SNA
80	SNA
90	SNA
100	SNA
110	SNA
120	SNA
130	SNA
140	SNA
150	SNA
160	SNA
170	SNA
180	SNA
190	SNA
200	SNA
210	SNA
220	SNA
230	SNA
240	SNA
250	SNA

Pre-Crash Data -5 to 0 Sec (Record 1)

Time (sec)	Speed, Vehicle Indicated (MPH [km/h])	Accelerator Pedal, % Full (%)	Service Brake (On/Off)	Engine RPM (RPM)	Steering Input (deg)
-5.0	5.0 [8]	4	Off	1,076	231.5
-4.5	5.0 [8]	3	Off	1,116	294.5
-4.0	5.6 [9]	3	Off	1,134	373.0
-3.5	5.6 [9]	3	Off	1,168	468.5
-3.0	5.6 [9]	3	Off	1,194	487.5
-2.5	5.6 [9]	3	Off	1,197	551.0
-2.0	5.6 [9]	5	Off	1,195	561.5
-1.5	5.6 [9]	26	Off	1,704	488.0
-1.0	9.9 [16]	87	Off	2,557	346.0
-0.5	13.0 [21]	92	Off	2,960	283.0
0.0	16.2 [26]	87	Off	3,737	283.0

Hexadecimal Data
Data that the vehicle manufacturer has specified for data retrieval is shown in the hexadecimal data section of the CDR report. The hexadecimal data section of the CDR report may contain data that is not translated by the CDR program. The control module contains additional data that is not retrievable by the CDR system.

61 2B 78 77 76 74 73 71 6F 6D 6C 6A 69 69 68 67 67 67 66 66 66 66 66 66 66 66 66 66 FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF

61 2C 66 FF

61 2D 68 FF

61 2E 08 08 09 09 09 09 09 09 10 15 1A FF FF FF FF FF FF FF FF FF FF FF

61 2F 3B 38 38 39 39 39 3D 63 D5 DE D5 FF FF FF FF FF FF FF FF FF

FF FF 61 30 00 00 00 00 00 00 00 00 00 00 00 FF FF FF FF FF FF FF

FF FF FF FF

61 31 0C 84 FF FF

61 32 0C 97

61 33 00 FF

61 34 00 FF

61 35 00 00 FF FF

61 36 00 00

FF FF 61 37

01 FF

61 38 00 00 FF FF

61 39 55 FF

61 3A 7C 7F 7E 75 83 7C 7C 7A 79 7B 7A 79 78 78 78 78 78 7B 7A 78 77 78 79 76 78 78 FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF

61 3B 72 6E 71 6A 70 70 71 6F 72 71 73 75 75 76 78 77 78 76 78 78 78 78 78 78 78 78 FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF

61 3C FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF

61 3D 78 78 79 7A 7B 7D 7D 7E 7E 7F 7F 80 80 80 80 80 80 80 80 80 80 80 80 80 80 80 FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF

61 3E 80 FF

61 3F 4C FF

61 40 40 FF

61 41 04 34 04 5C 04 6E 04 90 04 AA 04 AD 04 AB 06 A8 09 FD 0B 90 0E 99 FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF

61 42 FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF

61 45 11 CF 12 4D 12 EA 13 A9 13 CF 14 4E 14 63 13 D0 12 B4 12 36 12 36 FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF

61 46 00 FF

61 47 03 FF

61 48 FF FF FF FF

61 49 00 00 FF FF

61 4A 00 FF

61 4B 00 FF

61 4C 00 00 FF FF

61 4D 00 00 FF FF

61 4E 00 00 FF FF

61 4F 00 00 FF FF

61 50 00 00 FF FF

61 51 00 00 FF FF

61 52 04 FF

61 55 08 FF

61 60 3B 1F 80 0F 01 A0 02 A0 55

61 E1 4B 4A 46 41 20 18 04 09 81 30 49 23 30

5A 87 04 03 00 01 FF 03 06 00 09 00 38 36 33 35 41 33 32

31 20 20 5A 88 4A 4D 46 58 54 47 41 32 57 4A 55 30 30 39

31 39 36 5A 89 81 04 73 00

5A 90 4A 4D 46 58 54 47 41 32 57 4A 55 30 30 39 31 39 36

58 04 94 21 E0 94 31 A0 94 76 20 94 77 20

10.7 Bosch CDR Report 2: Lexus ES200H

IMPORTANT NOTICE: Robert Bosch LLC and the manufacturers whose vehicles are accessible using the CDR System urge end users to use the latest production release of the Crash Data Retrieval system software when viewing, printing or exporting any retrieved data from within the CDR program. Using the latest version of the CDR software is the best way to ensure that retrieved data has been translated using the most current information provided by the manufacturers of the vehicles supported by this product.

