The use of data obtained with the Bosch Crash Data Retrieval Tool

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Abstract

The use of data obtained using the Bosch CDR tool is widespread in the USA and common within the EU. Access to CDR data is not widely available in the UK and there is a lack of awareness of the potential of this additional strand of evidence in reconstruction. This paper describes a typical vehicle fitment and examines some ways in which the data may be used. It is intended to give some awareness of the limitations found within the data and to discuss some techniques that may be available in appropriate circumstances. The examination of CDR data should only be performed by suitably qualified analysts. It is hoped that this paper may give some appreciation of what the Analyst may, and my not, be able to do, and why.

Introduction

This paper concerns the use of the Bosch CDR tool in the UK. The Bosch tool has been available for use in the EU for a number of years, with analyst and technician courses run since 2015.

The Bosch CDR or Crash Data Retrieval tool allows the retrieval of data from a vehicle that has been involved in a crash. It is a third party cross platform tool that is independent of the vehicle manufacturer and does not require use of a manufacturer's diagnostic tool. The Bosch tool comprises hardware and software that allows the "imaging" or retrieval of CDR (sometimes referred to as EDR or Event Data Recorder) data that may be stored in the **SRS** (Supplementary Restraint Systems) ECU or **ACM** (Airbag Control Module). Access to this module post-collision may be either via the vehicle network via the DLC/OBD port; or by direct access to the Airbag Control Module.

Imaging crash data does not change the data stored in the Airbag Control Module; the CDR tool simply images the data in a secure digital file, and cannot be used to "reset", "remove", or "modify" data stored in the Airbag Control Module.

The use of Event Data Recorder technology has been the subject of legislation in the USA since 2008, currently in the form of Code of Federal Regulations Title 49, Article 563. This effectively requires that where EDR data is retained it should be accessible and downloadable. Vehicles that conform to this regulation are often referred to as '563 compliant', but the regulation does not formally require that vehicles are fitted with an EDR. Art 563 has promoted the widespread use of CDR data in the USA and is supported by many major manufacturers. Similar EU legislation has not been implemented so although many manufacturers produce vehicles that are downloadable in the US market, the identical vehicle sold in the EU cannot be downloaded by the CDR tool as access to the CDR data is restricted in the EU by the vehicle manufacturer. The principal manufacturers who make CDR data available in the EU are Toyota, from about 2005 onwards; Volvo from about 2011; and more recently some Vauxhall (GM) models. Although many other vehicles can be downloaded when supplied in the US market, data is not available from the corresponding EU market models, even where they appear identical.

In order to deal with CDR data the investigator must be trained, either as a Technician in order to download data from the vehicle or as an Analyst to analyse and interpret the data. Details of qualified experts can be found on the EuDarts website (https://www.eudarts-group.com).

Overview of a Typical System

Many cars are fitted with systems that are designed to activate in a collision situation and reduce the injury to the driver and occupants of the vehicle. These systems include air bags and seat belt pre-tensioning systems, and can be referred to generically as Supplementary Restraint Systems.

The control of the SRS system is usually achieved by using a dedicated electronic control module to control all the supplementary restraint devices fitted to the vehicle. The SRS control module – the ACM - continually monitors the deceleration of the vehicle either using internal accelerometers or by dedicated remote sensors positioned to the front and / or sides of the car. The decision to deploy individual restraints requires sensing of the vehicle behaviour, particularly acceleration being applied to the vehicle and the direction of the impulse. By monitoring acceleration over successive time periods the software can decide whether the impulse is becoming more serious, and whether, and often which, supplementary system should be deployed. The data from these sensors, which is principally accelerometer data, may be regarded as relevant once a collision has begun to occur.

