ELECTRONIC CONTROL MODULE DATA IN LARGE TRUCK COLLISON ANALYSIS

By

Dennis F. Andrews & Rudy Limpert

PC Brake Short Paper PCB 1-2013

Introduction

Motor vehicles are increasingly equipped with electronic controls to accomplish a large number of different safety, emissions and comfort functions. The first large truck electronic ABS controls were introduced in Mercedes-Benz trucks equipped with air brakes in 1976. Although FMVSS 121 required indirectly (only momentary wheel lock was allowed) ABS brake controls by 1975, wheel speed signal processing was done by relatively slow analogue circuitry. The ABS requirement was deleted until 1999. Currently, analogue signals from sensors are processed in the micro-processor. The micro-processor causes an analogue signal to be produced to actuate valves or other electric components.

With increasingly stringent emission controls placed on combustion engines, electronic micro-processors (ECM) were first used in the mid-80s and are standard equipment in motor vehicles today.

Today special expertise and equipment must be used to properly download stored data from micro-processors. Once downloaded, the data can yield valuable information about the operation of the vehicle at the time of a collision or emergency braking situation involving the vehicle.

Fundamental Considerations

Electronic Control Modules (ECM) often contains valuable data to assist in the analysis and reconstruction of large truck traffic accidents. ECM data are often compared to the data collection capabilities of Electronic Data Recorders (EDR) found in passenger vehicles. However, the two units are in fact different and designed with different algorithms and purposes of data collection.

The EDR is designed to monitor aspects of passenger vehicle operation and then capture and store a short period of vehicle operation data in the event of a collision requiring air bag deployment, usually about 5 seconds. Data captured usually consists of documenting vehicle speed, brake use, seat belt use and deceleration experienced by the vehicle as a function of time. For example, immediately before a collision, an EDR wakes from sleep mode to capture and store data when pre-determined pre-impact deceleration thresholds are met, or in the event of a collision, impact sensors are activated. When the program criteria for an airbag deployment are met, the airbags are deployed and the captured vehicle operation data is store in a locked file for download capabilities. This file is a permanent file and cannot be overwritten with new data.

The ECM in a large truck is designed to continually monitor vehicle operation and capture data when vehicle components fail to operate correctly. In addition to capturing data when a truck's component fails to operate correctly, the ECM captures data when the large truck experiences hard braking, or hard deceleration. A hard brake or hard deceleration is recognized by the ECM when the drive wheels experience a change in wheel speed of about 7 mph/sec. On dry ground this change in wheel speed equates to about a 0.31 g deceleration of the vehicle. However, because a change in wheel speed is being measured, wheel speed changes on wet or icy roads may occur quicker when brakes are applied because of reduced friction between the wheel and the roadway, triggering a hard brake data capture by the ECM.

In the event of hard braking or deceleration, data pertaining to the operation of the large truck is captured and stored in a temporary file which can be overwritten. Types of data captured by the ECM

include data pertaining to vehicle speed, brake use, engine load and rpm, throttle use, and clutch use. Data previously stored in the temporary data file is over written by newly captured data obtained by the most recent hard brake, or hard deceleration, experienced by the large truck.

The ECM is the main control unit of the large truck. Everything about the large truck is programmed into the ECM. Remove the ECM from the side of the engine, the large truck becomes inoperable. In short, the ECM is the central nervous system of the large truck. Data collected by the ECM are collected to facilitate servicing of the large truck engine.

The ECM captures data under two conditions:

1. When a vehicle fault is detected and recorded as a fault diagnostic code
2. When the vehicle experiences a hard brake deceleration where the drive wheel speed decelerates at a pre-set change in speed, usually about 7 mph/sec

When a vehicle fault is recognized, a fault diagnostic code is set and the ECM takes a snap shot of the vehicle's current parameters and performance. The snapshot records such parameters as wheel speed and engine RPM at the moment the fault was realized. Only a limited number of fault code snap shots are stored at any one time.

During hard brake applications, or hard deceleration, often referred to as critical braking events, the ECM takes a snap shot of the vehicles parameters and performance. The snapshot captures such parameters as vehicle speed, clutch use, engine RPM and throttle use. The data is stored in a temporary file and remains there until it is overwritten with new data captured and downloaded by the ECM during a new hard brake event experienced by the large truck.

The deceleration of a large truck's drive wheels is measured by a Vehicle Speed Sensor (VSS) pulse generator and tone ring that is mounted on the tail-shaft of the transmission. The ECM measures the VSS pulse frequency, and then calculates vehicle speed. (Ref. 2)

Preset decelerations vary from manufacture to manufacture. For example, the deceleration threshold for a Detroit Diesel ECM is 7 mph/sec., about 0.31 g's, while the deceleration threshold of a Mack ECM is set at 10 mph/sec., about 0.45 g's.

Because the speed data collected are based on the semi-tractor's driver axle wheel speed, proper investigation needs to include the size of the wheels on the semi-tractor at the time of the accident. The proper tire size for the semi-tractor is generally found inside the driver door on the door latch pillar or "B pillar". After insuring the semi-tractor is equipped with the proper tire size, the investigator can take his investigation one step further by measuring the radius of the drive wheels. Doing so will allow for calculation of the wheel speed when coupled with the appropriate axle ratio, engine RPM and transmission gear position at the time of the hard brake event.

Time periods recorded during hard brake events generally range from 32 to 105 seconds before the hard brake event and 15 seconds after the hard brake event. Fault code snapshot times are typically 44 seconds before the fault code detection and 15 seconds after.

Snapshots taken during hard brake events and fault code detection are not taken for use in accident reconstruction. These snapshots are taken for vehicle servicing and fleet management. Accident reconstruction personnel have adapted the use of the collected data to accident reconstruction. Because the data are not collected as an accident reconstruction tool, care must be taken to associate the collected data with a complete reconstruction of the accident utilizing traditional reconstruction procedures. For example, speed obtained from an ECM data recorder MUST be consistent with the calculated speed based on crush damage, distance traveled, and associated drag factors.

Fault codes can occur at any time during the operation of the large truck. Fault codes of interest to the accident reconstructionist are codes set during a collision under investigation. If power is not lost during the collision, fault codes can be set during the collision. For example, if the collision results in the radiator being ruptured and radiator fluid is lost, a radiator fault code can be triggered that captures the speed of the large truck at that moment. Fault codes captured during a collision may provide wheel speed, engine RPM and other pertinent data associated with the collision, even if a hard brake event before the collision was not detected. For example, a collision that occurs without pre-impact braking may still yield valuable information from fault codes triggered by collision damage and detected during the collision by the ECM.

Care must be taken when attempting to download fault codes. Fault codes are very sensitive in nature. Many fault codes can be cleared by starting the semi-tractor's engine. Others can be cleared by attempting to download the ECM data, which then clears all set codes to their default settings. Because fault codes are easily lost, care should be taken to insure the tech downloading the information has a good working knowledge of obtaining fault codes before attempting to download fault code snapshots.