CDR File Information

User Entered VIN/Frame Number	JTHB21B1902098107
User	JP
Case Number	TST040321
EDR Data Imaging Date	03/04/2021
Crash Date	03/04/2022
Filename	JTHB21B1902098107_ACM.CDRX
Saved on	Thursday, March 4 2021 at 11:17:00
Imaged with CDR version	Crash Data Retrieval Tool 21.0.1
Imaged with Software Licensed to (Company Name)	Insurance Australia Group-Research Centre
Reported with CDR version	Crash Data Retrieval Tool 21.0.1
Reported with Software Licensed to (Company Name)	Insurance Australia Group-Research Centre
EDR Device Type	Airbag Control Module
Event(s) recovered	Front/Rear/Side Events (1)

Comments

LEXUS ES300H
CDR900
Direct to vehicle
Battery boosted
215/55R17
Tyre placard
215/55R17

Data Limitations

CDR Record Information:

- Due to limitations of the data recorded by the airbag ECU, such as the resolution, data range, sampling interval, time period of the recording, and the items recorded, the information provided by this data may not be sufficient to capture the entire crash.
- Pre-Crash data is recorded in discrete intervals. Due to different refresh rates within the vehicle's electronics, the data recorded may not be synchronous to each other.
- Airbag ECU data should be used in conjunction with other physical evidence obtained from the vehicle and the surrounding circumstances.
- If any of the front passenger seat airbags, side airbags, or Curtain Shield Airbags have deployed, data will not be overwritten or deleted by the airbag ECU following that event. If none of the airbags have deployed, the data of that event may be overwritten by a following event even if other airbags (pretensioner, rear seat airbag, etc.) have deployed.
- If power supply to the airbag ECU is lost during an event, all or part of the data may not be recorded.
- "Diagnostic Trouble Codes" are information about faults when a recording trigger is established. Various diagnostic trouble codes could be set and recorded due to component or system damage during an accident.
- The airbag ECU records only diagnostic information related to the airbag system. It does not record diagnostic information related to other vehicle systems.
- The TaSCAN, Global Tech Stream, or Intelligent Tester II devices (or any other Toyota genuine diagnostic tool) can be used to obtain detailed information on the diagnostic trouble codes from the airbag system, as well as diagnostic information from other systems. However, in some cases, the diagnostic trouble codes of the airbag system recorded by the airbag ECU when the event occurred may not match the diagnostic trouble codes read out when the diagnostic tool is used.

General Information:

- The data recording specifications of Toyota's airbag ECUs are divided into the following categories. The specifications for 12EDR or later are designed to be compatible with NHTSA's 49CFR Part 563 rule.
  - 00EDR / 02EDR / 04EDR / 06EDR / 10EDR / 12EDR / 13EDR / 15EDR / 17EDR / 19EDR
- The airbag ECU records data for all or some of the following accident types: frontal crash, rear crash , side crash, and rollover events. Depending on the installed airbag ECU, data for side crash and/or rollover events may not be recorded.
- The airbag ECU has the following recording pages (memory maps) for each accident type to store event data: four pages for frontal/rear/side crash, four pages for a side crash, and two pages for rollover event.

- When a crash impact for a lateral direction is occurred, data may be recorded in a page for frontal/rear/side crash. And additional data may be recorded in a page for side crash.
- The data recorded by the airbag ECU includes correlating information between each previously occurring event (i.e., information that clarifies the collision event sequence. This correlation information consists of the following items. - Time from Previous TRG
  - TRG Count
  - Previous Crash Type
- In frontal/rear/side crash events, earlier point in the following is regarded as time zero for the recorded data.
  - the first point where a longitudinal cumulative delta-V of over 0.8 km/h (0.5 mph) is reached
  - the first point where a lateral cumulative delta-V of over 0.8 km/h (0.5 mph) is reached

  In side crash event and rollover event, the point in time at which the recording trigger is established is regarded as time zero for the recorded data.
- The recording trigger judgment threshold value differs depending on the collision type (i.e., frontal crash, rear crash, side crash, or rollover event).
- Some of the data recorded by the airbag ECU is transmitted to the airbag ECU from various vehicle control modules by the vehicle's Controller Area Network (CAN).
- In some cases, the airbag ECU part number printed on the ECU label may not match the airbag ECU part number that the CDR tool reports. The part number retrieved by the CDR tool should be considered as the official ECU part number.
- In frontal/rear/side collision events, the record time varies depending on the period during which a longitudinal and lateral cumulative delta-V of over 0.8 km/h (0.5 mph) is reached, and time series data is recorded for up to 250 ms. The record time described above is indicated as "Length of Delta-V". "Delta-V, Longitudinal" outside the record time is indicated by area shaded in the table, and not indicated in the graph.

