Enhancing Connecticut's Crash Data Collection for Serious Injury and Fatal Motor Vehicle Collisions

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16. Abstract
The Connecticut Crash Data Repository houses extensive data on all traffic crashes in Connecticut. However, pre-crash data and certain driver behaviors are unavailable as they cannot be gathered through traditional crash investigatory approach that does not involve use of an event data recorder. An Event Data Recorder (EDR), sometimes referred to as an automotive black box, is a valuable tool that can provide comprehensive snapshot of the entire crash event – pre-crash, crash and post-crash – including driver behavior on seatbelt use, gas and brake pattern. This study focused on enhancing Connecticut's crash data collection for serious injury and fatal motor vehicle collisions using the EDR data. Five case studies were examined under this study and they vary in type of collision, vehicles involved, cause of crash, injury severity, and driver behavior. The Bosch crash data recorder was used for retrieval of EDR data. In all the collisions, crash investigators were not able to determine exact speed of the vehicles involved or driver behavior at the time of crash by the traditional crash investigatory approach. However, EDR downloads provided this specific data to aid their investigations. Findings from this study showed that EDR data can help evaluate the true cause of a collision as well as identify reckless driver behavior. Furthermore, the implementation of a formal EDR data collection procedure will improve the efficiency of data collection for collision analysis systems. The ready availability of EDR data, in a crash database, will enable highway safety researchers to address numerous elusive research questions.

17. **Key Words**
Crash data, EDR (Event Data Recorder), EDR (Engine Data Recorder), fatal, pedestrian, head-on collision, download, Delta-V.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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Executive Summary

The Connecticut Crash Data Repository (www.CTCrash.uconn.edu) hosted by the Connecticut Transportation Safety Research Center (CTSRC) compiles and provides public access to motor vehicle crash reports, as drafted by an officer at the scene of a crash. With over 2 million crashes in the Connecticut database, there are numerous examples of fatal and serious injury crashes. However, the data collected has been primarily focused on post-crash observations of an officer and/or often inaccurate or incomplete observations from witnesses. This project examines the capability of Event Data Recorders (EDR) to serve as an impartial observer and to provide a comprehensive snapshot of a vehicle's actions, moments before and just after a crash event. This data is critical when looking to improve crash investigations, save lives, and prevent serious injuries in the future.

Five fatal crashes were examined as case studies in this project. Two cases involved a vehicle striking a pedestrian, the other three involved head-on collisions between two vehicles. The EDR downloads conducted in this study produced valuable data that would have been unavailable from traditional reconstruction techniques. In all circumstances, the downloading of the vehicles "black box" produced a complimentary and not contradictory report which enabled the investigators to develop more accurate and reliable collision reconstruction. Findings from this study showed that EDR data can help evaluate the true cause of a collision as well as identify reckless driver behavior. Furthermore, the implementation of a formal EDR data collection procedure will improve the quality of crash reporting for fatal and serious injury crashes. This improved data will lead to better decision making for safety engineers and advocates.

Chapter 1 Introduction and Background

The Event Data Recorder (EDR), sometimes referred to as the automotive black box, is a device installed in many automobiles to record or track vehicle data such as speed, acceleration, braking, steering, air-bag deployment etc. The EDR is a valuable tool that can provide comprehensive snapshot of the entire crash event – pre-crash, crash, and post-crash. EDRs improve crash reconstruction accuracy to identify the cause, when used with available scene evidence. However, if other evidence is lacking, then the EDR alone can be used as primary evidence.

According to 49 CFR 563, the National Highway Traffic Safety Administration updated the requirement for standardization of data and data retrieval methods for vehicles with a gross weight rating of 8,500 pounds or less that were already voluntarily recording time-series event data (1). The new requirement also ensured public access to this data. Although, the minimum data recorded in new vehicles equipped with EDRs is now standardized, the event data recording capability and data accessibility varies widely by manufacturer, model, and model year (2). Over 88% of model year 2016 and newer vehicles are equipped with the Bosch Crash Data Recorder (CDR) tool and 11% have other EDR tools, for a total of 99% of the model year 2016 and newer vehicles being equipped with an EDR system (3).

Improvements in EDR technology now allow the EDR to record data for 5 to 20 seconds prior to the crash, providing a critical snapshot of what happened in the moments before impact. The improved EDR systems provide data beyond just the deceleration and include information that ranges across as many as 16 different parameters, including braking and steering efficiency; vehicle speed; engine speed; throttle position; engine fuel management; whether the driver was wearing a seat belt; whether the vehicle's lights and cruise control were on; whether turn signals were used; Delta V in frontal collisions; maximum Delta V in near deployment events; and, the time between the moment of vehicle impact and the moment of maximum Delta V (4). Moreover, improvements in ABS technology have resulted in fewer tire marks visible at the scene of crashes making it difficult for law enforcement investigators to calculate pre-crash speeds, thus making EDR a valuable tool. Data from EDRs allow investigators to calculate speed at impact and closing speeds by combining EDR Delta V (change in velocity) data with normally collected scene and vehicle data such as post-crash travel distance, departure angle, drag factor and vehicle weights. They can apply this data to inline rear-end, head-on, and angular collisions. At the same time, investigators can use time-distance and overlay EDR data on scene maps/diagrams to show where critical driving inputs were made vs. inputs required to avoid collisions (5). However, EDRs do not record voices, pinpoint a vehicle's location, or identify who is driving the vehicle. The information gathered from EDRs is more useful than crash test results alone. Askland stated that EDR data includes real world crash impulses, i.e., the energy generated by the rapid deceleration on the vehicle and its occupants, and it can be correlated with real world injuries and fatalities. This information makes crash reconstruction more objective and provides a factual basis for regulatory and consumer information initiatives. It provides the opportunity to understand the interaction among the vehicle, road and the driver (4).

The Connecticut Crash Data Repository houses data for each crash that occurs in the state. However, data on pre-crash elements is not available, especially the pre-crash behavior of the driver. Researchers rely on the ability of the police officer to investigate and document the pre-crash data based on observation and witness accounts. Pre-crash data is highly susceptible to bias, poor or incorrect memories, fraud, and the ability of the officer to find and analyze evidence. Previous research on driver pre-crash behavior has relied heavily on controlled testing or observations such as simulator or naturalistic driving studies. Even when detailed reconstructions of crashes are conducted, there is uncertainty concerning the crash avoidance actions of driver prior to impact. EDR provides a new tool to study this pre-crash driver behavior. Widespread implementation and access to EDR data could provide a comprehensive, unbiased snapshot of the vehicle activity throughout the entire crash experience. By collecting and analyzing the details provided by EDR-equipped vehicles, the Connecticut Department of Transportation (CTDOT) and Law Enforcement have an unprecedented opportunity to increase the understanding of interactions between the vehicle, roadway environment, and driver behavior, through detailed unbiased information from hundreds of serious and fatal motor vehicle collisions each year. Literature review by Bortles and colleagues found that some studies are validation studies, whereas quite a few studies have focused on legal issues where EDR data is used in court rulings, rulemaking, and as evidence. A vast majority of studies have used EDR data for either informational studies pertaining to the development of technology, or epidemiological and automotive safety studies as an independent variable (6).

CTDOT and law enforcement agencies can expect both immediate and long-term benefits from the collection of EDR data. The initial benefit will be the use of EDR data from individual traffic collision investigations as a powerful new form of evidence in supporting improvements to the transportation infrastructure/system. Timely collection of vehicle dynamics data will allow for problem identification without the bias of driver testimony and inherent false statements to divert responsibility. This will allow CTDOT to efficiently evaluate the true cause of the collision and determine if any changes could be made to prevent these types of collisions in the future. This data may also aid in defending against lawsuits or to recover costs of repairing collision damage to State infrastructure. Furthermore, the implementation of a formal collection procedure will significantly improve the efficiency of data collection for collision analysis systems and driver behavior research. In the longer term, EDR data might influence highway crash campaigns to alter risk-taking behaviors. The ready availability of EDR data, in a crash database, will enable highway safety researchers to address a number of elusive research questions.

Chapter 2 Research Approach

To enhance the collection of crash data CTSRC purchased two complete BOSCH Crash Data Retrieval units for downloading vehicle EDR data (Figure 1). These units were purchased from Crash Data Group, Inc. who is the sole source distributor for the Bosch Crash Data Retrieval product line in the United States and Canada. These units are now used as part of an equipment loan program to allow authorized and trained law enforcement technicians to download data from vehicles involved in serious or fatal crashes as part of their crash investigations. This provides rapid, consistent, and uniform data collection while ensuring that Fatality Analysis Reporting System (F.A.R.S) reporting standards are met.

Figure 1: BOSCH EDR Download Kit

CTSRC facilitated two separate week-long (40 hour) EDR technician courses for certified law enforcement officers. This course trained officers to become certified EDR Technicians. A total of 60 local law enforcement officers throughout the State of Connecticut were trained and certified to provide regional support for future crash investigations. State troopers were invited to attend these trainings; however, state troopers are primarily only allowed to attend trainings performed by the CT Police Academy (Police Officer Standards and Training or POST). The training of the 60 officers resulted in 75% of all local police departments in Connecticut being reached.

To evaluate the accuracy and completeness of the data obtained from the EDRs, CTSRC worked with the trained technicians and local law enforcement to identify five serious or fatal motor vehicle crashes to perform a detailed analysis of the original crash report and the resulting report revised using data downloaded from the EDR. Local law enforcement that participated in this project, notified CTSRC of a serious or fatal crash as soon as it occurred. CTSRC then worked with the police department to obtain the rights to download the EDR data via a search warrant. The police department completed a draft version of the report without using the EDR data and then updated their report after using the downloaded EDR data. These case studies provided confirmation of the importance of EDR downloads to accurately report crash data. Furthermore, additional details were obtained from the EDR data downloads that were not available through a normal crash investigation without the EDR data. The results of each of the case studies are documented and used as justification for the continued use of EDR data in crash investigations.

Chapter 3 Findings and Applications

Before the CTSRC team was able to assist in any download, the police department requesting service was required to obtain a search and seizure warrant signed by a Connecticut Superior Court judge. Once obtained, CTSRC sent out our certified EDR technician with one of the BOSCH kits to perform the download. Due to the condition of many of the cars the team quickly realized that data downloads of in place EDR modules was challenging. Therefore, the CTSRC team requested that the EDR be removed from the vehicle prior to the technician's arrival. Performing these downloads in a garage or controlled lab setting made downloads much easier and lessened the likelihood of damaging the connector pins of the EDR. Upon arrival at the police department, the technician would identify the make, model and year of the vehicle to be downloaded and then select the appropriate cable(s) or adaptor(s) (Figure 2). After connecting the EDR to the reader and the reader to the laptop, the data download would begin and typically take less than 60 seconds to complete of the EDR download. The resulting data was then exported as a report from the EDR software and converted to a PDF. The resulting document was downloaded to a thumb drive and provided to the police department for analysis. The EDR technician would then assist the department in navigating the contents of the report but would leave the interpretation of the data to the investigating officer.