Unlike EDRs, data obtained by the ECM is not stored in a locked file that cannot be over written. With each hard braking event, the most recent snapshot is recorded. ECMs will store a preset number of fault codes and then start overwriting stored codes with the most recent recognized fault code. Because fault codes can be captured before a collision, care must be taken to ensure the data being reviewed pertains to the current event under investigation.

Care must also be taken when evaluating hard brake data captures. If more than one hard brake file is stored, be sure the correct file is attributed to the accident under investigation. For example, Detroit Diesel ECMs stores the last two hard brake events and the last stop. The last stop recorded will be identical to the most recent hard brake stop recorded if the last stop was the hard brake event that triggered the snapshot. However, if the semi-tractor was driven and wheel speed reaches 1.5 miles per hour and is then braked to a stop, the last stop record will show this most recent braking event as the last stop instead of a stop record identical to the last hard brake event (Ref. 2, 4).

Electronic Control Modules for Different Engine Manufactures

The following summaries are a review of what information may be obtained from the different engine ECMs.

1. Detroit Diesel and Mercedes-Benz ECM:

Detroit Diesel ECMs provide the most usable information of all the ECMs. Their ECMs record the last 2 hard stop brake events and the last vehicle stop when the wheel speed reaches 0 miles per hour. The hard brake event and last stop can sometimes be identical records when the hard brake is continued until the vehicle reaches a complete stop. Data recorded by Detroit Diesel's ECM relevant to accident reconstruction includes the following data:

DETROIT	SPEED	BRAKE USE	CLUTCH USE	ENGINE RPM	ENGINE LOAD	CRUISE CONTROL	DATA PLOT	THROTTLE POSITION	FAULT CODES
YES	X	X	X	X	X	X	X	X	X
NO									

Detroit Diesel data is obtained by using Detroit Diesel's Diagnostic Link Software.

In 2000 Detroit Diesel purchased a percentage of Mercedes-Benz. As a result of this merger, Mercedes Engines 4000 and 900 are accessed using Detroit Diesel's Diagnostic Link Software. Coverage of the Mercedes engines began in 2002 with Vehicle Control Unit Version 12. Data can be extracted from all 2000 and newer 900 series and 4000 series Mercedes-Benz Engines, provided the ECM is using software version 12.09 or higher. Because the Mercedes internal software version cannot be determined without actually accessing the ECM, an investigator should assume internal information exists and take steps to preserve the information. (Ref. 1)

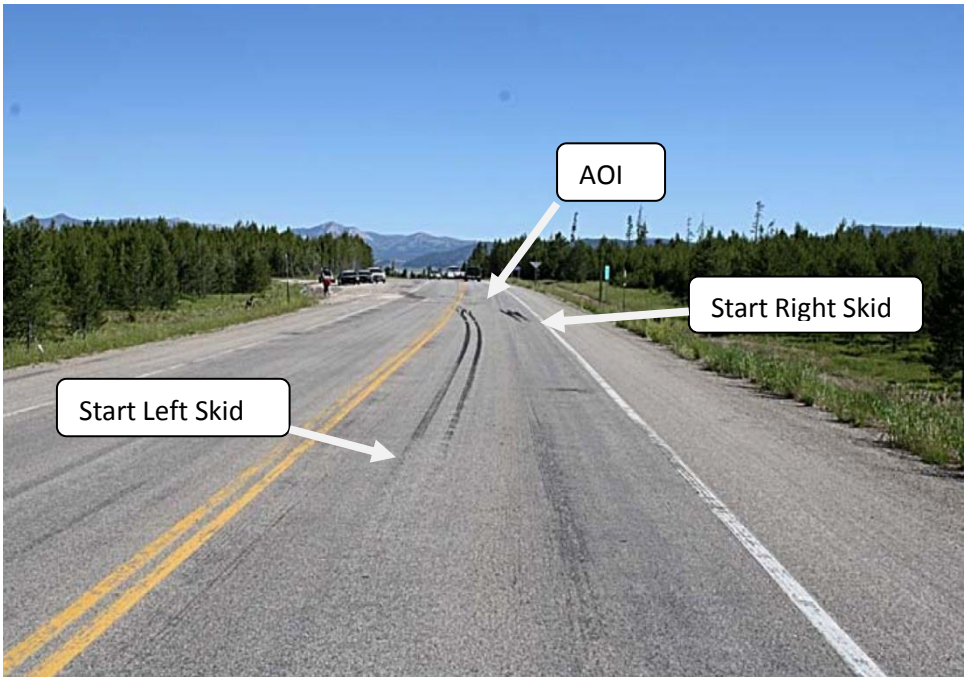
In Detroit Diesel DDEC III ECMs used in years 1993-1997 there is no internal battery. Care must be taken to insure that battery power is not lost to the vehicle, or the stored data might be lost. The DDEC III unit contains the least amount of information storing only trip and engine configuration data.

In 2009 to present, Detroit Diesel DDEC VI ECMs consisted of two components, a MCM (motor control mount) and PCP (power train controller). If it becomes necessary to remove the ECMs for download, both units must be removed and sent together for download.

Detroit Diesel's Hard Brake threshold is a deceleration of 7 mph/sec, about 0.31 g's.

The follow scene picture of pre-impact braking, Photograph 1, and 3 pages of Detroit Diesel's hard brake data and data plot are examples of their ECM data download and how it can be used.

The following scene picture Photograph 1 shows pre-impact braking marks made by a large truck before a head-on collision. Examination of the photograph shows the possibility of braking imbalance between the left and right sides of the semi-tractor and trailer. The semi-tractor and trailer eventually have a head-on collision with a passenger vehicle. One of the questions to be answered was what was the speed of the large truck when its brakes were applied?



Photograph 1

Large Truck Pre-Impact Brake Marks before Head-on Collision

Before the ECM data were obtained, efforts were made to calculate speed using traditional energy calculations by estimating the deceleration experienced by the semi-tractor and trailer due to braking. Most calculations used 50 percent of a full road surface drag factor of 0.73 for a deceleration of 0.36 g. Using 150 feet of pre-impact braking, the officer calculated pre-impact speed of 40 miles per hour to use later in his combined speed formula with calculated after impact speeds. He calculated an after impact speed of 29 miles per hour for the semi-tractor and trailer and an after impact speed of 40 miles per hour for the passenger car. Based on these calculations, he determined speed was not a major contributing factor in the collision. An initial travel speed of the large truck was never determined by the officer.