The ACM will also receive data from other systems around the vehicle. Vehicle speed is usually monitored. This is usually provided by wheel speed sensing, often via ABS or ESP systems. This speed is the speed used by the vehicle for ESP, transmission control and similar systems and will be the speed indicated on the vehicle speedometer. It is subject to the usual comments about accuracy and will be inaccurate if tyre pressures are grossly incorrect or different size wheels or tyres have been fitted. It will also be affected by tyre slip under acceleration and braking, so should be regarded with caution where high wheel slip is likely.

Other sensors and signals including engine rpm, brake pedal use, brake line pressure, throttle position may be available. Vehicles fitted with ESP systems may have steering angle and yaw rate data. It is significant that all this data is usually taken from the vehicle data network. This is often a CAN network but may be via a gateway or from a different type of network such as Flexray. The time delay between a sensor detecting a value or change of state and that signal arriving at the ACM may be an issue, especially where the data passes from one vehicle network to another.

In its normal mode of operation the Airbag Control Module will retain accelerometer data and other data from the CAN for a short period in a rolling buffer, where the newest data overwrites the oldest on a rolling basis.

Unfortunately this means that there is sometimes no clear indication of exactly when in time the data was generated or sampled, nor of the exact point in time at which it was stored in the buffer. This is a particular issue with Pre-Crash data and is described by the passage, taken from Toyota’s Data Limitations

> *“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.*

Of necessity this can make some analyses of time and position slightly less exact than might be desired.

When the ECM software identifies that an event of interest occurs it will, if it is necessary to deploy SRS components, issue the relevant trigger signals to facilitate deployment. If the event is assessed as particularly severe it may be classified as a ‘Deployment Event’ which will generally result in the Airbag Control Module recording the data from its rolling buffers to durable storage such as EPROM.

At this point in the crash event the primary function of the ACM is to ensure correct deployment of SRS devices and not the recording of data which has lower priority. It may be the case that in the course of collision power to the Airbag Control Module is lost. Internal power supplies are usually sufficient to complete both the deployment and the recording activities.

On occasion the Airbag Control Module will monitor an event but will decide that no deployment is required (a Non Deployment Event). Often systems will record data relating to Non Deployment Events, but this is frequently overwritten by later data. When the vehicle is downloaded shortly after a Non Deployment Event the data relating to that event may be available. It appears that in most cases deployment of the driver or passenger front airbag will be classed as a Deployment Event, but the exact boundary between a Deployment Event and a Non Deployment Event is less certain. The deployment of lesser airbags such as knee protection or side curtains, and particularly of reversible restraints, is a grey area with some manufacturers classifying them as a Deployment Event and some as a Non Deployment Event. The significance of this is that generally Deployment Events will be protected once written to durable storage, but a Non Deployment Event, once written to durable storage, may be overwritten.

Systems described as '563 compliant' will typically retain acceleration data relating to the crash event (Crash Data), usually recorded at 100Hz definition, for about 200ms of the crash pulse, together with typically 5 seconds of Pre Crash data at 1 or 2 Hz definition. Other data taken from the CAN, such as brake or accelerator use, may be recorded at the same frequency.

It is usual that there is some form of marker in the data to indicate that the device has successfully completed writing the full data to non-volatile memory before any loss of power to the ECM. Where this writing process has not been completed by the point of power loss, the marker remains unset, and may indicate that incomplete or old, irrelevant data exists.

It is worth noting that the ACM is not a complete "Black Box" system. It does not identify the driver or passengers or retain audio or video of the crash, or track driver's habits or behaviours. It does not provide GPS data or places where the car has been driven, although it may identify the activation of an automatic collision notification (ACN) system.

CDR data can generally be downloaded from the car using a Bosch download tool which allows communication between the ACM and a computer. The information concerning the event can then be retrieved from the vehicle as a string of digital data. To enable this process Bosch have the relevant coding to decode the digital data, and produce a CDR Report file in a Bosch specific format with the file extension .CDRx. This file can only be processed with the Bosch CDR software and contains error identifying code which establishes whether the file is correct or has been corrupted in some way. If corrupted the software will reject the file; this error detection confirms that the data in the file has not been altered or interfered with. It is usual to produce an easily readable .pdf document which will contain the same data as the .CDRx file.