Data Element Sign Convention:

The following table provides an explanation of the sign notation for data elements that may be included in this CDR report.

Data Element Name	Positive Sign Notation Indicates
Maximum Delta-V, Longitudinal	Forward
Delta-V, Longitudinal	Forward
Delta-V, Lateral	Left to Right
Lateral Acceleration, Side Satellite Sensor 1	Left to Right
Lateral Acceleration, Side Satellite Sensor 2	Left to Right
Lateral Acceleration, Side Satellite Sensor 3	Left to Right
Lateral Acceleration, Side Satellite Sensor 4	Left to Right
Rate of Change of Pressure, Side Satellite Sensor 1	The pressure of a door interior is applied.
Rate of Change of Pressure, Side Satellite Sensor 2	The pressure of a door interior is applied.
Rate of Change of Pressure, Side Satellite Sensor 3	The pressure of a door interior is applied.
Rate of Change of Pressure, Side Satellite Sensor 4	The pressure of a door interior is applied.
Lateral Acceleration for Side Crash, Floor Sensor	Left to Right
Roll Angle Peak	Clockwise Rotation
Roll Angle at the Time of TRG	Clockwise Rotation
Roll Rate	Clockwise Rotation
Lateral Acceleration for Rollover, Floor Sensor	Left to Right
Longitudinal Acceleration , VSC Sensor	Forward
Yaw Rate	Left Turn
Steering Input	Left Turn

Data Definitions:

- After "Freeze Signal" has been turned ON, subsequent events will not be recorded in the recording page.
- "Recording Status" indicates a state in which all recorded event data has been written into the non-volatile memory, or a state in which this process was interrupted and not fully written into the non-volatile memory. If "Recording Status" is "Incomplete", recorded event data may not be valid.
- "Engine RPM" indicates the number of engine revolutions, not the number of motor revolutions. The recorded value has an upper limit of 12,800 rpm. Resolution is 100 rpm and the value is rounded down and recorded. For example, if the actual engine speed is 799 rpm, the recorded value will be 700 rpm.
- If the electric vehicle is using a calculated/virtual engine RPM for drivetrain control, "Engine RPM" may be recorded, but should not be used during data analysis.
- The upper limit for the recorded "Vehicle Speed" value is 200 km/h (125mph). Resolution is 1km/h (0.6mph) and the value is rounded down and recorded. The accuracy of the "Vehicle Speed" value can be affected by various factors. These include, but not limited, to the following.
  - Significant changes in the tire’s rolling radius- Wheel lock and wheel slip
- "Accelerator Pedal" value is recorded as a percentage. The percentage increases as the driver depresses the accelerator.
- If M/T transmission vehicle of some limited model, "Shift Position" may display "Drive" regardless of the actual shift position.
- Depending on the type of occupant sensor installed in the vehicle, one of the following three recording formats for "Occupant Size Classification, Front Passenger" will be utilized.
  - Occupied / Not Occupied
  - AM50 / AF05 / Child / Not Occupied
  - AM50 / AF05 / Child or Not Occupied
- "Cruise Control Status" indicates whether the cruise control system is actuated or not. OFF indicates that the cruise control system is not actuated, but can also indicates that the vehicle is not equipped with the system.