Figure 2: EDR Cables by Make and Model

A sample EDR download report can be found in Appendix A. On page 8 of the sample report, the speed of the vehicle in question was captured 5 seconds prior to impact. In this report, the speed increased from 69 MPH (111 km/h) to 101 MPH (162 km/h). This page of the report also indicates that no braking was applied, the steering wheel was not moved, and the accelerator was depressed, on average, 95%. This information is critical to an investigation and can mean the difference been the driver facing charges of manslaughter in the first degree (a class B felony punishable by up to 20 years in prison and up to $15,000 in fines) vs. manslaughter in the second degree (a class C felony punishable by one to 10 years in prison, up to a $10,000 fine, or both). The absence of skid marks; physical evidence at the scene; and/or witnesses; make it difficult to prove manslaughter in the first degree, which according to Connecticut General Statute Sec. 53a-

55., requires evidence of an extreme indifference to human life. In many cases, the unbiased data from the EDR is the irrefutable evidence that is needed to determine the appropriate charges.

At the request of police departments, data from five fatal crashes has been secured through EDR downloads from the vehicle(s) involved. Each crash and the resulting findings are detailed below.

Synopsis of Collision #1

Collision #1 occurred in the town of Clinton, Connecticut on May 4, 2017, at 3:43 pm. The collision involved two vehicles, resulting in serious injuries to one operator and fatal injuries to the second operator. The collision is described as an offset/angle head-on (front to front) collision. The collision was the result of vehicle #1 crossing over the double yellow line into oncoming traffic and colliding with vehicle #2. The emergency response and collision investigation were conducted by the Clinton Police Department.

Vehicle Specifications

Vehicle #1 was documented as a 2002 GMC Envoy XL, bearing Public Vehicle Identification Number 1GKET16SX26103099, with a vehicle gross weight of 6,400 lbs.

Vehicle #2 was documented as a 2011 Ford Fusion, bearing Public Vehicle Identification Number 3FAHP0HAXBR304586, with a vehicle gross weight of 4,400 lbs.

Scene

The crash occurred on Killingworth Turnpike (CT Route 81) 212 feet south of the intersection of North Rocky Ledge Drive (Latitude 41.305376 and Longitude -72.534758) in the town of Clinton, Connecticut. Killingworth Turnpike travels in a north/south direction and is described as two-way traffic roadway consisting of one travel lane in each direction. The travel lanes are separated by a double yellow line. The posted speed limit in the area of the collision is 45 mph. The roadway was described by the investigator as being of level grade, free of defects and debris and with no noted conspicuity issues.

Weather Conditions

The weather conditions for the Clinton, Connecticut area on May 4, 2017, at approximately 3:43 pm were 57.2 ^{0}F, 36% humidity, 10 mile visibility and wind out of the south at 13.8 mph. There was no reported rainfall for the day.

Physical Evidence

The physical evidence at the scene of the collision showed the area of impact (AOI) occurred in the northbound travel lane. The location of the AOI confirmed the witnesses' statements. There was no physical evidence located at the scene that would have allowed for a conclusion regarding the speed of the vehicles involved. The discrepancies in weight would not allow for the use of a Conservation of Linear Momentum formula to determine a speed. There were no documented deceleration marks located within the roadway.

EDR Download
An EDR download was conducted on both vehicles.

Vehicle #1 (2002 GMC Envoy XL):
The results of the download indicated that the collision was a deployment event, thus indicating that the vehicle's airbags were deployed. The EDR recorded five one-second intervals prior to impact for this vehicle. The download further documented the vehicle's speed, engine speed, throttle percentage, brake switch circuit state (on/off), and driver's safety belt status. Five seconds prior to the collision, the vehicle's speed was 47 mph, with the engine speed recorded as 2240 revolutions per minute (RPM), and 15% throttle. The brake switch indicator showed "off". Three seconds prior to the collision, the vehicle's speed was 45 mph, with the engine speed recorded as 2176 RPM and 10% throttle. The brake switch indicator showed "off". One second prior to the collision, the vehicle's speed was 45 mph, with the engine speed recorded as 2240 RPM, and 10% throttle. The brake switch indicator showed "off". The download further indicated that the operator was utilizing the safety belt.

Vehicle #2 (2011 Ford Fusion)
The results of the download indicated that the collision was a deployment event, thus indicating that the vehicle's airbags were deployed. The EDR recorded five one-second intervals prior to impact for this vehicle. The download further documented the vehicle's speed, engine speed, throttle percentage, brake switch circuit state (on/off), and Delta V (change in velocity). Five seconds prior to the collision, the vehicle's speed was 39 mph, with the engine speed recorded as 1600 RPM, and 8% throttle. The brake switch indicator showed "off". Three seconds prior to the collision, the vehicle's speed was 40.4 mph, with the engine speed recorded as 1600 RPM, and 0% throttle. The brake switch indicator showed "off". One second prior to the collision, the vehicle's speed was 39.8 mph, with the engine speed recorded as 1600 RPM, and 0% throttle. The brake switch indicator showed "off". The download indicated that the operator was utilizing the safety belt. At impact the Delta V was recorded as -44.92 mph.

Conclusion
Based on the initial investigation and physical evidence gathered by the police, the investigator could not conclude the speeds of the vehicles prior to or at the time of impact. The EDR download produced speed and braking analysis of each vehicle involved in the collision. The download further confirmed the utilization of safety belts for both operators.

Synopsis of Collision #2

This collision occurred at 9:15 pm on September 15, 2017, in the town of Norwalk, Connecticut. The collision involved a single vehicle and a pedestrian, resulting in fatal injuries to the pedestrian who was crossing the street from west to east in the area of a marked and signalized crosswalk. The vehicle fled the scene immediately after striking the pedestrian. The vehicle and its operator were located shortly after the collision, parked behind a building away from the scene.

Vehicle Specifications

Vehicle #1 is documented as a 2003 Chevrolet Trailblazer bearing Public Vehicle Identification Number 1GNDT13S832151714. The vehicle had a recorded gross weight of 5,750 lbs.

Scene

The collision is documented on a State of Connecticut PR-1 Report Form occurring in the jurisdiction of the Norwalk Police Department. The crash occurred on Martin Luther King Drive at the intersection of Lowe Street (Latitude 41.092825711677 and Longitude -73.42509845283) in the town of Norwalk, Connecticut. Martin Luther King Drive travels in a north/south direction and is described as two-way traffic roadway consisting of two travel lanes in each direction that are separated by a double yellow line. The roadway grade is level and there are no noted conspicuity issues.

Operator

The operator of the vehicle is documented as a 40-year-old female who resides in the city of Norwalk. The female possessed a valid Connecticut, Class D, operator's license at the time of the collision. The lead investigator conducting the crash reconstruction requested a blood sample from the female operator immediately following her arrival at the local hospital for reported minor injuries resulting from the collision. A search and seizure warrant was applied for and granted to conduct a chemical analysis of the female operator's blood samples taken at the hospital the night of the collision. Upon execution of the search warrant and subsequent examination by the State of Connecticut Department of Emergency Services and Public Protection's Division of Scientific Services, it was determined that the female operator's blood contained 0.10g% of ethanol by weight, 23ng/ml of cocaine, and 249ng/ml of benzoylecgonine.

Pedestrian

The pedestrian is documented as a 65-year-old male, 5'11" tall, weighing 185 lbs. The State of Connecticut Office of the Medical Examiner's autopsy report concludes the cause of death as blunt impact injuries of the head, torso and extremities. As policy dictates, the Connecticut Medical Examiner's Office performed a post mortem examination of the pedestrian. As part of the post mortem exam, several samples of blood were taken for analysis. The resulting toxicology report showed the pedestrian's blood contained 88ng/ml of cocaine, and 24ng/ml of oxycodone at the time of his death.

Statements

In a statement to the investigators, the female operator initially stated that she believed she had struck a deer. She stated that she was traveling on Lowe Street and stopped at a red traffic control signal. The female further stated that upon the traffic control signal turning green she made a right turn and the collision immediately occurred. She further stated that after the collision she left the scene of the crash. The female later recanted a portion of her statement and stated that she knew she struck a person but fled out of fear.

Environmental Conditions

The weather conditions for the Norwalk, Connecticut area on September 15, 2017, at approximately 9:15 pm were 69.1 ^{0}F, 87% humidity, 10 mile visibility with no recorded rainfall for the day.

Speed Analysis
Based on limited physical evidence, the investigators conducted four mathematical equations using different points of measurements to determine a minimum velocity of the vehicle when it struck the pedestrian. The investigators utilized the Searle formula. The Searle formula is a pedestrian formula utilizing the throw distance, angle of departure and coefficient of friction to determine a minimum velocity/speed. This equation is utilized when a pedestrian is struck, thrown and tumbles to final rest. The investigators utilized a coefficient of friction value of 0.66 and a takeoff angle of 45 degrees in the calculations. Based on the physical evidence, such as marks in the roadway, the investigators concluded that the vehicle being driven by the female was traveling at a bracketed speed of between 34.26 mph and 41.65 mph at the point of impact with the pedestrian.

EDR Download
The EDR download was conducted. The results of the download indicated that the collision was a non-deployment event, indicating that the vehicles airbags were not deployed. The EDR recorded five one-second intervals prior to impact. The download further documented the vehicle's speed, engine speed, throttle percentage and brake switch circuit state (on/off). Five seconds prior to the collision, the vehicle's speed was 53 mph, with the engine speed recorded as 1536 RPM. The brake switch indicator showed "off". Three seconds prior to the collision, the vehicle's speed was 50 mph, with the engine speed recorded as 1408 RPM. The brake switch indicator showed "on". One second prior to the collision, the vehicle's speed was 46 mph, with the engine speed recorded as 1408 RPM. The brake switch indicator showed "off".

Conclusion
Based on the totality of the investigation and physical evidence gathered by the police, the investigator concluded that the vehicle that struck the pedestrian "most likely" did not turn right from Lowe Street prior to impact. Utilization of the physical vault of the pedestrian only produced an approximate bracketed speed of the vehicle at impact. The EDR download produced a definitive speed and braking analysis of the crash. The information from the EDR was conclusive evidence that the operator of the vehicle had not made a turn and was, in fact, traveling at a high rate of speed at impact.

Synopsis of Collision #3

Collision # 3 occurred in the town of Newtown, Connecticut on April 4, 2017, at 11:33 am. The collision involved two vehicles, resulting in injuries to both operators and a fatal injury to the front seat passenger in vehicle #2. The collision is described as a head-on (front to front) collision. The collision was the result of vehicle #1 traveling westbound and crossing over the double yellow line into oncoming traffic and colliding with vehicle #2, which was traveling eastbound in its proper travel lane. The emergency response and collision investigation were conducted by the Newtown Police Department. The collision report is documented on a State of Connecticut PR-1 Report Form.

Vehicle Specifications
Vehicle #1 is documented as a 2005 Buick Lesabre, bearing Public Vehicle Identification Number 1G4HR54K35U164775, with a vehicle gross weight of 3,567 lbs. The vehicle's sole occupant was the operator.

Vehicle #2 is documented as a 2016 GMC Terrain SLT, bearing Public Vehicle Identification Number 2GKFLUE39G6137584, with a vehicle gross weight of 4,960 lbs. The vehicle was occupied by the operator and a front seat passenger.

Scene
The crash occurred on Mt Pleasant Road 30 feet west of the intersection of Taunton Lane (Latitude 41.416336 and Longitude -73.358399) in the town of Newtown, Connecticut. Mt Pleasant Road travels in an east/west direction and is described as two-way traffic roadway consisting of one travel lane in each direction. The travel lanes are separated by a double yellow line. The posted speed limit in the area of the collision changes from 40 to 45 mph. The roadway was described by the investigator as an uphill grade, free of defects and debris, and with no noted conspicuity issues.