Identifying the Correct Data

It is essential for the analyst to identify the correct data for the collision. Table 1: Pre-Crash Data Set A (appended at the end of this paper); contains typical pre-crash data. This is data relating to the travel of the vehicle over a five second period before the crash event. The complete data record comprises 34 pages and includes three events and two sets of pre-crash data, so interpreting the order and relation of events is a complex task.

The origin of the various sets of data in the full CDR report is described in part by the data in the information in Fig 1, below, which is taken from information about the status of the ACM when the download was performed.

System Status at Time of Retrieval

ECU Part Number	89170-02C30
EDR Generation	12EDR
Complete File Recorded	Yes
Freeze Signal	ON
Freeze Signal Factor	Front Airbag Deployment
Diagnostic Trouble Codes Exist	No
Ignition Cycle ,Download (times)	2736
Multi-event, number of events (times)	2 or greater
Time from event 1 to 2 (s)	0.278
Time from Previous Pre Crash TRG (msec)	1371
Latest Pre-Crash Page	1
Contains Unlinked Pre-Crash Data	Yes

Event Record Summary at Retrieval

Events Recorded	TRG Count	Crash Type	Time (msec)
Most Recent Event	4	Front/Rear Crash	0
1st Prior Event	3	Side Crash	-278
2nd Prior Event	2	Side Crash	-379

TRG Count	Pre-Crash & DTC Data Recording Status	Event & Crash Pulse Data Recording Status
4	Complete (Page 1)	Complete (Front/Rear Page 0)
3	Complete (Page 1)	Complete (Side Page 0)
2	Complete (Page 1)	Complete (Side Page 1)

Fig 1: Status at Retrieval and Event Summary

Detailed explanations of the terms used in the report and specific information about the fidelity of data are contained in the ‘Data Limitations’ section of the CDR report.

It is crucial that the Analyst makes frequent reference to the Data Limitations in interpreting the CDR report.

The Event Summary indicates that the ACM has three complete stored events. These are numbered TRG (or Trigger) 2, 3 and 4 in chronological order. There is then an issue about TRG 1, which appears to be missing.

The System Status at Time of Retrieval also indicates that there is a page of Unlinked Pre-Crash Data. This is a page of Pre-Crash data that, when recorded, was associated with an event (or TRG) but which is now not associated with a currently recorded event.

It is not yet clear whether this relates to the collision being considered, or to a previous, unconnected and possibly historic collision, which might suggest enquiries should be made concerning the road worthiness and possible previous repair of the vehicle. This will be especially appropriate if there are issues concerning the possible non-deployment of SRS devices in the current collision. It should be noted that there is a healthy market in secondhand, previously used, ACM’s and these are frequently sold with data from historic collisions remaining in the device.

In this case it is necessary to consider the way in which the ACM records and retains data. This is a Gen. 12 Toyota EDR (Event Data Recorder), and the data structure used by the ACM is shown in Fig 2.

The airbag ECU has two recording pages (memory maps) to store pre-crash data. Additionally, to store post-crash data, the airbag ECU has two recording pages for front/rear crashes, two pages for side crashes, and two pages for rollover events.

Although the device can store crash data for up to six crash events it can only store two events of each type and only two pages of Pre-Crash data.

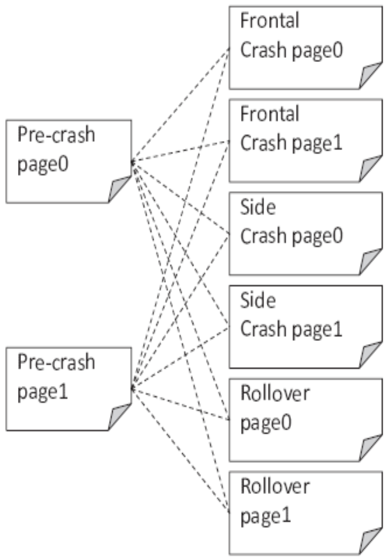

Fig 2: Toyota Gen 12 Data Structure (Toyota Motor Corporation)