DDEC® Reports - Hard Brake #1

Print Date: Jul 30, 2010 09:41 AM (MDT)

Analysis, Inc.
2207 Lyn St.
Grand Junction, CO 81505-
(970) 243-8585

Trip: 12/31/84 07:00 PM (EST) to 07/30/2010 (F
Vehicle ID: 308503
Driver ID:
Odometer: 229524.4 mi

Trip Distance	229524.4 mi	Trip Time	5686:12:57
Trip Fuel	30143.63 gal	Fuel Consumption	5.30 gal/h
Fuel Economy	7.61 mpg	Idle Time	1355:17:19
Avg Drive Load	40 %	Idle Percent	23.83 %
Avg Vehicle Speed	53.0 mph	Idle Fuel	563.75 gal
		Parked Regen Time	0:00:00

Incident Time: 07/16/2010 02:56:39 (EST)

Incident Odometer: 229524.4 mi

Time	Vehicle Speed (mph)	Engine Speed (rpm)	Brake	Clutch	Engine Load (%)	Throttle (%)	Cruise	Diagnostic Code
-1:00	58.5	1308	No	No	100.00	100.00	No	No
-0:59	58.5	1306	No	No	100.00	100.00	No	No
-0:58	59.0	1309	No	No	100.00	100.00	No	No
-0:57	59.0	1314	No	No	100.00	100.00	No	No
-0:56	59.0	1319	No	No	100.00	100.00	No	No
-0:55	59.5	1326	No	No	100.00	100.00	No	No
-0:54	60.0	1336	No	No	100.00	100.00	No	No
-0:53	60.0	1348	No	No	100.00	100.00	No	No
-0:52	60.5	1358	No	No	98.00	100.00	No	No
-0:51	61.0	1370	No	No	87.00	100.00	No	No
-0:50	61.5	1367	No	No	66.00	100.00	No	No
-0:49	62.0	1379	No	No	50.50	100.00	No	No
-0:48	62.0	1377	No	No	35.50	100.00	No	No
-0:47	62.0	1378	No	No	29.00	100.00	No	No
-0:46	62.0	1376	No	No	25.00	100.00	No	No
-0:45	62.0	1370	No	No	30.50	100.00	No	No
-0:44	61.5	1372	No	No	37.00	100.00	No	No
-0:43	61.5	1371	No	No	40.50	100.00	No	No
-0:42	61.5	1371	No	No	47.50	100.00	No	No
-0:41	61.5	1370	No	No	49.50	100.00	No	No
-0:40	61.5	1367	No	No	54.00	100.00	No	No
-0:39	61.5	1367	No	No	57.50	100.00	No	No
-0:38	61.5	1372	No	No	58.50	100.00	No	No
-0:37	61.5	1368	No	No	61.50	100.00	No	No
-0:36	61.5	1372	No	No	63.00	100.00	No	No
-0:35	61.5	1372	No	No	60.50	100.00	No	No
-0:34	61.5	1370	No	No	60.50	100.00	No	No
-0:33	61.5	1374	No	No	57.00	100.00	No	No
-0:32	61.5	1373	No	No	57.50	100.00	No	No
-0:31	61.5	1372	No	No	56.50	100.00	No	No
-0:30	61.5	1371	No	No	58.50	100.00	No	No
-0:29	61.5	1371	No	No	60.50	100.00	No	No
-0:28	61.5	1373	No	No	60.50	100.00	No	No
-0:27	61.5	1377	No	No	58.00	100.00	No	No
-0:26	61.5	1376	No	No	55.00	100.00	No	No
-0:25	61.5	1375	No	No	58.50	100.00	No	No
-0:24	61.5	1367	No	No	59.50	100.00	No	No
-0:23	61.5	1371	No	No	61.00	100.00	No	No
-0:22	61.5	1372	No	No	57.00	100.00	No	No
-0:21	61.5	1372	No	No	55.00	100.00	No	No

073001AA.XTR Engine S/N: 06R1010253 ECM S/W Version: 4.000 Version 6.43c Page 1

Page One Detroit Diesel Hard Brake Data

DDEC® Reports - Hard Brake #1

Print Date: Jul 30, 2010 09:41 AM (MDT)

Analysis, Inc.
2207 Lyn St.
Grand Junction, CO 81505-
(970) 243-8585

Trip: 12/31/84 07:00 PM (EST) to 07/30/2010 (ES
Vehicle ID: 308503
Driver ID:
Odometer: 229524.4 mi

Incident Time: 07/16/2010 02:56:39 (EST)

Incident Odometer: 229524.4 mi

Time	Vehicle Speed (mph)	Engine Speed (rpm)	Brake	Clutch	Engine Load (%)	Throttle (%)	Cruise	Diagnostic Code
-0:20	61.5	1375	No	No	59.50	100.00	No	No
-0:19	61.5	1372	No	No	55.50	100.00	No	No
-0:18	61.5	1370	No	No	56.00	100.00	No	No
-0:17	61.5	1370	No	No	60.50	100.00	No	No
-0:16	61.5	1368	No	No	68.50	100.00	No	No
-0:15	61.5	1371	No	No	76.00	100.00	No	No
-0:14	61.5	1369	No	No	77.50	100.00	No	No
-0:13	61.5	1373	No	No	81.50	100.00	No	No
-0:12	61.5	1373	No	No	80.00	100.00	No	No
-0:11	61.5	1368	No	No	79.50	100.00	No	No
-0:10	61.5	1372	No	No	74.50	100.00	No	No
-0:09	62.0	1375	No	No	67.50	100.00	No	No
-0:08	62.0	1378	No	No	57.50	100.00	No	No
-0:07	62.0	1379	No	No	48.50	100.00	No	No
-0:06	62.0	1377	No	No	41.00	100.00	No	No
-0:05	62.0	1380	No	No	32.50	100.00	No	No
-0:04	62.0	1382	No	No	22.50	100.00	No	No
-0:03	62.0	1378	No	No	12.50	100.00	No	No
-0:02	62.0	1373	Yes	No	0.50	0.00	Yes	No
-0:01	54.5	1068	Yes	No	0.00	0.00	No	No
0:00	43.5	827	Yes	No	0.00	0.00	No	No
+0:01	31.5	572	Yes	No	32.00	0.00	No	No
+0:02	22.5	1603	Yes	No	44.50	100.00	No	No
+0:03	19.5	1623	No	No	20.50	100.00	No	Yes
+0:04	18.0	1716	No	No	20.00	100.00	No	Yes
+0:05	14.5	1699	No	No	10.00	100.00	No	Yes
+0:06	10.5	1698	No	No	12.00	100.00	No	Yes
+0:07	7.5	1700	No	No	11.50	99.20	No	Yes
+0:08	4.5	1699	No	No	12.50	0.00	No	Yes
+0:09	2.5	1146	Yes	No	0.00	0.00	No	Yes
+0:10	0.5	701	Yes	No	0.50	0.00	No	Yes
+0:11	0.0	607	Yes	No	9.00	0.00	No	Yes
+0:12	0.0	597	Yes	No	9.50	0.00	No	Yes
+0:13	0.0	601	Yes	No	9.50	0.00	No	Yes
+0:14	0.0	597	Yes	No	9.50	0.00	No	Yes

073001AA.XTR Engine S/N: 06R1010253 ECM S/W Version: 4.000 Version 6.43c Page 2

Page Two Detroit Diesel Hard Brake Data

DDEC® Reports - Hard Brake #1

Print Date: Jul 30, 2010 09:41 AM (MDT)