- "Air Bag Warning Lamp, On/Off", "Ignition Cycle, Crash", "Seat Track Position Switch, Foremost, Status, Driver", "Occupant Size Classification,
  Front Passenger", "Safety Belt Status, Driver", "Safety Belt Status, Front Passenger", "Frontal Air Bag Suppression Switch Status, Front Passenger", and "RSCA Disable Switch" indicate the state approximately 1 second before time zero. They may not always indicate the state at the moment of collision.
- The upper and lower limits for the recorded value of "Motor RPM" is 17,500 rpm and -7,500 rpm respectively. Resolution is 100 rpm and the value is rounded down and recorded.
- "Brake Oil Pressure" has an upper limit of 12.14 Mpa. In the case of the vehicle that has not VSC system, "0 Mpa" or "Invalid" may be displayed.
- "Longitudinal Acceleration , VSC Sensor" has upper and lower limits for the recorded value of 8.973 m/s^2 and -8.973 m/s^2 respectively. This acceleration sensor does not sense collisions.
- "Sequential Shift Range" displaying "Undetermined" indicates the shift range is undetermined or was not being used.
- Some vehicles will not be equipped with all "Drive Mode" types indicated in the "Drive Mode" table. If some or all drive modes are not applicable to vehicle, "OFF" or "Invalid" may be displayed. The item in the "Drive Mode" table may not match the name of switch or indicator that equipped the vehicle.
- The upper and lower limits for the recorded value of "Steering Input" is 375 deg and -375 deg respectively. Resolution is 1.5 deg and the value is rounded down and recorded.
- Resolution of the "Air Bag Warning Lamp ON Time Since DTC was Set" is 15 minutes, and the value is rounded down and recorded.
- "Delta-V, Longitudinal" indicates the change in forward speed after time zero. This does not refer to vehicle speed, and it does not include the change in speed during the period from the start of the actual collision to establishment of the time zero.
- "Location of Side Satellite Sensor" shows the outline of a typical sensor position. Sensory location can be confirmed using the repair manual.
- "TRG Count" indicates a calculated value of the number of times recording triggers have been established for all crash types. The sequence in which each event occurred can be verified from the "TRG Count". The smaller the "TRG Count" value, the older the data. The upper limit for the recorded value is 65,533 times. When more than one event reaches the upper limit, the actual "TRG Count" may be greater than what is displayed for that event.
- Resolution of the "Time from Pre-Crash to TRG" is 50 [ms], and the value is rounded up and recorded.
- "Time from Previous TRG" indicates the time between the establishment of a most recent event's recording trigger to the establishment of a latest event's recording trigger. The upper limit for the recorded value is 32,767 milliseconds. In the event of establishment of the first recording trigger after the ignition is switched ON, the upper limit value(max value) is recorded.
- "Roll Angle at the Time of TRG" and "Roll Angle Peak" do not represent the actual roll angle of the vehicle. These values are used internally by the airbag ECU for sensing a rollover.
- Depending on the type of satellite sensor installed in the vehicle, "Lateral Acceleration" or "Rate of Change of Pressure" is displayed as Side satellite sensor. "Rate of Change of Pressure" indicates that of a door interior. 0% is displayed when the pressure of a door interior is equal with the outside air pressure.
- Depending on the type of satellite sensor installed in the vehicle, "Clipping Time, Lateral Acceleration" or "Clipping Time, Rate of Change of Pressure" is displayed.
- "VSC Control Status" displaying "OFF+ (disable)" indicates VSC is disable (a part of the behavior stabilization control is operated).
- "Trip count" indicates the number of ignition power applying to a vehicle. The upper limit for the recorded value is 65534 times. When trip count reaches the upper limit value, trip count is reset at the next counting up.
- "Time count input system" indicates a count method of "Time count" and "Trip count".
  - Normal: Airbag ECU correct the count value with vehicle common value and count it up.
  - IG: ECU uniquely counts up regardless of vehicle common value. (In case of IG system ECU.)
  - ACC: ECU uniquely counts up regardless of vehicle common value. (In case of ACC system ECU.)
  - +B: ECU uniquely counts up regardless of vehicle common value. (In case of +B system ECU.)
- "Time count" indicates time from ignition power applying. The upper limit for the recorded value is 1,677,721,400ms. The resolution is 100ms and the value is rounded down and recorded.

05017_ToyotaS00std_r028

System Status at Retrieval

ECU Part Number	89170-33D50
EDR Generation	17EDR
Complete File Recorded	Yes
Ignition Cycle, Download (times)	316
Multi-Event, Number of Events (times)	1
Time from Event 1 to 2 (sec)	N/A
Diagnostic Trouble Codes Exist	No
Location of Side Satellite Sensor 1, L	front door
Location of Side Satellite Sensor 2, L	B-Pillar
Location of Side Satellite Sensor 3, L	Not Equipped
Location of Side Satellite Sensor 4, L	C-Pillar
Location of Side Satellite Sensor 1, R	front door
Location of Side Satellite Sensor 2, R	B-Pillar
Location of Side Satellite Sensor 3, R	Not Equipped
Location of Side Satellite Sensor 4, R	C-Pillar
Location of Floor Sensor	Airbag ECU

Event Record Summary at Retrieval

Events Recorded	TRG Count	Crash Type	Time (msec)	Pre-Crash Recording Status	Diagnostic Data Recording Status	Occupant Data Recording Status	Crash Info Recording Status	Time Series Recording Status
Most Recent Event	1	Frontal/Rear/Side Crash	0	Complete	Complete	Complete	Complete	Complete

System Status at Event (Most Recent Event, TRG 1)

TRG Count (times)	1
Event Type	Frontal/Rear/Side Crash
Previous Crash Type	No Event
Time from Previous TRG (msec)	32767 or greater
Time from Time Zero to TRG (msec)	31.0
Event Establishment Factor	Rear Crash
TRG Establishment Factor	Rear Crash
Freeze Signal	OFF
Freeze Signal Factor	None
Recording Status , Front/Rear and Side Crash Info.	Complete
Odometer signal (miles [km])	2,325 [3,742]
Trip count (times)	296
Time count (msec)	317,400
Time count input system	Normal