Weather Conditions
The weather conditions for the Newtown, Connecticut area on April 4, 2017, at approximately 11:33 am were 44.6 ^{0}F, 87% humidity, 1.5 miles visibility with an east wind direction at 8.1 mph. Rainfall has been documented as starting at approximately 6:00 am, and it was raining at the time of the collision.

Physical Evidence
The physical evidence at the scene of the collision showed the area of impact (AOI) occurred in the eastbound travel lane. The location of the AOI confirmed what witnesses had stated occurred. There was no physical evidence located at the scene that would have allowed for a conclusion regarding the speed, braking or evasive movements of either vehicle prior to the collision. The discrepancies in the weight of each vehicle would not allow for the use of a Conservation of Linear Momentum formula to determine a speed. There were no documented deceleration marks located within the roadway. The investigating agency did not document obtaining a coefficient of friction value for the roadway at the approximate time of the collision.

EDR Download
An EDR download was conducted on both vehicles.

Vehicle #1 (2005 Buick Lesabre)
The results from this vehicle are limited in scope as 2005 versions of EDR's recorded fewer points of data. The results of the download showed that the collision was a deployment event thus indicating that the vehicle's airbags were deployed. The EDR recorded five one-second intervals prior to impact for this vehicle. The download further documented the vehicle's speed, engine speed, throttle percentage, brake switch circuit state (on/off), and driver's safety belt status. Five seconds prior to the collision, the vehicle's speed was 41 mph, with the engine speed recorded as 1536 RPM, and 24% throttle. The brake switch indicator showed "off". Three seconds prior to the collision, the vehicle's speed was 42 mph, with the engine speed recorded as

1536 RPM and 24% throttle. The brake switch indicator showed “off”. One second prior to the collision, the vehicle’s speed was 43 mph, with the engine speed recorded as 1600 RPM, and 24% throttle. The brake switch indicator showed “off”. The download further indicated that the operator of Vehicle #1 was not utilizing the safety belt and experienced a Delta V of -39.27 mph at impact. The information documented in the download of the EDR indicated that the operator of the vehicle was driving at a constant speed and had not applied any evasive or braking maneuver prior to the collision.

Vehicle #2 (2016 GMC Terrain SLT)
The results of the download indicated that the collision was a deployment event, thus indicating that the vehicle’s airbags were deployed. The EDR recorded five one-second intervals prior to impact for this vehicle. The download further documented the vehicle’s speed, engine speed, throttle percentage, brake switch circuit state (on/off), and Delta V. Five seconds prior to the collision, the vehicle’s speed was 41 mph, with the engine speed recorded as 16280 RPM, and 27% throttle. The brake switch indicator showed “off”. Three seconds prior to the collision, the vehicle’s speed was 39 mph, with the engine speed recorded as 16152 RPM, and 8% throttle. The brake switch indicator showed “off”. One second prior to the collision, the vehicle’s speed was 35 mph, with the engine speed recorded as 960 RPM, and 8% throttle. The brake switch indicator showed “off”. The download indicated that the operator was not utilizing the safety belt and the front seat passenger was utilizing the safety belt. At impact the Delta V was recorded as -32.9 mph.

Conclusion
Based on the initial investigation and physical evidence gathered by the police, the investigator could not conclude the speeds, evasive maneuvers, braking of the vehicles or safety belt usage prior to or at the time of impact. The EDR download produced speed, braking analysis, and Delta V of each vehicle involved in the collision. The download further showed the safety belt status for all involved.

Synopsis of Collision #4

Collision #4 occurred in the town of Wilton, Connecticut on August 16, 2017, at 8:27 pm. The collision involved two vehicles, resulting in injuries to both operators. The operator of Vehicle #1 received minor injuries and the operator of Vehicle #2 received a fatal injury. The collision is described as a head-on (front to front) collision. The collision was the result of vehicle # 2 traveling northbound and crossing over the double yellow line into oncoming traffic and colliding with vehicle #1, which was traveling southbound in its proper travel lane. The emergency response and collision investigation were conducted by the Wilton Police Department.

Vehicle Specifications
Vehicle #1 is documented as a 2013 Toyota Sienna X, bearing Public Vehicle Identification Number 5TDDK3DCXDS070139, with a vehicle gross weight of 5,995 lbs. The vehicle’s sole occupant was the operator.

Vehicle #2 is documented as a 2008 Toyota Corolla, bearing Public Vehicle Identification Number 2T1BR30EX8C888995, with a vehicle gross weight of 3,585 lbs. The vehicle's sole occupant was the operator.

Scene

The crash occurred on Danbury Road 2/10th of a mile south of Old Mill Road (Latitude 41.243037 and Longitude -73.433768) in the town of Wilton, Connecticut. Danbury Road travels in a north/south direction and is described as a two-way traffic roadway consisting of one travel lane in each direction. The travel lanes are separated by a double yellow line. The posted speed limit in the area of the collision changes from 40 to 45 mph. The roadway was described by the investigator as of a level grade, free of defects, debris, and no noted conspicuity issues.

Weather Conditions

The weather conditions for the Wilton, Connecticut area on August 16, 2017, at approximately 8:27 pm were partly cloudy, 70 ^{0}F, 84% humidity, 10 mile visibility with a south-west wind direction of 3.5 mph.

Physical Evidence

The physical evidence at the scene of the collision showed the area of impact (AOI) occurred in the southbound travel lane. The location of the AOI confirmed the witnesses' statements. There was no physical evidence located at the scene that would have allowed for a conclusion regarding the speed, braking or evasive movements of either vehicle prior to the collision. The discrepancies in the weight of each vehicle would not allow for the use of a Conservation of Linear Momentum formula to determine a speed. There were no documented deceleration marks located within the roadway. The vehicles were secured as evidence by the investigating law enforcement agency for analysis. After review and a mechanical inspection of both vehicles, it was determined that there were no mechanical issues with either of the involved vehicles.

EDR Download

An EDR download was conducted on both vehicles.

Vehicle #1 (2013 Toyota Sienna X)

The results of the download showed that the collision was a deployment event, thus indicating that the vehicle's airbags were deployed. The EDR recorded five one-second intervals prior to impact for this vehicle. The download further documented the vehicle's speed, engine speed, throttle percentage, brake switch circuit state (on/off) and driver's safety belt status. Five seconds prior to the collision, the vehicle's speed was 46 mph, with the engine speed recorded as 1400 RPM, and 3.5% throttle. The brake switch indicator showed "off". Three seconds prior to the collision, the vehicle's speed was 45.4 mph, with the engine speed recorded as 1400 RPM, and 3% throttle. The brake switch indicator showed "off". One second prior to the collision, the vehicle's speed was 44.7 mph, with the engine speed recorded as 1400 RPM, and 4% throttle. The brake switch indicator showed "off". At 0.5 seconds prior to impact, the brakes of the vehicle were activated, the gear shift indicator was in "Drive" and there was a slight steering input.

The download further indicated that the vehicle had four previously recorded trigger events. The information documented in the download of the EDR indicated that the operator of the vehicle was driving at a constant speed and had not applied any evasive or braking maneuver prior to 0.5 seconds prior to the collision.

Vehicle #2 (2008 Toyota Corolla)
Attempts were made to download the EDR from vehicle #2. The download was unsuccessful because of damage received during the collision. The EDR was removed from the vehicle and sent for further forensic analysis. It has been confirmed that a download is possible, and the investigator is currently waiting for the EDR report to be completed by the forensic company.

Conclusion
Based on the initial investigation and physical evidence gathered, the police investigator could not conclude the speeds, evasive maneuvers, braking of the vehicles or safety belt usage prior to or at the time of impact. The EDR download produced speed, braking analysis, and evasive action of vehicle #1.

Synopsis of Collision #5

This collision occurred at 9:10 pm on August 12, 2017, in the town of Norwalk, Connecticut. The collision involved a single vehicle and a pedestrian, resulting in fatal injuries to the pedestrian who was crossing the street from east to west. There was no marked crosswalk in the area. The vehicle operator immediately stopped after striking the pedestrian.

Vehicle Specifications
Vehicle #1 is documented as a 2013 Mazda 3i, bearing Public Vehicle Identification Number JM1BL1VPXD1785770. The vehicle has a recorded gross weight of 2,866 lbs.

Scene
The collision is documented on a State of Connecticut PR-1 Report Form occurring in the jurisdiction of the Norwalk Police Department. The crash occurred on Main Street 28 feet south of Van Tassel Street (Latitude 41.1281 and Longitude -73.4229) in the town of Norwalk, Connecticut. Main Street travels in a north/south direction and is described as two-way traffic roadway consisting of two travel lanes in each direction that are separated by a double yellow line. The roadway was described by the investigator as being of level grade, free of defects and debris, and with no noted conspicuity issues. The investigator noted that the area of the collision was illuminated at the time of the collision.

Operator
The operator of the vehicle is documented as a 43-year-old male who resides in a neighboring city. The operator possessed a valid Connecticut, Class D, operator’s license at the time of the collision. The investigators determined that the operator was not under the influence of any substance and was not distracted while operating his vehicle.

Pedestrian

The pedestrian is documented as a 49-year-old male, 5'8" tall, weighing 221 lbs. The State of Connecticut Office of the Medical Examiner's autopsy report concludes the cause of death as blunt impact injuries of the head, neck, torso, and extremities. As a course of procedure, the Connecticut Medical Examiner's Office performed a post-mortem examination of the pedestrian. As part of the post-mortem examination, samples of the pedestrian's blood were taken for analysis. The resulting toxicology report showed the pedestrian's blood contained 0.05 grams % of ethanol. There were no noted traces of narcotics or drugs found. The pedestrian was within the travel portion of the roadway and not wearing reflective clothing at the time of the collision. A female witness, who was also driving on Main Street at the time of the collision, reported that two pedestrians (a male and female) attempted to run across the roadway. The witness stated that she was able to stop without striking the pedestrian, but Vehicle #1 struck the male.

Environmental Conditions

The weather conditions for the Norwalk Connecticut area on August 12, 2017, at approximately 9:12 pm were 72 ^{0}F, 87% humidity, 10 mile visibility, and cloudy skies with no recorded rainfall for the day.

Speed Analysis

The investigator utilized the Searle formula. The Searle formula is a pedestrian formula utilizing the throw distance, angle of departure, and coefficient of friction, to determine a minimum velocity/speed. This equation is utilized when a pedestrian is struck, thrown and tumbles to final rest. Based on the physical evidence such as marks in the roadway the investigators concluded that the vehicle being driven by the female was traveling at a bracketed speed of between 35 mph and 41 mph at the point of impact with the pedestrian.

EDR Download

The EDR download was conducted. The results of the download indicated that the collision was a non-deployment event, indicating that the vehicle's airbags were not deployed. The EDR recorded five one-second intervals prior to impact. The download documented the vehicle's speed, throttle percentage and brake switch circuit state (on/off). Five seconds prior to the collision, the vehicle's speed was 43 mph, with 25% throttle. The brake switch indicator showed "off". Three seconds prior to the collision, the vehicle's speed was 44 mph, with 35% throttle. The brake switch indicator showed "off". One second prior to the collision, the vehicle's speed was 46 mph, with 0% throttle. The brake switch indicator showed "on".