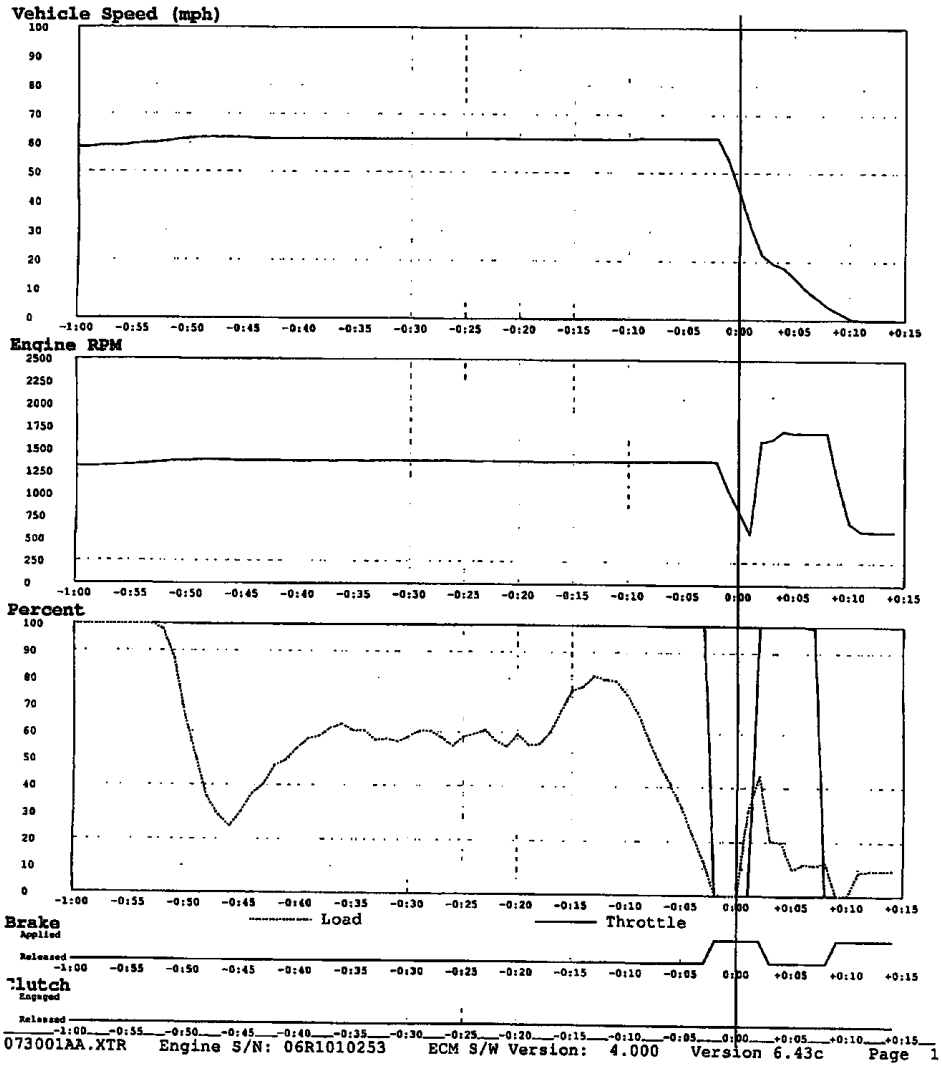
Analysis, Inc.
2207 Lyn St.
Grand Junction, CO 81505-
(970) 243-8585

Trip: 12/31/84 07:00 PM (EST) to 07/30/2010 (ES
Vehicle ID: 308503
Driver ID:
Odometer: 229524.4 mi

Trip Distance	229524.4 mi	Trip Time	5686:12:57
Trip Fuel	30143.63 gal	Fuel Consumption	5.30 gal/h
Fuel Economy	7.61 mpg	Idle Time	1355:17:19
Avg Drive Load	40 %	Idle Percent	23.83 %
Avg Vehicle Speed	53.0 mph	Idle Fuel	563.75 gal
		Parked Regen Time	0:00:00

Incident Time: 07/16/2010 02:56:39 (EST)

Incident Odometer: 229524.4 mi



073001AA.XTR Engine S/N: 06R1010253 ECM S/W Version: 4.000 Version 6.43c Page 1

Page Three Detroit Diesel Hard Brake Data Graph

After the ECM data was obtained, an analysis of the above data was performed relative to the head-on collision. The first step was to insure the data belonged to the head-on collision. It did, and analysis began.

Because ECM hard braking data is not capturing data specific to a collision occurring, the data analyzer needs to determine where the collision possibly occurred within the data. A review of the above data reveals that 1 minute before the data snap shot the vehicle's speed was 58.5 miles per hour with no brake, no clutch, engine load at 100 percent, and no diagnostic fault codes. The readings in 1 second intervals remain relatively constant until -0.02 seconds. At this point, the analyst should recognize the onset of the hard brake event. The data table now shows a speed of 62 miles per hour, with brake, no clutch, and an engine load of only 32 percent. These conditions descend in a constant manner until +0.03 seconds. At +0.03 seconds, conditions change, the vehicle's speed has dropped to 19.5 miles per hour, the brake goes to the off position, throttle returns to 100 percent, and diagnostic fault codes are detected. The diagnostic fault codes continue showing for the rest of the data record.

From the sudden change in status readings between +0.02 and +0.03 seconds the analyzer can infer that the collision between the large truck and passenger car occurred at this point in time. Hence, the appearance of diagnostic codes corresponding with damage sustained in the head-on collision.

By determining the time of impact, one can now analyze the pre-impact data. Speed changed from 62 to 22.5 miles per hour. The change in speed occurred over a time period of 4 seconds. The average deceleration experience by the vehicle is determined using the equation $a = (V_1 - V_2)/t$ and equates to 0.449 g. The distance of deceleration is determined by using the equation $d = Vt - a(t^2)/2$ and equates to 247.9 feet.

How well does our calculated data correlate with data gather at the scene? The investigating officer and a private investigator on the scene a day following the collision measured 139 to 150 feet of pre-pact skidding. Our calculations show deceleration occurred over 247.9 feet. The investigators estimated a vehicle deceleration of 0.36 g. Our calculation shows a deceleration of 0.449 g. Our data shows and impact speed of 19 to 22 miles per hour, their calculations estimate an impact speed of 34 to 37 miles per hour, what explains these differences?

The accident reconstructionist is now in a position to analyze the collision. Did the tractor and trailer have ABS? Was ABS brake marks not detected before the visible brake marks are made as seen in Photograph 1? Were the ABS brakes working properly? Answering these questions will lead the investigator to a better understanding of the collision and closer to a correct analysis of the physical evidence.