Deployment Command Data (Most Recent Event, TRG 1)

Active Head Restraint, Time to Deploy, Driver (msec)	SNA
Active Head Restraint, Time to Deploy, Front Passenger (msec)	SNA
Frontal Airbag Deployment, Time to 1st Stage Deployment, Driver (msec)	No
Frontal Airbag Deployment, Time to 1st Stage Deployment, Front Passenger (msec)	No
Frontal Airbag Deployment, Time to 2nd Stage, Driver (msec)	No
Frontal Airbag Deployment, Time to 2nd Stage, Front Passenger (msec)	No
Frontal Airbag Deployment, Time to 3rd Stage, Front Passenger (msec)	SNA
Pretensioner Deployment, Time to Fire, 1st Seat, Driver (msec)	No
Pretensioner Deployment, Time to Fire, 1st Seat, Passenger (msec)	No
Pretensioner Deployment, Time to Fire, 2nd Seat, Driver (msec)	No
Pretensioner Deployment, Time to Fire, 2nd Seat, Passenger (msec)	No
Rear Window Airbag Deployment, Time to Deploy (msec)	SNA
Side Airbag Deployment, Time to Deploy, 1st Seat, Driver (msec)	No
Side Airbag Deployment, Time to Deploy, 1st Seat, Passenger (msec)	No
Side Airbag Deployment, Time to Deploy, 2nd Seat, Driver (msec)	No
Side Airbag Deployment, Time to Deploy, 2nd Seat, Passenger (msec)	No
Side Curtain Airbag Deployment, Time to Deploy, Driver (msec)	No
Side Curtain Airbag Deployment, Time to Deploy, Passenger (msec)	No

DTCs Present at Time of Event (Most Recent Event, TRG 1)

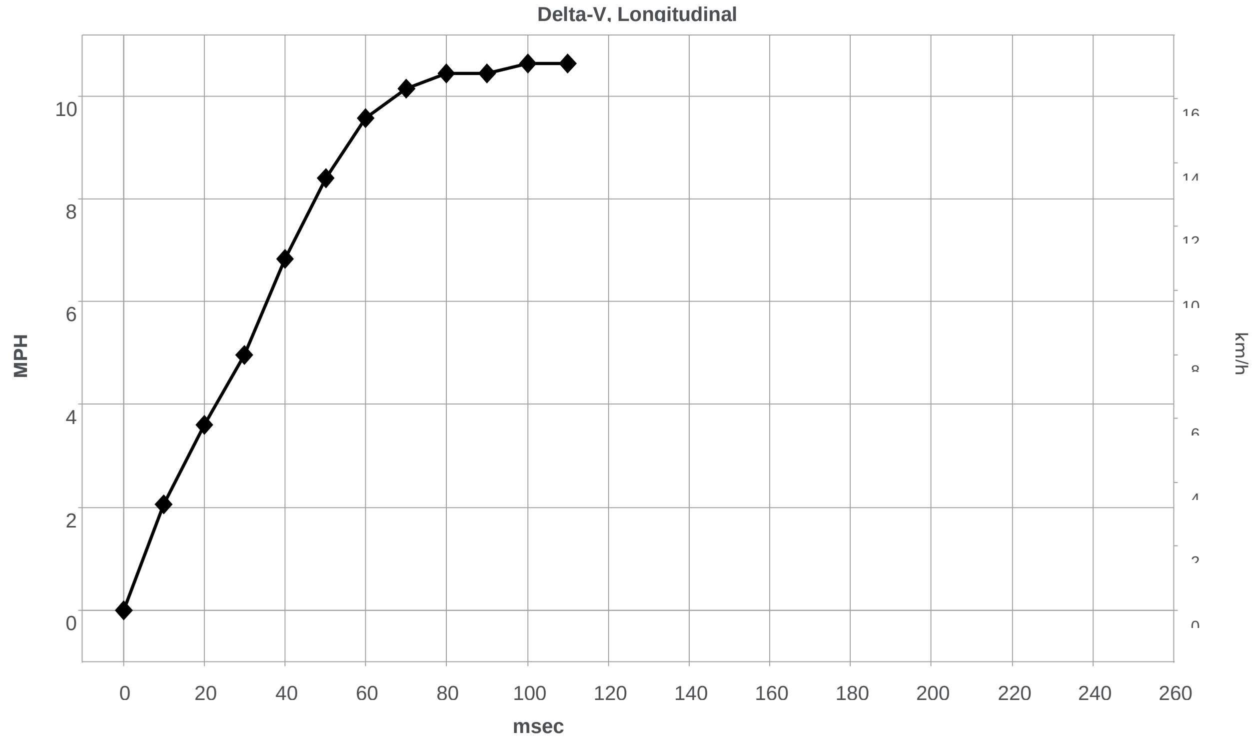
Recording Status, Diagnostic	Complete
Ignition Cycle Since DTC was Set (times)	0
Airbag Warning Lamp ON Time Since DTC was Set (min)	0
Diagnostic Trouble Codes	None