Conclusion

The EDR download produced a definitive speed and braking analysis of the crash. The information from the EDR was conclusive evidence that the operator of the vehicle was not traveling at excessive speeds, and had made no evasive moves prior to impact. A review of the totality of this collision showed that two pedestrians attempted to run across the roadway in front of several vehicles. The male pedestrian was struck by the operator of vehicle #1. The deceased pedestrian was determined to be at fault for this collision. The Supervising States Attorney for the Norwalk area determined that no charges would be filed against the operator of vehicle #1.

Case Study Summary

A summary of each collision is represented in Table 1 below.

Table 1: Collision Summary

Collision	Vehicles involved	Reason for Request of EDR Service	EDR data download elements	Advantage of using EDR
1	2002 GMC Envoy 2011 Ford Fusion	There was no physical evidence at the scene to calculate speed of the vehicles involved. The discrepancies in weight would not allow for the use of a Conservation of Linear Momentum formula to determine a speed. There were no documented deceleration marks located within the roadway.	Vehicle #1 – vehicle's speed, engine speed, throttle percentage, brake switch circuit state (on/off), and driver's safety belt status. Vehicle #2 – vehicle's speed, engine speed, throttle percentage, brake switch circuit state (on/off), and Delta V.	The EDR download produced speed and braking analysis of each vehicle involved in the collision. The download further confirmed the utilization of safety belts for both operators.
2	2003 Chevrolet Trailblazer	The physical evidence and initial investigation concluded that the vehicle "most likely" did not turn right prior to impact. Utilizing the physical vault of the pedestrian produced an approximate bracketed speed of the vehicle at impact.	Vehicle #1 – vehicle's speed, engine speed, throttle percentage, and brake switch circuit state (on/off).	The EDR download produced a definitive speed and braking analysis of the crash. It was conclusive evidence that the operator of the vehicle had not made a turn and was in fact traveling at a high rate of speed at impact.
3	2005 Buick Lesabre 2016 GMC Terrain	There was no physical evidence at the scene to calculate speed of the vehicles involved. The discrepancies in weight would not allow for the use of a Conservation of Linear Momentum formula to determine a speed. There were no documented deceleration marks located within the roadway. The investigating agency did not document obtaining a coefficient of friction value for the roadway at the approximate time of the collision.	Vehicle #1 – vehicle's speed, engine speed, throttle percentage, brake switch circuit state (on/off), driver's safety belt status, and Delta V. Vehicle #2 – vehicle's speed, engine speed, throttle percentage, brake switch circuit state (on/off), and Delta V.	The EDR download produced speed, braking analysis, and Delta V of each vehicle involved in the collision. The download further showed the safety belt status for all involved.

Collision	Vehicles involved	Reason for Request of EDR Service	EDR data download elements	Advantage of using EDR
4	2013 Toyota Sienna 2008 Toyota Corolla	There was no physical evidence located at the scene that would have allowed for a conclusion regarding the speed, braking or evasive movements of either vehicle prior to the collision. The discrepancies in the weight of each vehicle would not allow for the use of a Conservation of Linear Momentum formula to determine a speed. There were no documented deceleration marks located within the roadway.	Vehicle #1 – speed, engine speed, throttle percentage, brake switch circuit state (on/off), and driver's safety belt status. Vehicle #2 – download was unsuccessful because of the damage to the vehicle.	The EDR download produced speed, braking analysis, and Delta V for vehicle #1. We are still waiting for vehicle #2.
5	2013 Mazda 3i	The Searle formula gave the range for the speed whereas investigators needed exact speed to determine if the driver was speeding at the time of crash.	Vehicle #1 – vehicle's speed, throttle percentage, brake switch circuit state (on/off), and air bag deployment.	The EDR download produced a definitive speed and braking analysis of the crash. The information from the EDR was conclusive evidence that the operator of the vehicle was not traveling at excessive speeds and had made no evasive moves prior to impact.

Chapter 4 Conclusions, Recommendations, and Suggested Research

Five motor vehicle collisions were analyzed for the study. Two of the collisions involved a vehicle striking a pedestrian, whereas the other three involved head-on collisions between two vehicles. The EDR downloads conducted in this study produced valuable data that were unavailable from traditional reconstruction techniques. This enhanced data allowed for the precise analysis of each collision. In all circumstances, the download of data produced complimentary evidence in the crash and did not contradict the officer's original report, when compared to the analysis of the physical evidence located at the scene of a crash. However, the EDR downloads were contradictory to the statements of one driver, who fatally injured a pedestrian, when there were no other witnesses. Without the EDR data to show the vehicle did not turn and that the vehicle was traveling at a high rate of speed, this crash may not have resulted in as severe charges against the driver. The use of an EDR download enables the investigators to develop more accurate and reliable supplemental data to support collision reconstruction. The continued documentation of the enhanced information gathered through the utilization of an EDR will produce a comprehensive database, allowing for in-depth analysis and improved overall highway safety.

We recommend that the CTDOT continue this program and support future enhancements to the EDR kit such as new cables and modules that are released each year. The service that CTSRC now provides, through essentially an equipment loan program, has allowed police departments to have access to an expensive tool that they may only need once or twice a year. Assisting in downloads for fatal and serious injury crashes allows police departments to draft a more complete and in-depth investigation, which results in better crash data for CTDOT safety analysis. Through a central agency such as CTSRC, police departments across the state, now have access to a tool kit that costs over $20,000 at no charge. As a result, we receive at least two calls a month for assistance with a crash download. A recent request was received from the Connecticut State Police (CSP) for our FlexRay module. This is a module that CSP does not have as part of their kit but needed for a download of a BMW in a fatal crash. EDR pins, software, and design are not standardized by the government, across vehicle manufacturers or even with the individual manufacturers. Therefore there is an annual need to purchase new cable(s) and module(s) to keep the kit up-to-date with the latest vehicles on the road.

The limited case studies presented here show the benefits of this technology. The minimal physical effort required to download the EDR data results in information that is critical to an officer's investigation. However, the EDR data is the property of the vehicle owner and is considered personal and private. Therefore, the need for a search and seizure warrant is a major limitation in this process. Without this requirement, CTSRC would recommend that police departments download the computer data of every vehicle equipped with this technology for every fatal and serious injury crash. However, the CTSRC team recommends that the effort to obtain the search and seizure warrant is justified and will significantly improve crash investigations in the future. We would recommend that police departments generate a standard template for a search and seizure warrant for this purpose, if they don't already have one. This will expedite the process and reduce the work required to obtain this data.

Chapter 5 Implementation of Research Results

The CTSRC research team will continue to provide this service to the law enforcement community. We expect that the CTDOT, and other state agencies, will continue to support and promote this technology for crash investigations. The state should work towards developing a repository for EDR data downloads that is linked to the crash reports to allow researchers access to this detailed information for safety analysis and integration. Traditionally, collision investigation has relied upon the methodology of collision reconstruction. This methodology involves mathematical calculation, which in most cases does not allow for absolute answers. This methodology is also incumbent upon the availability of physical evidence, combined with witness and operator portrayal of how the collision occurred. While the use of an EDR is not recommended to replace a traditional collision reconstruction, it should be used as a tool to enhance the accuracy of the investigation, allowing for a more inclusive and complete report. The EDR data allows for the collection of unbiased factors, leading to a comprehensive and undisputable evaluation of many facts, including driver behavior and vehicle dynamics. This allows all stakeholders to precisely evaluate the true cause of a collision and ensure that a complete examination of an event is conducted. Through an increased utilization and study of EDR data, all stakeholders can ultimately use this data to improve road safety within Connecticut.

References

1. National Archives and Records Administration, “Part 563 -Event Data Recorders,” Federal Register 71(166): 51043-51048, Docket No. NHTSA-2006-25666, Aug. 28, 2006.
2. Ruth, R., “Crash Data Retrieval Update,” IPTM EDR working group, retrieved at http://www.ruthconsulting.com/docs/2015-11/EDR%20Update%20MdATAI%20conf%2010%2015%202015%20Rick%20Ruth.pdf
3. Event Data Recorder, Wikipedia, retrieved at https://en.wikipedia.org/wiki/Event_data_recorder
4. Askland, A., “The Double Edged Sword that is the Event Data Recorder,” Temple Journal of Science, Technology and Environmental Law, 25(1), Spring 2006.
5. Bortles, W., Biever, W., Carter, N. and Smith, C., “A Compendium of Passenger Vehicle Event Data Recorder Literature and Analysis of Validation Studies,” SAE Technical Paper 2016-01-1497, 2016, doi:10.4271/2016-01-1497.
6. Applying Automotive EDR Cata to Traffic Crash Reconstruction. SAE training, retrieved at http://training.sae.org/seminars/c1210/

APPENDIX A

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	
User	
Case Number	
EDR Data Imaging Date	02/27/2018
Crash Date	
Filename	
Saved on	Tuesday, February 27 2018 at 11:06:20
Imaged with CDR version	Crash Data Retrieval Tool 17.6.1
Imaged with Software Licensed to (Company Name)	Connecticut Transportation Institute
Reported with CDR version	Crash Data Retrieval Tool 17.6.1
Reported with Software Licensed to (Company Name)	Connecticut Transportation Institute
EDR Device Type	Airbag Control Module
Event(s) recovered	Record 1

Comments

No comments entered.

Data Limitations

BMW AIRBAG CONTROL MODULE (ACSM) DATA LIMITATIONS:

General Information:
These limitations are intended to assist you in reading the event data that has been imaged from the vehicle’s ACSM. 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.

BMW passenger vehicles designated as 2016 or later model year are designed to fulfill the "NHTSA 49 CFR 563 - Event Data Recorders" and to be compatible with the Bosch CDR tool.

The Recorded Crash Events can be read by the CDR over the vehicle’s OBD connector which is the preferred procedure. Imaging data by connecting directly to the ACSM should only be attempted if the vehicle’s electrical system is damaged. In this case proceed with CAUTION. When imaging by directly connecting to the ACSM, make sure the ACSM is not moved, tilted or turned over while connected to and powered by the CDR Interface Module. Also, after a CDR imaging process, wait at least one minute after power is removed from the ACSM before attempting to move the module. Not following these general ACSM guidelines for bench top imaging could cause new events to be recorded in the ACSM.

The ACSM current fault status will be altered if the ACSM is powered-up without having all of the other vehicle inputs connected. This situation will occur when imaging data while connected directly to the ACSM. This will not affect the stored fault data information in any of the Event Records.

To ensure the integrity of the data during imaging, the transmitted data will be signed (signature is like a CRC) by the ACSM before being read by the CDR tool. This can take up to 60 seconds for each recorded event.
In case the signature build takes longer, a gateway timeout can occur. In this case the retrieving procedure should be retried under the same ignition cycle and could be successful, if not then a download directly from ECU is necessary.