Continued analysis of the above downloaded data shows that following the impact the driver of the semi-tractor was off the brake for 5 seconds and on the throttle at 100 percent. After 5 seconds the brake is on again and the throttle is off, and remains in this configuration until the semi-tractor and trailer are stopped. Information like the data contained in the snap shot download, helps investigators understand and evaluate each phase of a collision's pre and post impact vehicle activity, and hopefully leads to better conclusions as to what really happened.

For a complete LT truck – motorcycle crash reconstruction see Short Paper PCB 7- 2007. A critical analysis tool was the use of the velocity diagram to determine braking severity and driver error.

2. Cummins ECM

The Cummins ECM stores much of the same data as the Detroit Diesel ECM. However, it does not plot the data into a graph like the Detroit Diesel software does. Cummins calls their report "Sudden Deceleration Data Report". Cummins ECM will capture up to three sudden stops, or hard braking events, but does not record a last stop record.

CUMMINS	SPEED	BRAKE USE	CLUTCH USE	ENGINE RPM	ENGINE LOAD	CRUISE CONTROL	DATA PLOT	THROTTLE POSITION	FAULT CODES
YES	X	X	X		X				
NO				X		X	X	X	X

Cummins uses two software programs to retrieve data. The first is called Insite used to retrieve trip data, and fault code information. The second program is called PowerSpec. This program retrieves configuration, trip and fault code data as well as extracting sudden deceleration information from the ECM. The data collected for sudden stops stores 59 seconds before the event and 15 seconds after the event. The 2002 and newer ISM and ISX engines have the ability to store sudden deceleration information.

Cummins ECMs threshold for sudden deceleration is wheel speed change of 9 mph/sec., about 0.40 g.

The following 2 tables are Cummins PowerSpec Examples:

PowerSpec - Sudden Deceleration Data Report

Report Date: 4/30/2013 10:22:42 AM

Engine Type	ISX 2010	**ECM Code**	CL10132.21	**Last Tool Used**	PowerSpec
Engine Serial Number	79542039	**Software Phase**	7.70.0.27	**Customer Name**	CUSTOMER
Unit Number	12132	**ECM Runtime** hh:mm:ss	4803:43:40	**PowerSpec Version**	4.3.0.15

Record 1 **View Record 2** **View Record 3**

Occurrence Date	N/A	**Total ECM Run Time @ Occurrence (HH:MM:SS)**	2450:30:58
Air Temp @ Occurrence (°F)	269	**Occurrence Distance (miles)**	87215.1

Time (Seconds)	Vehicle Speed (mph)	Engine Speed (rpm)	Engine Load (%)	Throttle (%)	Brake Status	Clutch Status	Cruise Status	Lamp Status
-59	44	1299	56.3	68.1	-	-	-	-
-58	45	1322	54.3	66.7	-	-	-	-
-57	46	1344	59.4	69.9	-	-	-	-
-56	46	1361	56.3	68.1	-	-	-	-
-55	47	1378	56.3	67.8	-	-	-	-
-54	47	1390	50.4	64.3	-	-	-	-
-53	48	1406	51.2	65.0	-	-	-	-
-52	48	1421	52.0	65.6	-	-	-	-
-51	49	1428	51.2	65.0	-	-	-	-
-50	49	1441	48.8	64.2	-	-	-	-
Time (Seconds)	**Vehicle Speed (mph)**	**Engine Speed (rpm)**	**Engine Load (%)**	**Throttle (%)**	**Brake Status**	**Clutch Status**	**Cruise Status**	**Lamp Status**
-49	50	1453	49.2	64.4	-	-	-	-
-48	50	1470	49.2	64.6	-	-	-	-
-47	50	1471	44.9	62.3	-	-	-	-
-46	50	1468	34.8	56.7	-	-	-	-
-45	51	1480	46.5	63.4	-	-	-	-
-44	51	1486	43.4	61.6	-	-	-	-
-43	51	1494	43.0	61.8	-	-	-	-
-42	51	1491	40.2	62.0	-	-	-	-
-41	51	1493	34.8	60.4	-	-	-	-
-40	51	1495	29.7	61.9	-	-	-	-
Time (Seconds)	**Vehicle Speed (mph)**	**Engine Speed (rpm)**	**Engine Load (%)**	**Throttle (%)**	**Brake Status**	**Clutch Status**	**Cruise Status**	**Lamp Status**
-39	51	1496	25.0	62.9	-	-	-	-
-38	51	1490	26.6	67.9	-	-	-	-
-37	51	1487	30.5	70.5	-	-	-	-
-36	51	1488	28.5	74.4	-	-	-	-
-35	51	1484	30.5	78.7	-	-	-	-
-34	51	1489	33.2	81.1	-	-	-	-
-33	51	1489	31.6	79.3	-	-	-	-
-32	51	1492	33.6	78.0	-	-	-	-
-31	51	1487	29.3	79.3	-	-	-	-
-30	51	1485	30.9	70.2	-	-	-	-
Time (Seconds)	**Vehicle Speed (mph)**	**Engine Speed (rpm)**	**Engine Load (%)**	**Throttle (%)**	**Brake Status**	**Clutch Status**	**Cruise Status**	**Lamp Status**
-29	51	1491	32.4	59.5	-	-	-	-
-28	51	1451	0.0	31.0	-	-	-	-
-27	50	1434	0.0	0.0	-	-	-	-
-26	49	1404	0.0	0.0	-	-	-	-
-25	48	1429	51.2	65.6	-	-	-	-
-24	49	1426	55.1	67.3	-	-	-	-