Stored data can sometimes be overwritten following a hierarchy set by the manufacturer. In this case a 'Freeze Signal’ has been set, in response to the deployment of the front airbag during the event TRG4. In this device the "Freeze Signal" indicates a state in which the non-volatile memory cannot be overwritten or deleted by the ACM. After "Freeze Signal" has been turned on, subsequent events will not be recorded. This raises the possibility that a collision event occurring after TRG4 could have occurred and not been recorded by the device. This would be a potentially significant issue if trying to use the accelerometer based changes of speed in successive collisions to reconstruct vehicle behaviour, where a significant change of speed could possibly go unidentified, though that is beyond the scope of this discussion.

It should be noted that other manufacturers deal with freezing or locking ACM data in different ways.

In this case TRG4 was a significant frontal collision at the end of the car’s travel and this possibility could be eliminated by reference to scene evidence. It is always the case that the CDR data is one strand of the available evidence and it should always be considered in the context of other evidence, especially physical scene evidence.

The data presented in the CDR report can then be interpreted as four events TRG1 to TRG4 occurring in that order.

TRG1 was an event that generated the data contained in Pre-Crash page zero.

When TRG2, a side impact, occurred it was written to the data area ‘Side Page 1’. This implies that TRG1 was not a Deployment Event, as the Freeze Signal was not set. It also indicates that ‘Side Page 0’ was already used, so TRG1 was a side impact and was stored, at the start of TRG2, in ‘Side Page 0’ and linked to the pre-crash data in Pre-Crash Page 0.

When TRG3, also a side impact, occurred ‘Side Page 0’ and ‘Side Page 1’ had both been used, but as the Freeze Signal was not set data could be overwritten. The exact order of overwriting varies from system to system but in this case TRG3 overwrote Side Page 0, the oldest event. Further pre-crash data was not created for TRG 3 as it occurred within 0.5 sec of TRG2. This is common. If the events occur within 0.5 sec the buffer will not have updated, so fresh data would not be available.

When TRG4, a frontal collision occurred Front/Rear Page 0 was available and was used for the crash data. This collision too was within 500ms of TRG2, so uses the same Pre-Crash data in Pre-Crash Page 1.

TRG4 was a Deployment Event and at this point the Freeze Signal was set, preventing further data being written by the ACM.

Reference to the Event Record Summary at Retrieval (Fig 1) shows TRG3 actually occurred about 100ms after TRG2 and TRG4 about 380ms after TRG2: these are a side impact followed by a side impact followed by a frontal impact all within about 0.4 seconds; so part of the same collision event. This conclusion can also be reached using the ‘Time from Pre-Crash TRG’ data recorded for each impact event, relating the start of the impact event to the start of the Pre-Crash data.

The time between Pre-Crash Triggers can also be used to decide the time period between the start of Pre-Crash Page 0 and Pre-Crash Page 1; in this case 1371 ms. The significance of this is that the trigger for Pre-Crash Page 0 occurred about 1.4 seconds before the trigger for Pre-Crash Page 1, so they overlap by 1.4 seconds. When the data in Table 1A: Overlapping Pre-Crash Data is compared to that in Table 1: Pre-Crash Data Set A this becomes clear, with the data at Pre-Crash Page 0, t = -0.25 corresponding to Pre-Crash Page 1 t = -1.6 (or about 1.4 + 0.25), and so on.

Whilst Pre-Crash Page 1 shows the accelerator fully applied for most of the recording the additional second and a half (three data points) of data show that the accelerator application before this was more moderate.