Recorded Crash Events:
The recordered events can be front, side, rear, pedestrian or rollover events.
Data for front, side and rear events can be recorded as either non-deployment or deployment events. Both types of events can contain pre-crash and crash data. The ACSM can store up to five events such as Non-Deployment Events (NDE) and Deployment Events (DE):
- a Non-Deployment Event is recorded if the change in longitudinal or lateral velocity equals or exceeds 8km/h over a 150ms timeframe.
- a Deployment Event is recorded if any type of non-reversible deployable restraint device (e.g. front airbag(s), side airbag(s), side curtain airbag(s), pretensioner(s), ...) are commanded to deploy. This includes a deployment caused by a rollover event.
- Deployment Events are locked into memory and cannot be over-written.
- Non-Deployment Events are not locked into memory and (the oldest) can be over-written by subsequent Non-Deployment or Deployment Events.
- Recorded events will be imaged by the CDR tool in chronological order (the first event is the most recent one).

- If power to the ACSM is lost during an event, all the data of this event will be stored (see information "Complete file recorded"). For following events all or part of the event data record may not be recorded. Such events cannot be retrieved by the CDR tool.

The “event begin” t0 is:
- the change in longitudinal velocity equals or exceeds 0.8km/h over a 20ms timeframe (front threshold)
- the change in lateral velocity equals or exceeds 0.8km/h over a 5ms timeframe (side threshold)
- deployment of a restraint by the rollover algorithm.

The event recording will always be 300ms even if:
- the change in longitudinal and lateral velocity equals or falls below 0.8km/h over a 20ms timeframe.

Multiple Events:
Data recorded by the ACSM and imaged by the CDR tool is displayed relative to t0 (generally always after), not the time at which the vehicle made contact with another vehicle or object.

In case of multiple algorithm activities during an event (e.g. angular impact where algorithm start to algorithm reset for each individual algorithm) overlap in time (< 300ms) this is considered a “parallel event”. The the first threshold reached or the deployment command of the rollover algorithm classifies the event type as “initial event”. The triggering times of the subsequent event(s) are in reference to t0 of the initial event and are reported.

If an accident consists of multiple events, during which the algorithm activities do not overlap in time and whose start times t0 are set apart less than 5 s, this is considered a multiple event.
A multiple event can consist of more than two events, provided their start times t0 are all within the 5 s following the initial event.
The chronological sequence within a multiple event is marked by the data element "multi-event, number of events." The time period between this event and the preceding event is marked in the data element "time from event n to n+1."

Data Element Sign Convention:
The sign convention is according to "NHTSA 49 CFR 563 - Event Data Recorders".

Data Element Name	Positive Sign Notation Indicates
Longitudinal Acceleration	Forward
Delta-V, Longitudinal	Forward
Maximum Delta-V, Longitudinal	Forward
Lateral Acceleration	Left to Right
Delta-V, Lateral	Left to Right
Maximum Delta-V, Lateral	Left to Right
Normal Acceleration	Downward
Vehicle Roll Angle	Clockwise Rotation around vehicles longitudinal axis
Steering Input	Right Turn

Data Elements:
Pre-Crash Data:
- Pre-Crash Data is recorded at 2 samples per second starting 5 seconds before t0.
- Pre-Crash Data is recorded asynchronously.
- Recorded Pre-Crash Data have a time resolution of 500ms. This can cause a possible delay of the collected data up to 500ms.
- Pre-Crash Data indicates “Data Invalid” if a message with an “invalid” flag from the module sending the pre-crash data is sent.
- Pre-Crash Data indicates “Data Not Available” if data is not received from the module sending the pre-crash data.
- Speed, vehicle indicated data is reported as an average of all wheels.
- Speed, vehicle indicated data accuracy can be affected by various factors, such as significant changes in tire size from the factory setting, wheel lockup or slip.
- Accelerator Pedal Position, percent full is the ratio of accelerator pedal position compared to the fully depressed position.
- Steering Input Angle is recorded in 5 degree increments and limited to -250 and 250 degrees.
- Service Brake Status only indicates driver initiated braking. An automatic braking (e.g. brake intervention by Adaptive Cruise Control) will not be recorded.
- ABS Activity Status indicates an ABS Control Intervention during driver initiated braking.
- Stability Control Status indicates a Stability Control Intervention. If the Stability Control is switched off by the driver, the recorded value is "Data Not Available".

Crash data:
- Acceleration data is recorded at 100Hz from t0 to 300ms.
- Delta-V data is recorded at 100Hz from t0 to 300ms.
- Delta-V, longitudinal reflects the change in velocity that the ACSM experienced in the longitudinal direction during the recorded portion of the event and is not the speed the vehicle was traveling before the event.
- Depending on the severity of the event and the accelerometer characteristics, saturation of the ACSM longitudinal or lateral accelerometers may occur. If the saturation exceeds duration of 10ms, the integration of Delta-V is stopped. The reported Delta-V values are displayed as "Data Not Available".
- Restraint Deployment Time (e.g. airbag(s)) is reported as deployment request of this device.
- Restraint Disposal (e.g. 2nd stage of the frontal airbag(s)) is reported if a disposal request of this device occurs.
- Seat Track Position Switch Status is only reported as "foremost" or "not foremost".
- Occupant size classification, right front passenger airbag suppressed data is recorded as “yes” (suppressed) if the front passenger seat

sensor system determined the passenger seat was empty or occupied by a child-seat.

Data Source:
All recorded data is measured and calculated within the ACSM except for the following parameters (if applicable) which are transmitted via the vehicle's communication network to the ACSM:
- Speed, vehicle indicated
- Accelerator pedal position, percent full
- Service brake
- ABS activity
- Stability control
- Steering input angle
- Engine RPM

The Belt Switch Circuit is wired directly to the ACSM.

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 ACSM may contain additional data that is not retrievable by the CDR tool.

0805_BMW_ACSM5_r001

System Status at Event (Record 1, Most Recent)

Event Type	Frontal
Maximum Delta-V, Longitudinal (MPH [km/h])	-60.9 [-98]
Maximum Delta-V, Lateral (MPH [km/h])	8.7 [14]
Time, Maximum Delta-V, Longitudinal (msec)	187.5
Time, Maximum Delta-V, Lateral (msec)	45.0
Time, Maximum Delta-V, Resultant (msec)	187.5
Multi-Event, Number of Events	1. Event
Time From Previous Event to Current Event (msec)	Data Not Available
Time From Last Speed Data Sample (Precrash) to Time Zero (msec)	393
Complete File Recorded, Priority 1 Data	Completed Successfully
Ignition Cycle, Crash (Cycle)	300
Ignition Cycle, Download (Cycle)	301
Vehicle Clock, Date and Time at Event (YYYY-MM-DD, HH:MM:SS)	2018-01-08, 22:10:30
Vehicle Mileage (km)	1,940
Operating Time (min)	4,776
Vehicle Identification Number	WC54473
Event Counter (Counts)	1
Clipping Time Longitudinal Sensor (msec)	28
Clipping Time Lateral Sensor (msec)	Clipping Not Reached
Integration Time Delta-V, Longitudinal (msec)	199
Integration Time Delta-V, Lateral (msec)	199
Time From Initial Event to Current Event (msec)	Data Not Available

Deployment Command Data (Record 1, Most Recent)

Time From Time Zero to Algorithm Wake-Up Start (Front) (msec)	Algorithm Started at t0
Time From Time Zero to Algorithm Wake-Up Start (Side) (msec)	2
Time From Time Zero to Algorithm Wake-Up Start (Rear) (msec)	4
Time From Time Zero to Algorithm Reset (Front) (msec)	169
Time From Time Zero to Algorithm Reset (Side) (msec)	120
Time From Time Zero to Algorithm Reset (Rear) (msec)	168
Frontal Air Bag, Time to First Stage Deployment, Driver (msec)	6
Frontal Air Bag, Time to Second Stage Deployment, Driver (msec)	11
Frontal Air Bag, Time to Third Stage Deployment (Vent), Driver (msec)	256
Frontal Air Bag, Second Stage Disposal, Driver	No Disposal
Frontal Air Bag, Third Stage Disposal (Vent), Driver	No Disposal
Frontal Air Bag, Time to First Stage Deployment, Front Passenger (msec)	Not Deployed
Frontal Air Bag, Time to Second Stage Deployment, Front Passenger (msec)	Not Deployed
Frontal Air Bag, Time to Third Stage Deployment (Vent), Front Passenger (msec)	Not Deployed
Frontal Air Bag, Second Stage Disposal, Front Passenger	Data Not Available
Frontal Air Bag, Third Stage Disposal (Vent), Front Passenger	Data Not Available
Side Air Bag, Time to Deployment First Stage, Driver (msec)	38
Side Curtain/Tube Air Bag,Time to Deployment, Driver Side (msec)	6
Pretensioner (1), Time to Deploy, Driver (msec)	Not Deployed
Side Air Bag, Time to Deployment First Stage, Front Passenger (msec)	Not Deployed
Side Curtain/Tube Air Bag, Time to Deployment, Passenger Side (msec)	6
Pretensioner (1), Time to Deploy, Front Passenger (msec)	Not Deployed
Knee Air Bag, Time to Deploy, Driver (msec)	6
Knee Air Bag, Time to Deploy, Front Passenger (msec)	Not Deployed
Pretensioner (2), Time to Deploy, Driver (msec)	Not Deployed
Pretensioner (2), Time to Deploy, Front Passenger (msec)	Not Deployed
Pretensioner (3), Time to Deploy, Driver (msec)	6
Pretensioner (3), Time to Deploy, Front Passenger (msec)	Not Deployed
Belt Load Limiter Deployment, Time to Deploy, Driver (msec)	54
Belt Load Limiter Deployment, Time to Deploy, Front Passenger (msec)	Not Deployed
Belt Load Limiter, Disposal, Driver	No Disposal
Belt Load Limiter, Disposal, Front Passenger	Data Not Available
Active Head Rest, Time to Deployment, Front Driver (msec)	Not Deployed
Active Head Rest, Time to Deployment, Front Passenger (msec)	Not Deployed
Side Air Bag (Vent), Time to Deployment, Driver (msec)	Not Deployed
Side Air Bag (Vent), Time to Deployment, Front Passenger (msec)	Not Deployed
Side Air Bag, Time to Deployment First Stage, Second Row, Left Side (msec)	Not Deployed
Side Air Bag, Time to Deployment First Stage, Second Row, Right Side (msec)	Not Deployed
Side Air Bag (Vent), Time to Deployment, Second Row, Left Side (msec)	Not Deployed
Side Air Bag (Vent), Time to Deployment, Second Row, Right Side (msec)	Not Deployed
Pretensioner (1), Time to Deploy, Second Row, Left Side (msec)	Not Deployed
Pretensioner (1), Time to Deploy, Second Row, Right Side (msec)	Not Deployed
Pretensioner (1), Time to Deploy, Second Row, Center (msec)	Not Deployed
Pretensioner (2), Time to Deploy, Second Row, Left Side (msec)	Not Deployed
Pretensioner (2), Time to Deploy, Second Row, Right Side (msec)	Not Deployed
Pretensioner (2), Time to Deploy, Second Row, Center (msec)	Not Deployed
Pretensioner (3), Time to Deploy, Second Row, Left Side (msec)	Not Deployed
Pretensioner (3), Time to Deploy, Second Row, Right Side (msec)	Not Deployed
Pretensioner (3), Time to Deploy, Second Row, Center (msec)	Not Deployed
Belt Load Limiter Deployment, Time to Deploy, Second Row, Left Side (msec)	Not Deployed
Belt Load Limiter Deployment, Time to Deploy, Second Row, Right Side (msec)	Not Deployed
Belt Load Limiter Deployment, Time to Deploy, Second Row, Center (msec)	Not Deployed
Belt Load Limiter, Disposal, Second Row, Left Side	Data Not Available
Belt Load Limiter, Disposal, Second Row, Right Side	Data Not Available
Belt Load Limiter, Disposal, Second Row, Center	Data Not Available
Rollover Protection System, Time to Deploy, Driver (msec)	Not Deployed
Rollover Protection System, Time to Deploy, Passenger (msec)	Not Deployed
Battery Disconnect 1, Time to Deploy (msec)	6