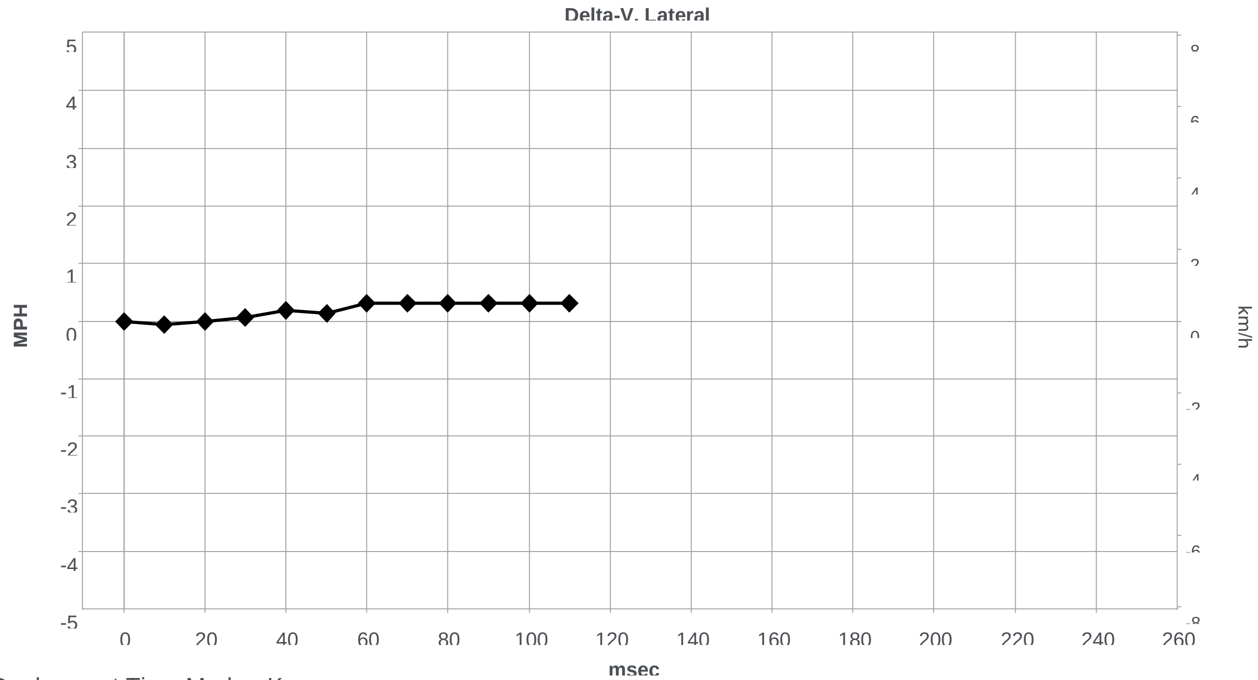
Pre-Crash Data, 1 Sample (Most Recent Event, TRG 1)

Recording Status, Occupant	Complete
Recording Status, Pre-Crash	Complete
Time from Pre-Crash to TRG (msec)	200
Safety Belt Status, Driver	ON
Safety Belt Status, Front Passenger	OFF
Occupant Size Classification, Front Passenger	SNA
Frontal Airbag Suppression Switch Status, Front Passenger	SNA
RSCA Disable Switch	SNA
Seat Track Position Switch, Foremost, Status, Driver	No
Airbag Warning Lamp, On/Off	OFF
Ignition Cycle, Crash (times)	276

Longitudinal/Lateral Crash Pulse (Most Recent Event, TRG 1)

Recording Status , Time Series Data	Complete
Power Supply Status at the time of Max. Delta-V	ON
Maximum Delta-V, Longitudinal (MPH [km/h])	10.8 [17.4]
Time, Maximum Delta-V, Longitudinal (msec)	102.5
Clipping Time, Longitudinal Delta-V (msec)	No
Clipping Time, Lateral Delta-V (msec)	No
Length of Delta-V (msec)	110