Page One Cummins Sudden Deceleration Data Report

Sudden Decel

Page 2 of 6

-23	49	1430	37.9	57.7	-	-	-	-
-22	49	1440	37.5	57.4	-	-	-	-
-21	49	1441	28.9	52.4	-	-	-	-
-20	49	1435	11.3	42.5	-	-	-	-
Time (Seconds)	**Vehicle Speed (mph)**	**Engine Speed (rpm)**	**Engine Load (%)**	**Throttle (%)**	**Brake Status**	**Clutch Status**	**Cruise Status**	**Lamp Status**
-19	49	1428	14.5	44.0	-	-	-	-
-18	49	1419	14.5	43.8	-	-	-	-
-17	49	1419	13.3	43.0	-	-	-	-
-16	48	1409	12.1	42.3	-	-	-	-
-15	48	1401	7.8	39.5	-	-	-	-
-14	48	1387	0.0	0.0	-	-	-	-
-13	47	1395	7.0	38.8	-	-	-	-
-12	47	1368	14.5	42.4	-	-	-	-
-11	47	1363	11.3	40.6	-	-	-	-
-10	47	1362	24.2	48.6	-	-	-	-
Time (Seconds)	**Vehicle Speed (mph)**	**Engine Speed (rpm)**	**Engine Load (%)**	**Throttle (%)**	**Brake Status**	**Clutch Status**	**Cruise Status**	**Lamp Status**
-9	47	1367	39.5	57.5	-	-	-	-
-8	47	1363	7.0	38.9	-	-	-	-
-7	47	1361	16.8	44.1	-	-	-	-
-6	47	1364	22.7	47.6	-	-	-	-
-5	46	1342	22.7	46.2	-	-	-	-
-4	46	1338	0.0	11.9	-	-	-	-
-3	46	1026	0.0	0.0	On	On	-	-
-2	38	690	3.9	0.0	On	On	-	-
-1	31	699	1.2	0.0	On	On	-	-
0	23	691	3.5	0.0	On	On	-	-
Time (Seconds)	**Vehicle Speed (mph)**	**Engine Speed (rpm)**	**Engine Load (%)**	**Throttle (%)**	**Brake Status**	**Clutch Status**	**Cruise Status**	**Lamp Status**
1	11	690	6.3	0.0	On	On	-	-
2	4	690	9.0	0.0	On	On	-	-
3	0	700	8.2	0.0	On	On	-	-
4	0	703	7.4	0.0	On	On	-	-
5	0	712	1.6	0.0	On	On	-	-
6	0	696	6.3	0.0	On	On	-	-
7	0	693	8.2	0.0	On	On	-	-
8	0	695	9.4	0.0	On	On	-	-
9	0	695	10.5	0.0	On	On	-	-
10	0	696	11.3	0.0	On	On	-	-
Time (Seconds)	**Vehicle Speed (mph)**	**Engine Speed (rpm)**	**Engine Load (%)**	**Throttle (%)**	**Brake Status**	**Clutch Status**	**Cruise Status**	**Lamp Status**
11	0	698	11.7	0.0	On	On	-	-
12	0	699	11.7	0.0	On	On	-	-
13	0	700	11.3	0.0	On	On	-	-
14	0	699	11.7	0.0	On	On	-	-
15	0	700	12.5	0.0	On	On	-	-

Record 2 To Top

Occurrence Date	N/A	**Total ECM Run Time @ Occurrence (HH:MM:SS)**	119:5:19
Air Temp @ Occurrence (°F)	265	**Occurrence Distance (miles)**	5151.8

Time (Seconds)	**Vehicle Speed (mph)**	**Engine Speed (rpm)**	**Engine Load (%)**	**Throttle (%)**	**Brake Status**	**Clutch Status**	**Cruise Status**	**Lamp Status**
-59	0	669	95.7	9.6	-	On	-	-
-58	0	435	93.0	14.5	-	On	-	-

file://C:\Documents and Settings\Owner\Desktop\2013 Crash Folders\Power Spec. Stevens... 6/19/2013

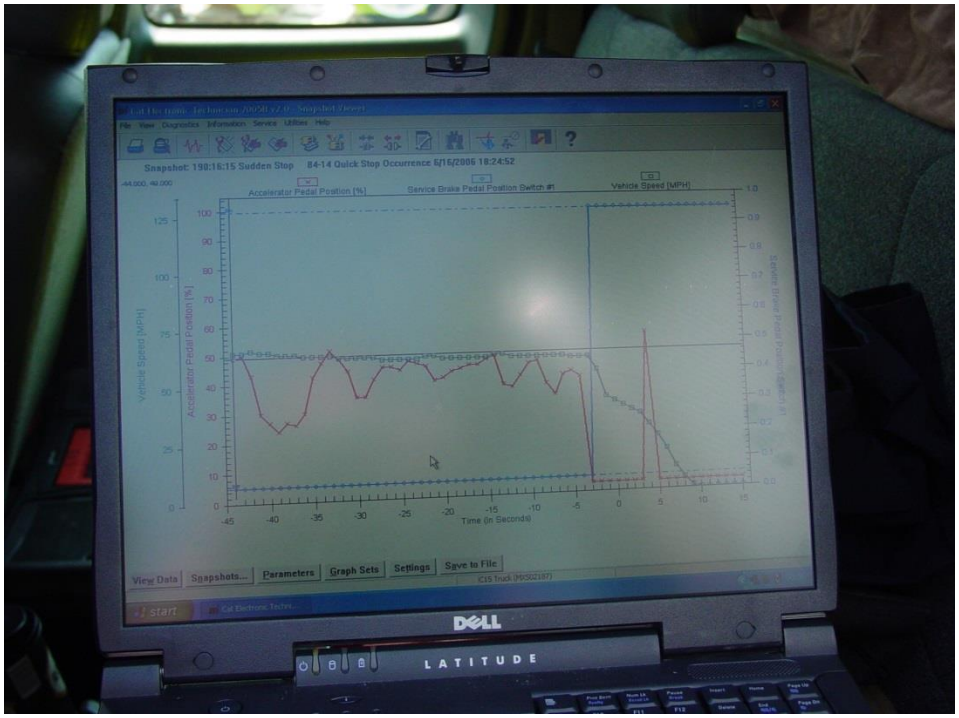
Page Two Cummins Sudden Deceleration Data Report

3. Caterpillar ECM

Most Caterpillar engines since 1994 contain ECM data. The data capture records data for 44 seconds before the event and 15 seconds after. In addition to hard brake captures, snapshots are taken of fault codes capturing vehicle parameters surrounding the event. Caterpillar engines prior to 2007 could have the hard brake capture setting switched off. By setting the option to zero during programming the ECM will not record hard brake information. Since 2007 the factory default of hard brake data capture is set to on.

There is a known issue concerning 1999 and newer ECMs with software revisions prior to 2009. Iin these situations, the reported snapshot timeframes may be incorrect (Ref. 1, 7). While the readouts show 1.0 second interval for quick stops and 0.48 second intervals for critical events, the actual time may be one-half of the shown duration. Therefore, displayed times may need to be reduced when comparing the information to the scene data. See Photograph 2 for wrong time scale example.

CATERPILLAR	SPEED	BRAKE USE	CLUTCH USE	ENGINE RPM	ENGINE LOAD	CRUISE CONTROL	DATA PLOT	THROTTLE POSITION	FAULT CODES
YES	X	X	X	X	X	X	X	X	X
NO									



Photograph 2

Caterpillar ECM Data Screen with wrong Time Scale

The following two examples are of Caterpillar ECM data capture reports

Cat Electronic Technician 2006A v1.0
30301:13:47 Diagnostic 100-11 Very Low Oil Pressure (46) 10/16/2006 12:35:36 PM

10/20/2006 9:27 PM

3406E Truck

Parameter	Value
ECM Serial Number	
Vehicle ID	
Personality Module Part Number	1573002-00
Personality Module Release Date	FEB98
Engine Serial Number	
Personality Module Code	113
ECM Date/Time	10/20/2006 8:44:51 AM

Description	Value	Unit
3406E Truck - Status Group #1		
Vehicle Speed	18	MPH
Engine Speed	822	RPM
Throttle Position	3	%
Fuel Position	1.53	mm
Boost Pressure	0	PSI
Engine Oil Pressure	36	PSI
Engine Coolant Temperature	199	Deg F
Engine Retarder	Disabled	
Powertrain Status	Unavailable	