BOSCH CDR CRASH DATA RETRIEVAL

Battery Disconnect 2, Time to Deploy (msec)	Not Deployed
HV Battery Deactivation, Time to Deploy (msec)	Not Deployed

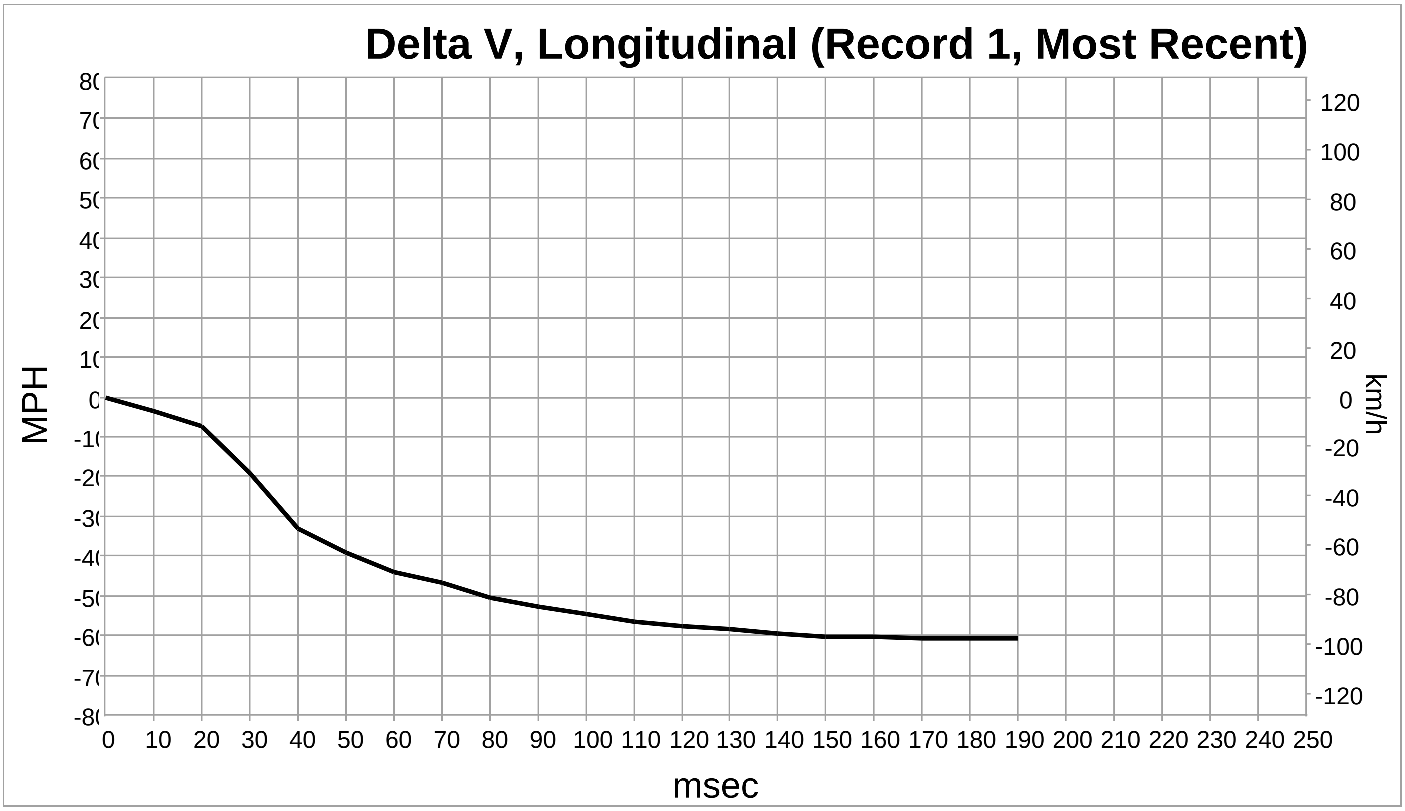
Pre-Crash Data -1 Sec (Record 1, Most Recent)

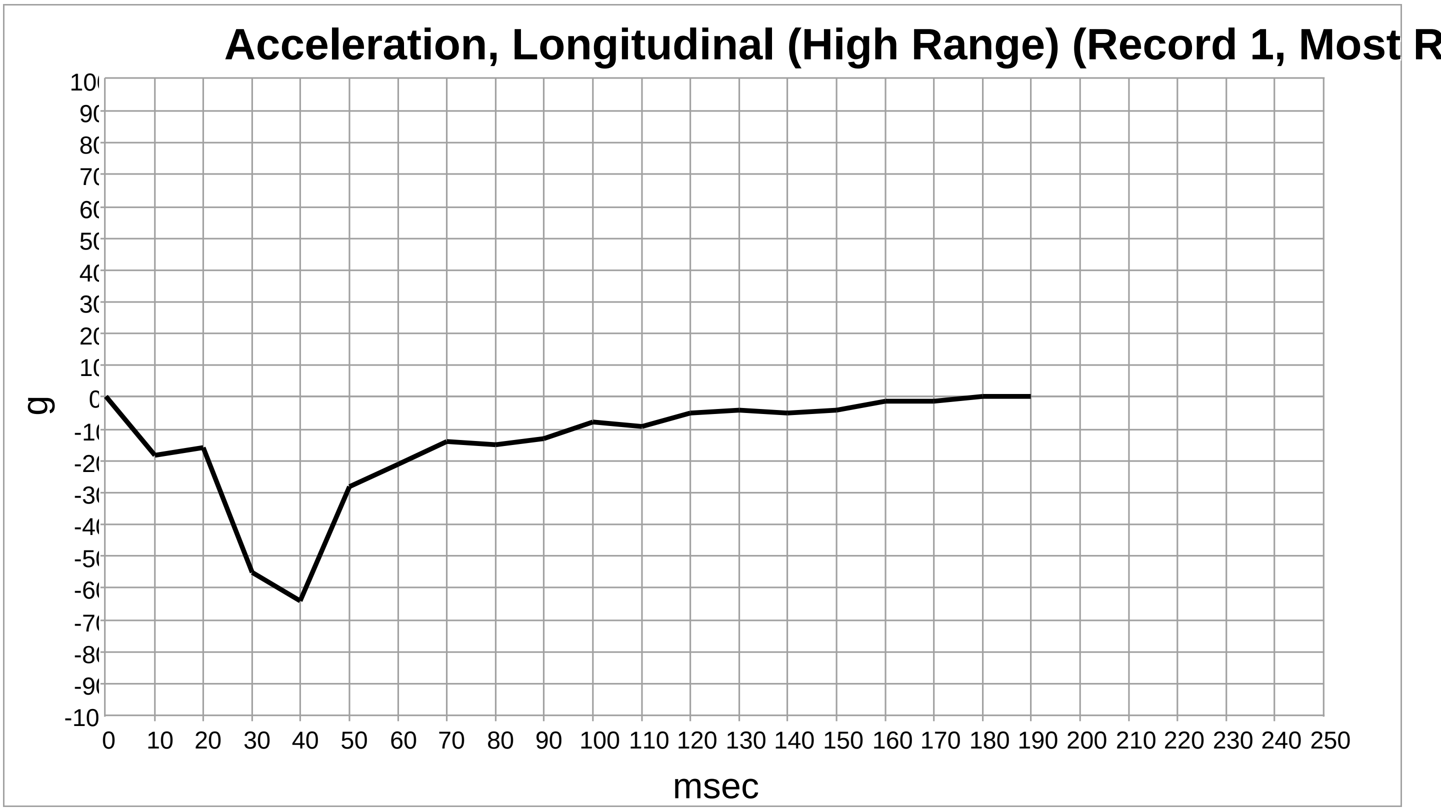
Safety Belt Status, Driver	Belted
Seat Track Position Switch Status, Driver	Not Foremost (Middle/Rear)
Air Bag Warning Lamp (On,Off)	Off
Air Bag Suppression Switch Status, Front Passenger	Suppressed
Safety Belt Status, Front Passenger	Not Belted
Seat Track Position Switch Status, Foremost, Front Passenger	Not Foremost (Middle/Rear)
Occupant Size Classification, Front Passenger (Child)	Empty/Child
Frontal Air Bag Disable Indicator Status, Passenger (POL)	On
Safety Belt Status, Second Row, Left Side	Not Belted
Safety Belt Status, Second Row, Center	Not Belted
Safety Belt Status, Second Row, Right Side	Not Belted
Safety Belt Status, Third Row, Left Side	Data Not Available
Safety Belt Status, Third Row, Center	Data Not Available
Safety Belt Status, Third Row, Right Side	Data Not Available

Pre-Crash Data -5 to 0 sec (Record 1, Most Recent)

Time (sec)	Speed, Vehicle Indicated (MPH [km/h])	Accelerator Pedal, % Full (%)	Engine RPM (RPM)	Steering Input (deg)	Service Brake, On/Off	ABS Activity (Engaged, Non-engaged)	Stability Control (On Engaged, Non-engaged)	Qualifyier Stability Control Function
-5.0	69 [111]	96	5440	0	Off	No ABS Activity	No ESC Activity	2097664
-4.5	73 [118]	96	5760	0	Off	No ABS Activity	No ESC Activity	2097664
-4.0	78 [125]	96	6080	0	Off	No ABS Activity	No ESC Activity	2097664
-3.5	81 [131]	96	6400	0	Off	No ABS Activity	No ESC Activity	2097664
-3.0	85 [137]	96	6656	0	Off	No ABS Activity	No ESC Activity	2097664
-2.5	88 [141]	95	6848	0	Off	No ABS Activity	No ESC Activity	2097664
-2.0	91 [146]	95	5760	0	Off	No ABS Activity	No ESC Activity	2097664
-1.5	94 [151]	94	5888	0	Off	No ABS Activity	No ESC Activity	2097664
-1.0	96 [155]	94	6080	0	Off	No ABS Activity	No ESC Activity	2097664
-0.5	99 [159]	95	6208	0	Off	No ABS Activity	No ESC Activity	2097664
0.0	101 [162]	93	4864	0	Off	No ABS Activity	No ESC Activity	2097664

Longitudinal Crash Pulse (Record 1, Most Recent)