Using Wheel Speeds

The accelerator is shown as 100% or fully applied until or after t = -0.6, reducing to zero by t = -0.1, but the vehicle speed (wheel speed) falls from t = -1.1 to t = -0.6. This appears inconsistent. The vehicle longitudinal acceleration indicated by ‘Longitudinal Acceleration, VSC Sensor’ signal also appears at odds with the indicated vehicle speed. VSC is a Toyota Vehicle Stability System or ESP system which contains its own accelerometers and yaw rate sensing. Data from the VSC unit will pass to the ACM across vehicle networks in the manner previously described. It is significant that Pre-Crash Page 0 overlaps Pre-Crash Page 1 with a 1.4 second offset. The event that was the trigger for TRG 1 occurred at about this point in time. The car in this case was travelling at about 58mph or 26ms^{-1}, so a time of 1.4 seconds corresponds to a distance of about 35m. The scene evidence included a kerb contact on a central traffic island at this point so again the scene evidence can be reconciled with the CDR data, and the ‘inconsistent’ vehicle speed potentially attributed to the wheel breaking contact with the ground on contact with the kerb. This potentially explains the disturbance in the wheel speed at the end of the record without casting doubt on the early part of the recording, where excessive wheel slip could be discounted.

As a final point in this matter the last data in Pre-Crash Page 0 is identical to the data at t = -0.25. This is simply because the buffer had not updated by that point, 0 (TRG), but had done so by Pre-Crash Page 1, t = -1.1, which occurred 0.5 seconds after Pre-Crash Page 0 t = -0.25.

Again this does not indicate an error in the data if the operation of the system is correctly understood.

This discussion can be continued with reference to the data in Table 2: Pre-Crash Data Set B. The wheel speed indicated vehicle acceleration has been calculated from the successive changes of wheel speed, and is shown with the deceleration indicated by the VSC acceleration sensor in Fig 3.

Time	Speed (kph)	Change (kph)	Calculated accel. (ms^{-2})	VSC accel. (ms^{-2})
4.85	111			
4.35	111	0	0.0	0.431
3.85	110	1	0.6	0.144
3.35	109	1	0.6	0.646
2.85	107	2	1.1	0.646
2.35	104	3	1.7	2.656
1.85	97	7	3.9	2.225
1.35	85	12	6.7	1.077
0.85	83	2	1.1	8.973
0.35	73	10	5.6	5.025
0	63	10	7.9	8.973

Fig 3: Data Set B wheel and VSC accelerations

The deceleration rates calculated from wheel speed are reasonable at first sight but in this collision the car travelled a significant distance along a grass verge. Decelerations of 6 - 8 ms^{-2} may not be reasonable in these circumstances.

The wheel speed indicated acceleration and the VSC accelerations were plotted (Fig 4). It is clear that the wheel speed and VSC accelerations appear in step for the early part of this data set.

About 2.5 seconds before the crash event the wheel speed falls rapidly compared to the VSC deceleration. This can often be due to excessive wheel slip on a low friction surface such as wet grass, where the wheel speed falls faster than the car decelerates. In such cases the investigator must either regard the indicated wheel speed as unreliable, in that it does not accurately represent the speed of the vehicle, or make an appropriate allowance for the degree of wheel slip present.

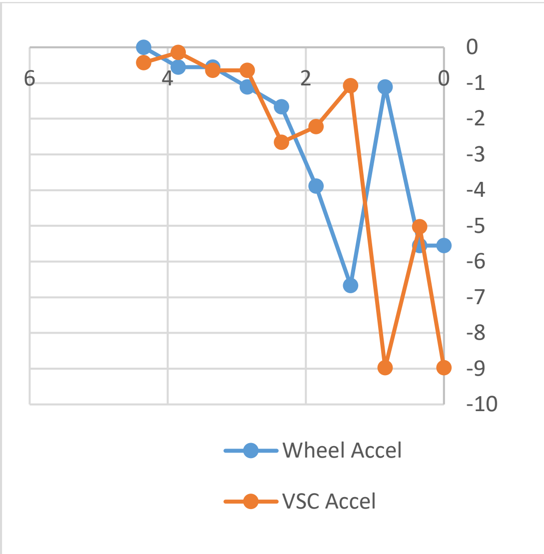

Fig 4: Wheel acceleration and VSC acceleration

Closer to the crash event the VSC acceleration fluctuates significantly. The wheel speed cannot be relied on in this area, and it appears that the VSC acceleration may also be questionable. Again reference to the scene evidence may indicate the cause of this apparent inconsistency.