Deployment Time Marker Key

1	Driver Airbag Deployment Time
2	Passenger Airbag Deployment Time
3	Driver 2nd Stage Airbag Deployment
4	Passenger 2nd Stage Airbag
5	Driver Pretensioner Deployment

6	Passenger Pretensioner Deployment
7	Driver AHR
8	Passenger AHR
9	Driver CSA
10	Passenger CSA
11	Rear Window Airbag Deployment
12	Driver SAB
13	Passenger SAB

Longitudinal/Lateral Crash Pulse (Most Recent Event, TRG 1)

Time (msec)	Delta-V, Longitudinal (MPH [km/h])	Delta-V, Lateral (MPH [km/h])	Power Supply Status
0	0.0 [0.0]	0.0 [0.0]	ON
10	2.1 [3.3]	-0.1 [-0.1]	ON
20	3.6 [5.8]	0.0 [0.0]	ON
30	5.0 [8.0]	0.1 [0.1]	ON
40	6.8 [11.0]	0.2 [0.3]	ON
50	8.4 [13.5]	0.1 [0.2]	ON
60	9.6 [15.4]	0.3 [0.5]	ON
70	10.1 [16.3]	0.3 [0.5]	ON
80	10.4 [16.8]	0.3 [0.5]	ON
90	10.4 [16.8]	0.3 [0.5]	ON
100	10.6 [17.1]	0.3 [0.5]	ON
110	10.6 [17.1]	0.3 [0.5]	ON
120	0.0 [0.0]	0.0 [0.0]	ON
130	0.0 [0.0]	0.0 [0.0]	ON
140	0.0 [0.0]	0.0 [0.0]	ON
150	0.0 [0.0]	0.0 [0.0]	ON
160	0.0 [0.0]	0.0 [0.0]	ON
170	0.0 [0.0]	0.0 [0.0]	ON
180	0.0 [0.0]	0.0 [0.0]	ON
190	0.0 [0.0]	0.0 [0.0]	ON
200	0.0 [0.0]	0.0 [0.0]	ON
210	0.0 [0.0]	0.0 [0.0]	ON
220	0.0 [0.0]	0.0 [0.0]	ON
230	0.0 [0.0]	0.0 [0.0]	ON
240	0.0 [0.0]	0.0 [0.0]	ON
250	0.0 [0.0]	0.0 [0.0]	ON

Pre-Crash Data -5 to 0 Seconds (Most Recent Event, TRG 1) - Table 1 of 4

Time (sec)	Vehicle Speed (MPH [km/h])	Accelerator Pedal, % Full (%)	Percentage of Engine Throttle (%)	Fuel Injection Quantity (mm^3/st)	Engine RPM (RPM)	Motor RPM (RPM)	Service Brake, ON/OFF
-4.70	32.3 [52]	30.0	Invalid	Invalid	0	4,800	OFF
-4.20	32.3 [52]	39.0	Invalid	Invalid	0	4,800	OFF
-3.70	32.9 [53]	39.0	Invalid	Invalid	0	4,900	OFF
-3.20	32.9 [53]	42.5	Invalid	Invalid	1,200	4,900	OFF
-2.70	32.3 [52]	0.0	Invalid	Invalid	1,000	4,800	ON
-2.20	27.3 [44]	0.0	Invalid	Invalid	900	4,100	ON
-1.70	19.3 [31]	0.0	Invalid	Invalid	100	2,900	ON
-1.20	13.0 [21]	0.0	Invalid	Invalid	0	2,000	ON
-0.70	6.8 [11]	0.0	Invalid	Invalid	0	1,100	ON
-0.20	2.5 [4]	0.0	Invalid	Invalid	0	400	ON
TRG(0)	1.2 [2]	0.0	Invalid	Invalid	0	200	ON

Pre-Crash Data -5 to 0 Seconds (Most Recent Event, TRG 1) - Table 2 of 4

Time (sec)	ABS Control Status	BOS Control Status	Brake Oil Pressure (Mpa)	Longitudinal Acceleration , VSC Sensor (m/s^2)	Yaw Rate (deg/s)	Steering Input (degrees)	Shift Position
-4.70	OFF	OFF	0.00	-0.072	-1.46	-3.0	D
-4.20	OFF	OFF	0.00	0.144	-1.46	-3.0	D
-3.70	OFF	OFF	0.00	0.144	-1.46	-3.0	D
-3.20	OFF	OFF	0.00	0.431	-1.46	-3.0	D
-2.70	OFF	OFF	0.38	-2.082	-1.46	-3.0	D
-2.20	OFF	OFF	0.86	-5.886	-0.49	-3.0	D
-1.70	OFF	OFF	1.01	-8.039	-1.46	-3.0	D
-1.20	OFF	OFF	0.62	-5.599	-1.95	-6.0	D
-0.70	OFF	OFF	0.43	-5.168	-1.46	-6.0	D
-0.20	OFF	OFF	0.24	-4.020	-0.98	-6.0	D
TRG(0)	OFF	OFF	0.24	8.973	-4.39	-6.0	D