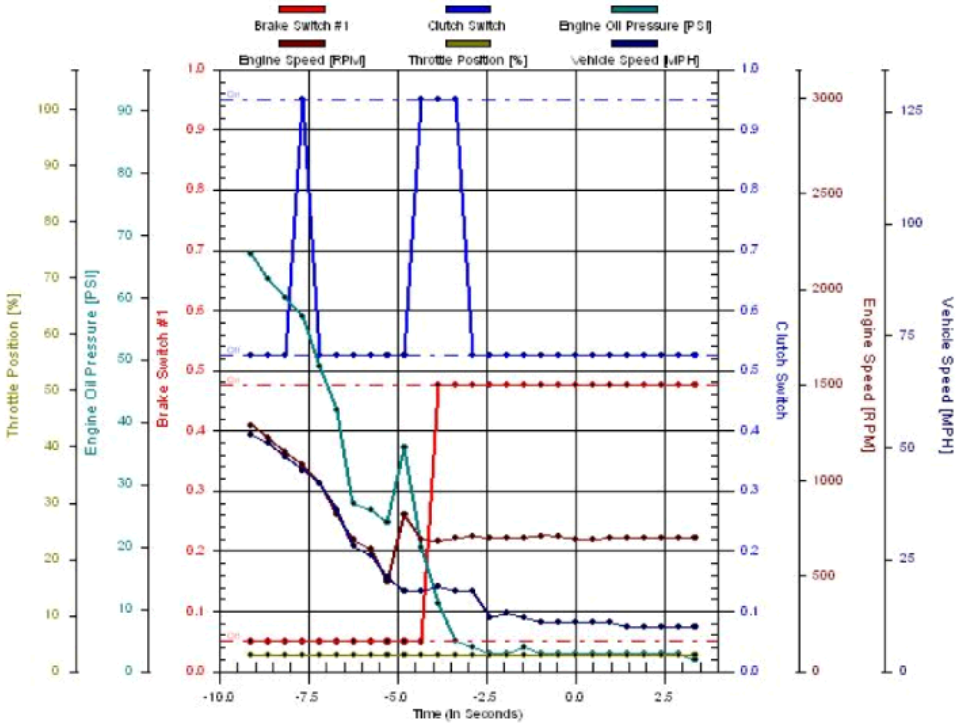
Page One Caterpillar Diagnostic Report

Cat Electronic Technician 2006A v1.0
30301:13:47 Diagnostic 100-11 Very Low Oil Pressure (46) 10/16/2006 12:35:36 PM

10/20/2006 9:45 PM

3406E Truck

Parameter	Value
ECM Serial Number	
Vehicle ID	
Personality Module Part Number	1573002-00
Personality Module Release Date	FEB98
Engine Serial Number	
Personality Module Code	113
ECM Date/Time	10/20/2006 8:44:51 AM



4. International ECM

The international ECM does not store as much data as Detroit, Cummins, or Mack. However, it will store data such as setting parameters and fault codes. This data can be useful in analyzing parameters of a collision under investigation.

In 2010 International started producing the MaxxForce 11-liter, 13-liter, and 15-liter engines (Ref.2). These engines likely store the following data:

- Configuration Data
- Trip/event data recording
- Two last stop records
- Two incident event reports
- Diagnostic Trouble Code Snapshots

Trucks with the ability to capture EDR type data will have the letters "AK" in their software.

5. Mack ECM

Mack started storing data in 1998. The amount of information is less than that stored by Detroit and Cummins ECMs but still has information valuable to the analysis and reconstruction of a collision. The VMAC III ECM records trip time, fuel use, distance traveled, moving time, cruise time, fault codes, fault time, hard brake events and maximum trip miles per hour.

Mack incident records record data for 16 seconds before and event and 16 seconds after the event.

Mack III and IV ECMs store two incidents. The threshold for these events is a reduction in wheel speed of 10 mph/sec., about 0.45 g's. However, this parameter can be changed at the customer's request.

MACK	SPEED	BRAKE USE	CLUTCH USE	ENGINE RPM	ENGINE LOAD	CRUISE CONTROL	DATA PLOT	FAULT CODES
YES	X	X	X	X		X		X
NO								

Mack ECMs are made of two units. Both units must be obtained from the vehicle and sent to an authorized Mack Service Technician for downloading. Configuration and Fault codes are available for public download. Quick Stop Events are not available to public download. This information can only be downloaded by individuals authorized by Mack.

The following table is an example of data printout of a Mack ECM:

7. DataMax Incident Log Information

7.1.1. **Logged Incident Table No. 1**

Vehicle Unit ID:
Extract Date: **Thu Jun 22 09:12:21 2006**

Mileage At Extraction: **101,848**

TIME	BEFORE/AFTER	VS		RPM		SW1	SW2	SW3	SW4	SW5	SW6	SW7	SW8
-15.8	Sec before incident	47	MPH	1550	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-15.6	Sec before incident	47	MPH	1540	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-15.4	Sec before incident	46	MPH	1540	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-15.2	Sec before incident	46	MPH	1550	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-15	Sec before incident	46	MPH	1540	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-14.8	Sec before incident	46	MPH	1540	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-14.6	Sec before incident	46	MPH	1520	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-14.4	Sec before incident	46	MPH	1560	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-14.2	Sec before incident	46	MPH	1540	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-14	Sec before incident	46	MPH	1500	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-13.8	Sec before incident	45	MPH	1490	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-13.6	Sec before incident	45	MPH	1480	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-13.4	Sec before incident	45	MPH	1460	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-13.2	Sec before incident	44	MPH	1470	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-13	Sec before incident	44	MPH	1470	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-12.8	Sec before incident	44	MPH	1470	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-12.6	Sec before incident	44	MPH	1480	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-12.4	Sec before incident	44	MPH	1470	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
-12.2	Sec before incident	44	MPH	1480	RPM	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF

SW1 - Service Brake SW3 - Clutch Pushed SW5 - Engine Brake High SW7 - Key Switch Page 17 of 32
SW2- Park Brake SW4 - Engine Brake Low SW6 - Cruise Control SW8 - Undefined

Mack DataMax Incident Log Information

5. Volvo ECM

Early Volvo engines, before 2010, ECMs do not record a sudden stop incident. The ECM will do a snapshot when and engine fault code is realized. The fault code snapshot may include vehicle speed and engine rpm with the fault code. A download of the data may include configuration data for the vehicle.