Yaw Rate Data

The use of the yaw rate data can be considered with reference to the illustrative data in Table 3. The yaw rate data is sometimes available via the CAN network from the ESP or VSC module. This discussion considers two broad approaches, but with both the Analyst should be fully mindful of the synchronicity issue.

Considering the Pre-Crash data is only usually available at 2Hz resolution the Analyst in each case should also consider carefully whether the indicated signal is stable or whether significant fluctuation between sample points could make it unreliable; for example a car crashing through small trees might experience widely fluctuating accelerations that might not be adequately identified in 2Hz data. A detailed consideration of this would require knowledge of any processing or smoothing applied to the raw data; such information is not generally available.

The yaw rate and forward speed remain stable during the first three periods, respectively averaging 77.3 kph and 15.19 deg s^{-1}.

Using $v = \omega . r$ and converting to ms^{-1} and radians,

$$r = \frac{v}{\omega} = \frac{77.3 \div 3.6}{15.19 \times \frac{\pi}{180}} = 80.99 \text{ m}$$, or about

80m. This gives the path radius for this reasonably stable vehicle over at least a second, or more than 20m of travel. This may usefully be compared to scene evidence, for example to establish whether a driver was taking a racing line, or able to remain on the correct side of the road, or travelling near critical speed.

Using $a = \frac{v^2}{r}$ and noting that $v = \omega . r$

$r = \frac{v}{\omega}$ so that $a = v^2 \frac{\omega}{v} = \omega . v$ so that in this case $a = 0.265 \times 21.47 = 5.7 ms^{-2}$ This might then usefully be compared to the available tyre-road grip.

Whilst this has been applied by taking an average across three time periods it could also be used on a piecewise basis and the individual results compared. Doing this over the first three time periods yields radii 82.3, 80.7 and 80.2 m. This could be used to infer that the vehicle was travelling on a reasonably constant radius path over this period; again this might be usefully related to the scene geometry.

The data appears to show the car returning to a straight path at around t = - 2.9 s. After this the steering input and yaw rate both increase again. It may be that this follows a second curve or it may be that the car should be travelling straight ahead at this point. As the yaw is fairly steady for the last 1.4 seconds the lateral deviation from a straight path can be calculated.

Considering Fig 5, if the vehicle is in steady state steering: i.e. the yaw rate matches the rate of turn; as it turns from the initial path AD to the path BE it will yaw through an angle θ. The lateral movement is DB.

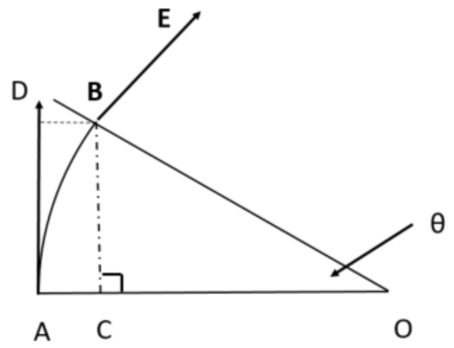

Fig 5: The Lateral Deviation of a turning vehicle

Noting that AO = r, the lateral movement

$$l = DB = AC = AO - CO$$
$$= r - r.\cos\theta = r(1 - \cos\theta)$$

and $v = \omega . r$ so that $r = \frac{v}{\omega}$; then

$$l = \frac{v}{\omega}(1 - \cos\theta) = \frac{v}{\omega}(1 - \cos\omega t)$$

where ω is the yaw rate.