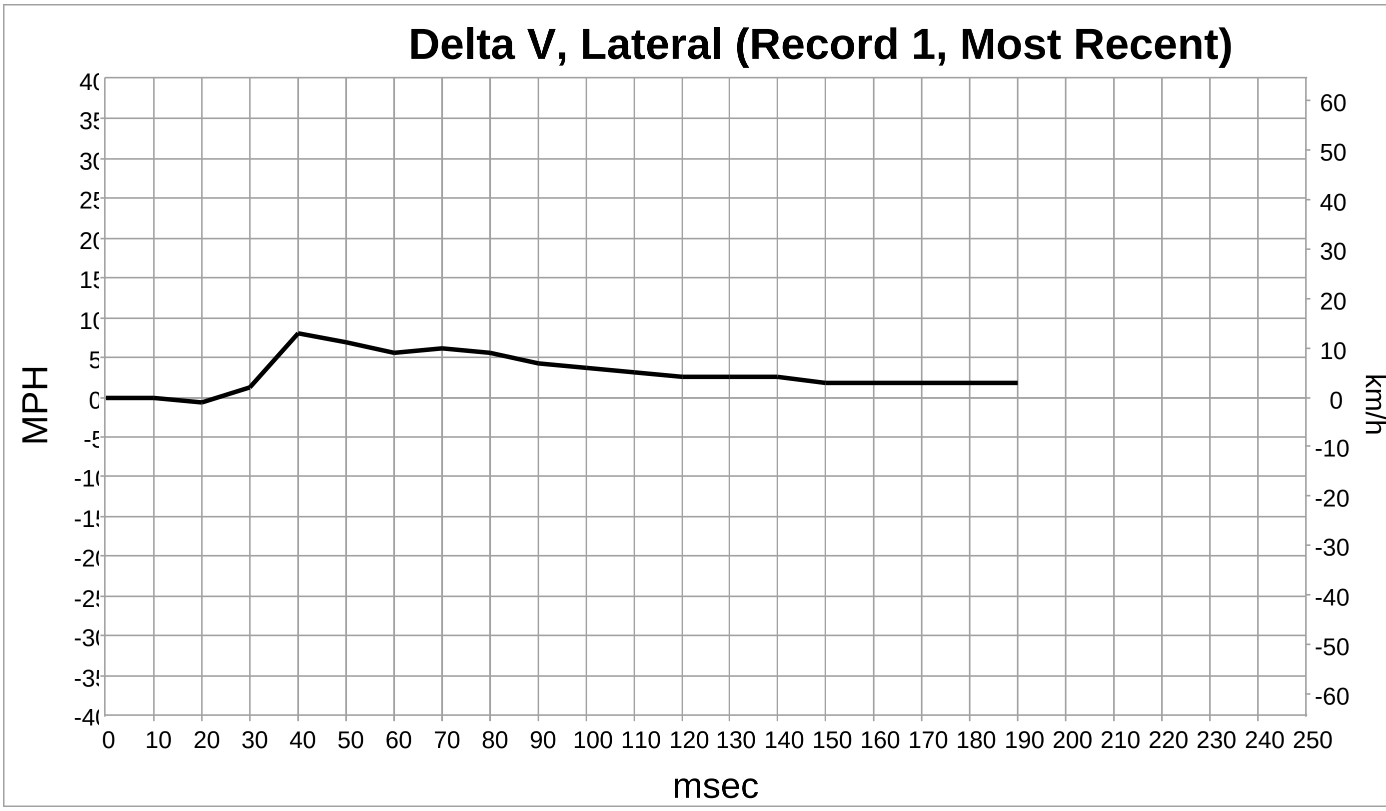


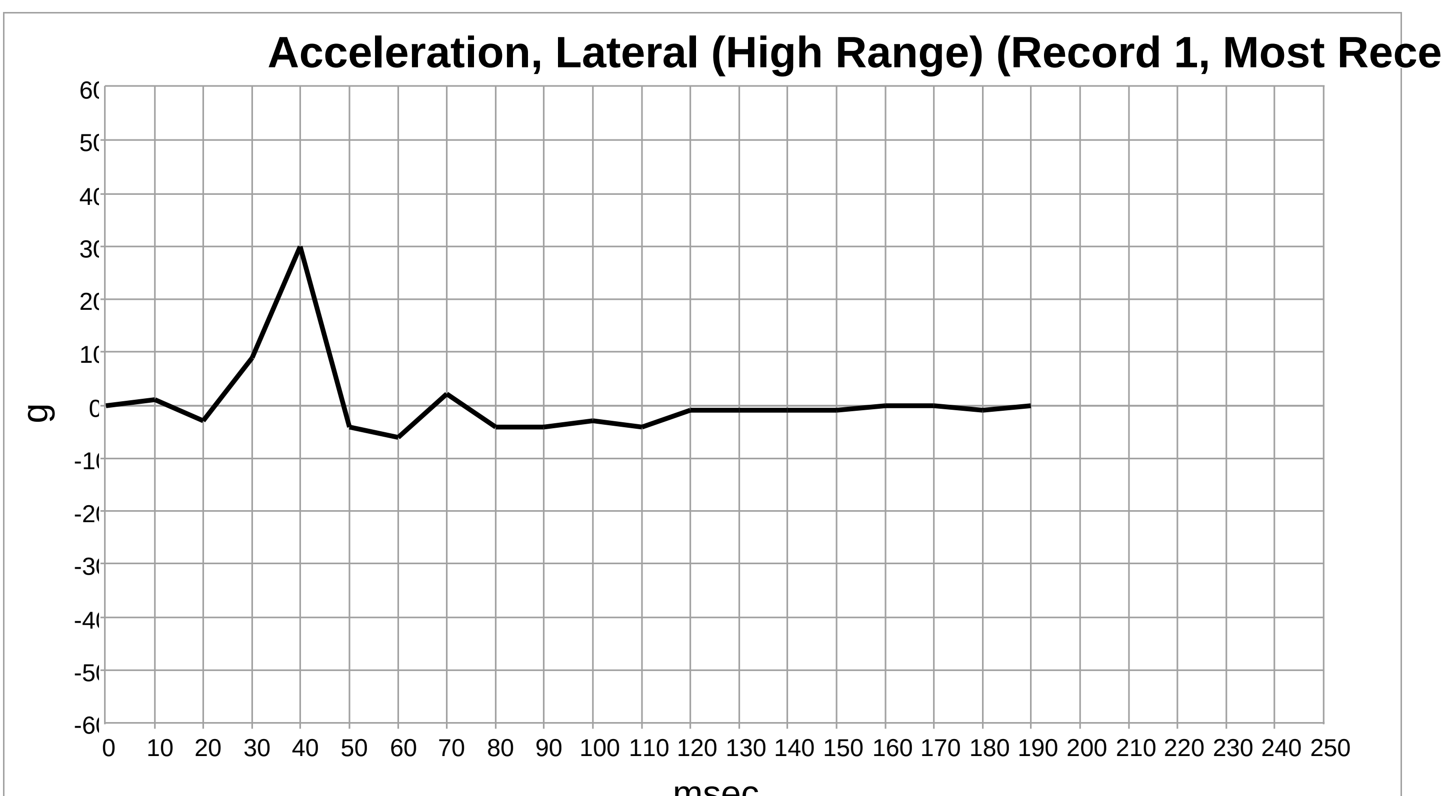


Longitudinal Crash Pulse (Record 1, Most Recent)

Time (msec)	Delta-V, Longitudinal (MPH [km/h])	Longitudinal Acceleration (g)
0	0.0 [0]	-0.29
10	-3.7 [-6]	-18.03
20	-7.5 [-12]	-15.75
30	-19.3 [-31]	-54.64
40	-32.9 [-53]	-63.80
50	-39.1 [-63]	-28.13
60	-44.1 [-71]	-20.94
70	-46.6 [-75]	-14.21
80	-50.3 [-81]	-14.79
90	-52.8 [-85]	-12.94
100	-54.7 [-88]	-8.40
110	-56.5 [-91]	-9.12
120	-57.8 [-93]	-5.27
130	-58.4 [-94]	-4.10
140	-59.7 [-96]	-4.54
150	-60.3 [-97]	-3.54
160	-60.3 [-97]	-1.02
170	-60.9 [-98]	-0.60
180	-60.9 [-98]	0.09
190	-60.9 [-98]	-0.41
200	Data Not Available	Data Not Available
210	Data Not Available	Data Not Available
220	Data Not Available	Data Not Available
230	Data Not Available	Data Not Available
240	Data Not Available	Data Not Available
250	Data Not Available	Data Not Available

Lateral Crash Pulse (Record 1, Most Recent)

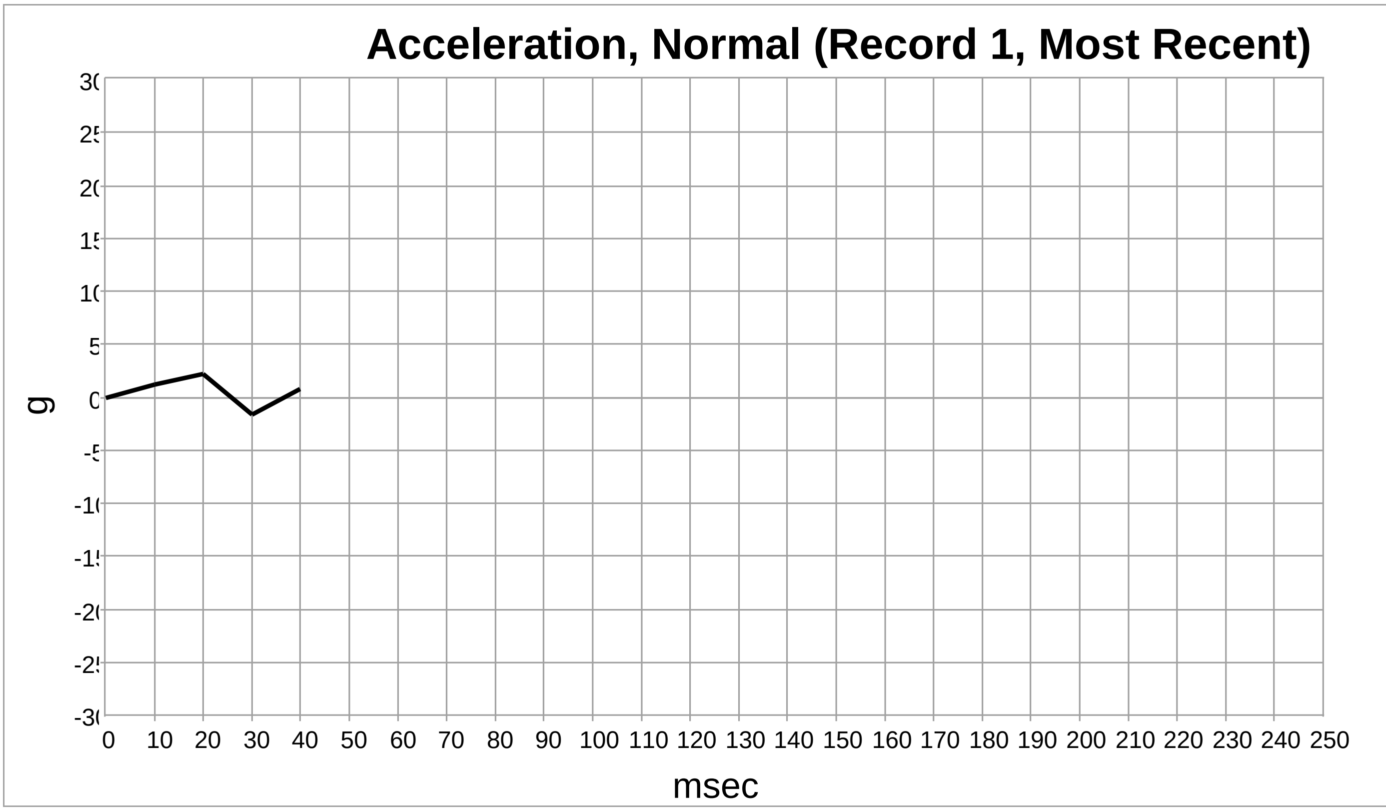




Lateral Crash Pulse (Record 1, Most Recent)