Pre-Crash Data -5 to 0 Seconds (Most Recent Event, TRG 1) - Table 3 of 4

Time (sec)	Sequential Shift Range	Cruise Control Status	VSC Control Status	READY Signal	Drive Mode, Power Train	Drive Mode, Snow	Drive Mode, EV
-4.70	Undetermined	OFF	ON (enable)	ON	ECO	OFF	OFF
-4.20	Undetermined	OFF	ON (enable)	ON	ECO	OFF	OFF
-3.70	Undetermined	OFF	ON (enable)	ON	ECO	OFF	OFF
-3.20	Undetermined	OFF	ON (enable)	ON	ECO	OFF	OFF
-2.70	Undetermined	OFF	ON (enable)	ON	ECO	OFF	OFF
-2.20	Undetermined	OFF	ON (enable)	ON	ECO	OFF	OFF
-1.70	Undetermined	OFF	ON (enable)	ON	ECO	OFF	OFF
-1.20	Undetermined	OFF	ON (enable)	ON	ECO	OFF	OFF
-0.70	Undetermined	OFF	ON (enable)	ON	ECO	OFF	OFF
-0.20	Undetermined	OFF	ON (enable)	ON	ECO	OFF	OFF
TRG(0)	Undetermined	OFF	ON (enable)	ON	ECO	OFF	OFF

Pre-Crash Data -5 to 0 Seconds (Most Recent Event, TRG 1) - Table 4 of 4

Time (sec)	Drive mode select signal
-4.70	ECO
-4.20	ECO
-3.70	ECO
-3.20	ECO
-2.70	ECO
-2.20	ECO
-1.70	ECO
-1.20	ECO
-0.70	ECO
-0.20	ECO
TRG(0)	ECO

Hexadecimal Data

Data that the vehicle manufacturer has specified for data retrieval is shown in the hexadecimal data section of the CDR report. The hexadecimal data section of the CDR report may contain data that is not translated by the CDR program. The control module contains additional data that is not retrievable by the CDR system.

PIDs PID Data
00 BC F5 00 01
01 00
03 33 33 44 35 30 30 30 30 36 39 30 30 30 36 39 30 30 30 36 44 30 30 30 36 44
04 02 01 01
05 01
06 38 05
09 30 30 30 36 39 30 30 30 36 39
0A 06
0B 00
0C 30 30 30 33 41 30 30 30 33 41
10 02
20 E8 00 00 01
21 02 A0
22 00 00 00 00 00 00
23 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
25 00 00 00 00 00 00 00 00 00
40 00 00 00 01
60 F7 77 00 01
61 02 0A 05 00 14 D8 00 00 00 00 00 00 03 55 03 55 00 00 00 00 03 55 03 55 14 D8 00 00 00 00 00
00 00 00 E0 00 FF FE 30 00 81 02 81 02 80 00 00 00 01 3C 00 00 00 00
62 55 3F FE 3F FE 3F FE 3F FE 3F FE 3F FE 3F FE 3F FE 3F FE 3F FE 3F FE 3F FE 3F FE 3F FE 3F FE 3F FE
3F FE 3F FE 3F FE 55 38 3E FF FE 00 01 22 00 00
63 03 FE 0C 00 00 3F F4 3F EB 3F E3 3F D8 3F CF 3F C8 3F C5 3F C3 3F C3 3F C2 3F C2 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 3F C1 00 CD
64 03 FE 00 00 00 01 00 00 3F FE 3F FC 3F FD 3F F9 3F F8 3F F9 3F F9 3F F9 3F F9 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
66 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
67 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
68 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
6A 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

6B 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
6C 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
6E 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
6F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
70 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
80 00 00 00 01
A0 0C 0C FF FD
A5 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
A6 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
AD 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
AE 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
B3 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
B4 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
B5 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
B6 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
B7 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
B8 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
B9 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
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C0 FF FF FF E1
C1 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
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C2 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
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C3 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
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CB 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
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CC 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
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00 00 0C 66 00 00 0E 9E 01 55 10 10 00 00
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00 00 55 54 00 00 00 0C 0A 09 01 00 00 00 00 00 00 00 00 00 00
CF 00 00 00 00 08 12 15 0D 09 05 05 FD FD FD FD FD FF FD FC FD FE F7 FF 02 02 06 E3 AE 90 B2
B8 C8 7D FE FE FE FE FE FE FE FE FE FE FE 00 00 00
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