Applying this to the data over the 1.4 second period, where the average speed is 84.5 kph or $23.47 ms^{-1}$ and the average yaw rate is 0.177 rad s^{-1} the lateral displacement is given by

$$l = \frac{23.47}{0.177}\left(1 - \cos(1.4 \times 0.177)\right)$$
$$= 4.05 \text{ m}$$

Again considering the geometry of the scene this might be used to examine whether the car crossed into the oncoming carriageway on a straight road, or whether it was accurately following a particular curve. It should be noted that the lateral deviation can be calculated for successive intervals, but the results cannot simply be added together. Fig 6 gives a graphical explanation of this, where DC is clearly not the sum of the individual lateral deviations.

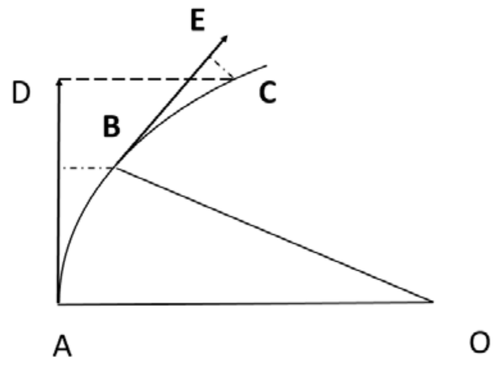

Fig 6: A piecewise approach.

Considering the synchronisation issue, it is known that the yaw rate was 10.3 ^{0} s^{-1} 1.4 seconds before TRG, but that this value might have been appropriate up to nearly half a second earlier. In this case repeating the above calculation

$$l_2 = \frac{23.47}{0.177}\left(1 - cos\left(1.9 \times 0.177\right)\right)$$
$$= 7.43 \text{ m}$$

This is highly likely to overestimate the lateral displacement in this case, but the result should perhaps be quoted as a range.

This analysis does however illustrate the issues that can be caused by uncertainties about when exactly particular values change, and this may to some degree explain why the CDR Analysts calculations may not give such tightly defined results as more conventional reconstruction techniques.

Conclusions

The Pre-Crash data available with the CDR tool is highly valuable as it can give reliable recorded speeds during the approach to a collision. Obtaining the approach speed is often the objective of more conventional reconstruction techniques.

The Pre-Crash data available with the CDR tool is often derived from other systems around the vehicle via the vehicle networks which may lead to issues of timeliness and synchronicity. The use of rolling buffer structures within the ACM adds further complexity. Understanding these issues can often explain apparent anomalies in the data.

The way in which data is written, and overwritten, in durable storage must be clearly identified to ensure that the right data relating to the correct incident is analysed. There are particular concerns with partially recorded data, and with historic data which may relate to a completely different event.

The Analyst should ensure that the data is internally consistent, and should particularly be mindful of wheel slip affecting the accuracy of vehicle speed.

Some possible calculations based on Pre-Crash data have been presented. In all cases the Analyst should be satisfied that the underlying data is an appropriate basis for such calculations. Where the Analyst is not confident of the reliability or stability of the data, these calculations will not be appropriate.

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Table 1: Pre-Crash Data Set A

Pre-Crash Data, -5 to 0 seconds (Most Recent Event, TRG 4)

Time (sec)	-4.6	-4.1	-3.6	-3.1	-2.6	-2.1	-1.6	-1.1	-0.6	-0.1	0 (TRG)
Vehicle Speed (MPH [km/h])	50.3 [81]	51.6 [83]	53.4 [86]	54.7 [88]	56.5 [91]	57.8 [93]	59.7 [96]	67.1 [108]	59 [95]	70.2 [113]	67.7 [109]
Accelerator Pedal, % Full (%)	72.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	0.0
Percentage of Engine Throttle (%)	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
Engine RPM (RPM)	3,300	4,000	4,400	4,600	4,400	4,600	4,600	4,700	4,200	4,100	3,900
Motor RPM (RPM)	6,100	6,200	6,400	6,600	6,700	6,900	7,200	8,600	7,000	8,300	8,400
Service Brake, ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Brake Oil Pressure (Mpa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longitudinal Acceleration , VSC Sensor (m/sec^2)	0.431	1.364	1.077	1.723	0.718	1.148	2.225	1.364	-0.574	-0.215	-5.814
Yaw Rate (deg/sec)	3.90	5.37	5.37	4.39	4.39	-0.49	-12.20	-10.74	-17.57	-16.10	-19.03
Steering Input (degrees)	9	15	15	9	12	-15	-42	-69	-90	-57	-48
Shift Position	D	D	D	D	D	D	D	D	D	D	D
Sequential Shift Range	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined	Undetermined
Cruise Control Status	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF