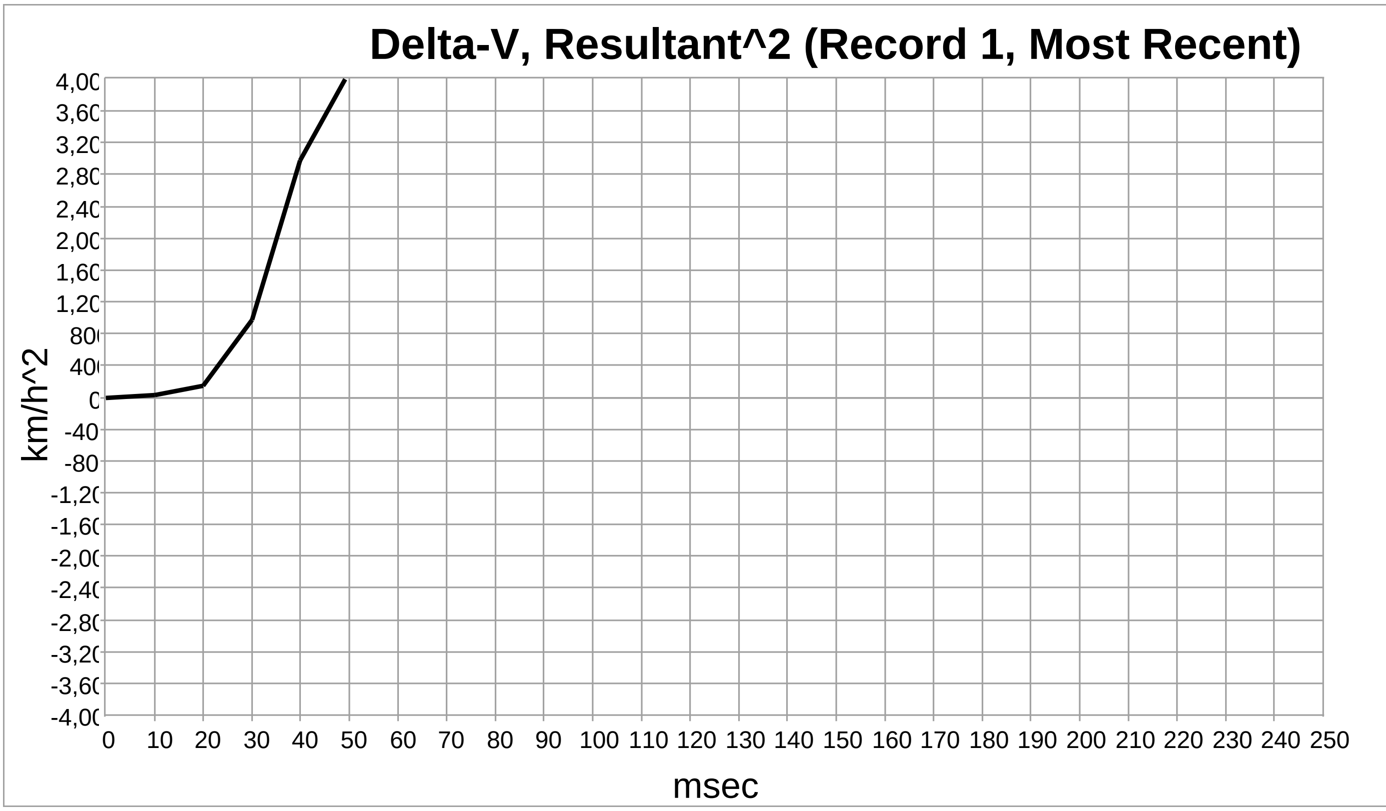
Time (msec)	Delta-V, Lateral (MPH [km/h])	Lateral Acceleration (Lateral G High Range) (g)
0	0.0 [0]	0.25
10	0.0 [0]	0.58
20	-0.6 [-1]	-2.98
30	1.2 [2]	9.28
40	8.1 [13]	29.58
50	6.8 [11]	-4.26
60	5.6 [9]	-6.00
70	6.2 [10]	1.95
80	5.6 [9]	-3.53
90	4.3 [7]	-4.12
100	3.7 [6]	-3.28
110	3.1 [5]	-4.00
120	2.5 [4]	-0.73
130	2.5 [4]	-1.40
140	2.5 [4]	-1.14
150	1.9 [3]	-0.57
160	1.9 [3]	0.03
170	1.9 [3]	0.13
180	1.9 [3]	-0.72
190	1.9 [3]	-0.36
200	Data Not Available	Data Not Available
210	Data Not Available	Data Not Available
220	Data Not Available	Data Not Available
230	Data Not Available	Data Not Available
240	Data Not Available	Data Not Available
250	Data Not Available	Data Not Available

Normal Acceleration (Record 1, Most Recent)



Time (msec)	Normal Acceleration (Vertical G Low Range) (g)
0	0.0
10	1.2
20	2.2
30	-1.6
40	0.8
50	Invalid Data
60	Invalid Data
70	Invalid Data
80	Invalid Data
90	Invalid Data
100	Invalid Data
110	Invalid Data
120	Invalid Data
130	Invalid Data
140	Invalid Data
150	Invalid Data
160	Invalid Data
170	Invalid Data
180	Invalid Data
190	Invalid Data
200	Data Not Available
210	Data Not Available
220	Data Not Available
230	Data Not Available
240	Data Not Available
250	Data Not Available

Resultant Crash Pulse (Record 1, Most Recent)



Time (msec)	Delta-V, Resultant^2 (km/h^2)
0	0
10	36
20	145
30	965
40	2,978
50	4,090
60	5,122
70	5,725
80	6,642
90	7,274
100	7,780
110	8,306
120	8,665
130	8,852
140	9,232
150	9,418
160	9,418
170	9,613
180	9,613
190	9,613
200	Data Not Available
210	Data Not Available
220	Data Not Available
230	Data Not Available
240	Data Not Available
250	Data Not Available

Hexadecimal Data

FA10 02

FA12 02 00 00 06 F1 00 00 06 01

FA11 04 00 04

FA13 00 01 00 01 00 00 04 00 00 00 05 00 02 00 06 00
04 00 0C 00 A9 00 0D 00 78 00 0E 00 A8 00 16 64
06 FF 12 80 18 80 39 7E D5 83 9F 8B 8D 7E 55 7D
A7 80 C2 7E 9E 7E 63 7E B7 7E 6F 7F B6 7F 73 7F
8D 7F C6 80 02 80 0C 7F B7 7F DB FF FF FF FF FF
FF FF FF FF FF FF FF 00 17 64 06 FF 12 7F E2 78
F4 79 D8 6A A7 67 13 75 02 77 D1 7A 72 7A 38 7A
F1 7C B7 7C 6F 7D F0 7E 65 7E 39 7E 9D 7F 99 7F
C3 80 08 7F D6 FF FF FF FF FF FF FF FF FF FF FF
FF 00 19 64 06 FF 04 7F 8B 95 6F 87 FE FE FE FE
FE FE FE FE FE FE FE FE FE FE FE FF FF FF FF FF
FF 00 1F 64 06 FF 12 7F 79 73 60 4A 40 38 34 2E
2A 27 24 22 21 1F 1E 1E 1D 1D 1D FF FF FF FF FF
FF 00 20 64 06 FF 12 7F 7F 7E 81 8C 8A 88 89 88
86 85 84 83 83 83 82 82 82 82 82 FF FF FF FF FF
FF 00 21 1D 00 22 8D 00 23 4B 00 24 12 00 25 4B
00 26 64 06 FF 12 00 00 00 24 00 91 03 C5 0B A2
0F FA 14 02 16 5D 19 F2 1C 6A 1E 64 20 72 21 D9
22 94 24 10 24 CA 24 CA 25 8D 25 8D 25 8D FF FF
FF FF FF FF FF FF FF FF FF FF 00 28 1C 00 29 FF
00 2A 00 C7 00 2B 00 C7 00 2D 01 00 2E FF FF 00
2F 01 89 00 30 FF FF 00 33 00 06 00 34 00 0B 00
35 01 00 00 36 00 00 37 00 00 38 FF FF 00 39 FF
FF 00 3A FF FF 00 3B FF 00 3C FF 00 3D 00 26 00
3E 00 06 00 3F FF FF 00 41 FF FF 00 42 00 06 00
43 FF FF 00 47 01 00 48 03 00 4B 00 00 4C 01 00
4D 00 00 4E 03 00 4F 05 00 51 01 00 52 00 00 53
00 00 54 00 00 55 FF 00 56 FF 00 57 FF 00 5B 6F
76 7D 83 89 8D 92 97 9B 9F A2 00 5C 60 60 60 60
60 5F 5F 5E 5E 5F 5D 00 5D 55 5A 5F 64 68 6B 5A
5C 5F 61 4C 00 5E 7F 7F 7F 7F 7F 7F 7F 7F 7F 7F
7F 00 5F 00 00 00 00 00 00 00 00 00 00 00 00 60
00 00 00 00 00 00 00 00 00 00 00 00 61 00 00 00
00 00 00 00 00 00 00 00 00 65 00 06 00 66 FF FF
00 6D FF FF 00 6E FF FF 00 70 00 06 00 71 FF FF
00 73 00 36 00 74 FF FF 00 76 00 00 77 FF 00 79
FF FF 00 7A FF FF 00 83 FF FF 00 84 FF FF 00 8D
FF FF 00 8E FF FF 00 8F FF FF 00 90 FF FF 00 91
FF FF 00 92 FF FF 00 93 FF FF 00 94 FF FF 00 95
FF FF 00 96 FF FF 00 97 FF FF 00 98 FF FF 00 99
FF FF 00 9A FF FF 00 9B FF FF 00 9C FF FF 00 9D
FF 00 9E FF 00 9F FF 00 F1 FF FF 00 F2 FF FF 01
0F 00 06 01 10 FF FF 01 11 FF FF 01 8F 20 02 00
20 02 00 20 02 00 20 02 00 20 02 00 20 02 00 20
02 00 20 02 00 20 02 00 20 02 00 20 02 00 03 E8
A5 03 E9 01 2C 03 EA 01 2D 03 EB 76 03 EC 01 03
ED 08 03 EE 16 03 EF 0A 03 F0 1E 03 F1 00 C2 03
F2 00 12 A8 03 F3 20 20 20 20 20 20 20 20 20 20
57 43 35 34 34 37 33 03 FB 04 03 FC 40 03 FD 00
01 03 FE 08 45 DF 6D 03 FF FD A5 70 74 F3 54 27
CB D8 15 C9 AC B7 24 8B BD 95 A3 67 A1 B0 2E 5B
6F 17 F9 55 70 71 A7 50 32 FC 8F E4 AB 80 FD 34
E2 E7 4E CF 86 33 E9 70 5D 67 E2 66 24 A2 86 1E
94 AF 05 66 4B 21 70 12 7F

FA14 00 01

FA15	00 01
FA16	No Data received (CRC checksum did not complete successfully)
FA17	No Data received (Signature did not complete successfully)
FA18	No Data received (CRC checksum and signature did not complete successfully)

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