Table 1A: Overlapping Pre-Crash Data

Pre-Crash Data, -5 to 0 seconds (Unlinked, Page 0)

Time (sec)	-4.75	-4.25	-3.75	-3.25	-2.75	-2.25	-1.75	-1.25	-0.75	-0.25	0 (TRG)
Vehicle Speed (MPH [km/h])	48.5 [78]	48.5 [78]	49.7 [80]	50.3 [81]	51.6 [83]	53.4 [86]	54.7 [88]	56.5 [91]	57.8 [93]	59.7 [96]	59.7 [96]
Accelerator Pedal, % Full (%)	41.5	87.0	42.5	72.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Engine RPM (RPM)	3,400	3,300	3,800	3,300	4,000	4,400	4,600	4,400	4,600	4,600	4,700

Table 2: Pre-Crash Data Set B

Pre-Crash Data, -5 to 0 seconds (Most Recent Event, TRG 5)

Time (sec)	-4.85	-4.35	-3.85	-3.35	-2.85	-2.35	-1.85	-1.35	-0.85	-0.35	0 (TRG)
Vehicle Speed (MPH [km/h])	69 [111]	69 [111]	68.4 [110]	67.7 [109]	66.5 [107]	64.6 [104]	60.3 [97]	52.8 [85]	51.6 [83]	45.4 [73]	39.1 [63]
Service Brake, ON/OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	ON
Brake Oil Pressure (Mpa)	0.00	0.00	0.00	0.00	0.43	1.49	2.06	2.54	0.00	0.05	9.36
Longitudinal Acceleration , VSC Sensor (m/sec^2)	0.215	-0.431	-0.144	-0.646	-0.646	-2.656	-2.225	-1.077	-8.973	-5.025	-8.973
Yaw Rate (deg/sec)	0.00	-1.46	-0.98	-1.95	-11.71	-12.69	-21.47	-11.71	-6.83	3.90	-10.74
Steering Input (degrees)	0	-3	-3	-6	-39	-48	-78	-114	-105	-120	-126

Table 3: Example Pre-Crash Data

Pre-Crash Data, -5 to 0 seconds (Most Recent Event, TRG 2)

Time (sec)	-4.9	-4.4	-3.9	-3.4	-2.9	-2.4	-1.9	-1.4	-0.9	-0.4	0 (TRG)
Vehicle Speed (MPH [km/h])	47.2 [76]	47.8 [77]	49.1 [79]	49.7 [80]	50.3 [81]	51.6 [83]	52.2 [84]	52.8 [85]	52.2 [84]	52.2 [84]	52.8 [85]
Accelerator Pedal, % Full (%)	88.0	87.5	87.5	87.5	86.5	77.5	76.5	76.0	75.5	73.0	0.0
Service Brake, ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Brake Oil Pressure (Mpa)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longitudinal Acceleration , VSC Sensor (m/sec^2)	1.364	1.220	1.005	1.077	1.077	1.077	1.148	1.220	0.933	1.220	-1.651
Yaw Rate (deg/sec)	14.70	15.19	15.68	6.86	0.98	-0.49	5.88	9.31	10.29	10.78	10.29
Steering Input (degrees)	60	63	63	27	3	0	24	39	42	45	42