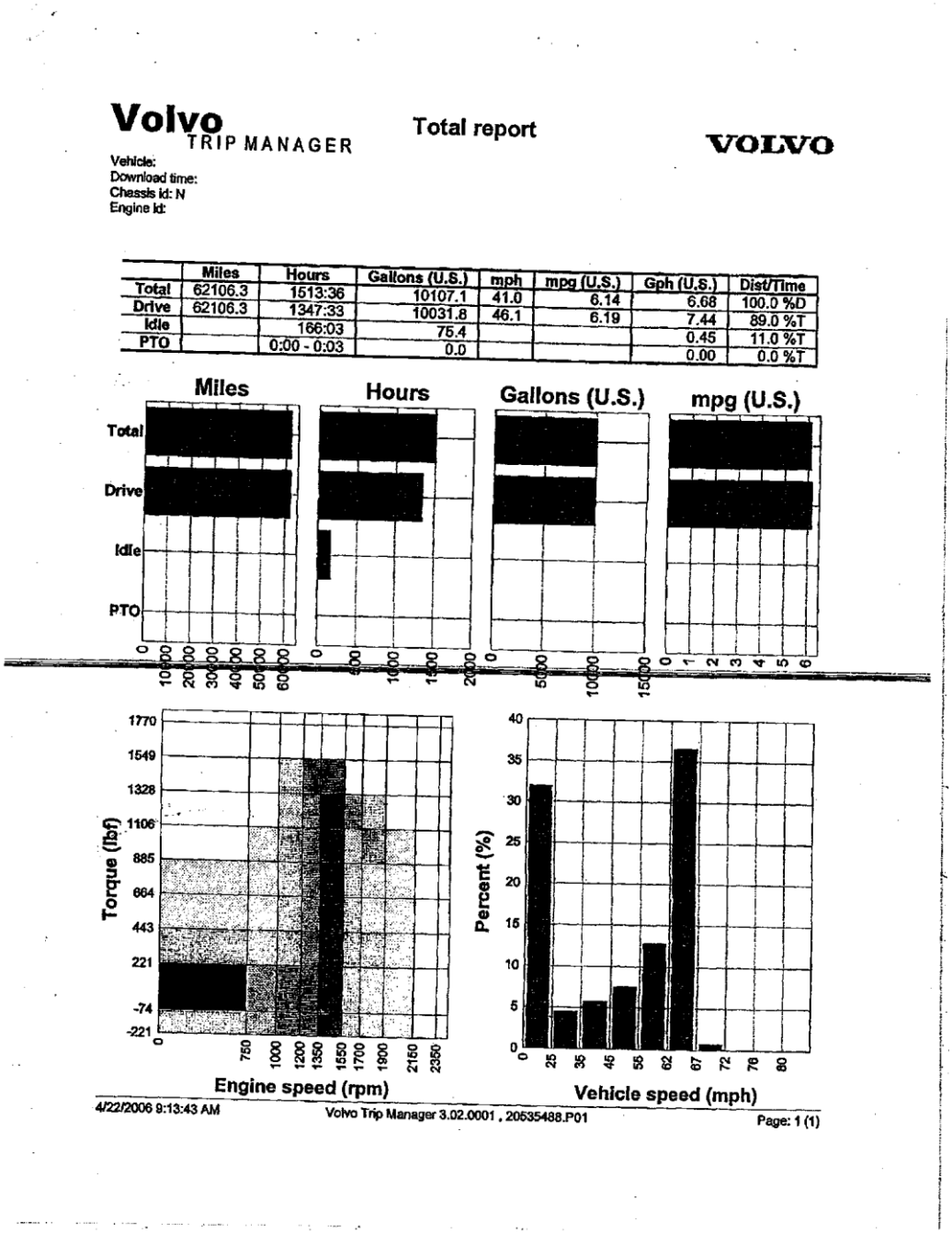
In 2009 Volvo merged with Mack. 2010 and newer Volvo engines share the V-Mack IV electronics and will gather the same data as the V-Mack:

- Configuration Data
- Trip/event data recording
- Two last stop records
- Two incident event reports
- Diagnostic Trouble Code Snapshots

It should also be noted that some Volvo trucks have an air bag system, which may record crash data.

Just like Mack trucks, Volvo ECMs must be downloaded by authorized Mack/Volvo providers.

The following is an example of a Volvo ECM printout:



Volvo TRIP MANAGER

Total report

VOLVO

Vehicle:
Download time:
Chassis id: N
Engine id:

	Miles	Hours	Gallons (U.S.)	mph	mpg (U.S.)	Gph (U.S.)	Dist/Time
Total	62106.3	1513:36	10107.1	41.0	6.14	6.68	100.0 %D
Drive	62106.3	1347:33	10031.8	46.1	6.19	7.44	89.0 %T
Idle		166:03	75.4			0.45	11.0 %T
PTO		0:00 - 0:03	0.0			0.00	0.0 %T

Volvo ECM Report

Conclusions

As can be seen in the information above, large truck ECMs can contain valuable information to assist in the reconstruction and analysis of large truck collisions. But like any tool, the ECM information is not a tell-all about the collision. The information must be used in conjunction with a complete analysis of all the evidence and information available. The investigator should become familiar with the type of engine and ECM on the vehicle so proper precautions and procedures can be taken to insure the safe download and usability of any stored information on the ECM in question.

Testing to determine the reliability of ECM speed data recorded by the various ECMs shows a good correlation between the captured data and the actual measured data of the large truck. When proper analysis between the captured data and the physical evidence is performed, an accurate representation of the large trucks speed at the time of the accident can be given.

ECM data downloads are another tool in the arsenal of accident investigators resources to reconstruct an accident involving large trucks. When proper precautions are taken so data is not lost or destroyed, the reconstructionist can obtain valuable data to assist in the analysis and reconstruction of these complex traffic accidents.

References

1. Electronic Control Module Field Guide, June 2009. Wisconsin State Patrol – Technical Reconstruction Unit.
2. John C. Glennon, Chartered: Truck Crash Event Data Recorder Downloading. http://www.crashforensics.com/truck datarecorders.cfm
3. William Messerschmidt, Benjamin Smith, Kelly Messerschmidt, Messerschmidt Safety Consultants: Minimizing the Risk of Losing Valuable Forensic Data When Downloading the Electronic Control Modules (ECMs) of Heavy Commercial Vehicles, Technical White Paper by Messerschmidt Safety Consultants 2011
4. Heavy Vehicle EDRs, Understanding Heavy Vehicle EDRs (event data recorders) Messerschmidt Safety Consultants, Bloomberg Consulting, Armstrong Forensic Engineers, Michael R. Yosko Consulting, http://www.heavytruckedr.org
5. Joseph C. Jur, M.S.E., P.E. Big Trucks…. LITTLE BLACK BOXES. Prepared for: National Truck & Heavy Equipment Claims Council 2004 Fall Meeting – Charleston, South Carolina, October 2, 2004
6. Motor Vehicle Accident Reconstruction and Cause Analysis, Seventh Edition, Rudolf Limpert
7. The Reliability of Snapshot Data from Caterpillar Engines for Accident Investigation and Analysis, Kerry Drew, Sebastian A. B. van Nooten, Roger Bortolin, Jeff Gervais and James R. Hrycay, Hrcay Consulting Engineers Inc., SAE Technical Paper Series 2008-01-2708
8. Velocity-Time Diagram, Its Effective Use in Accident Reconstruction and Court Room Presentation, Short Paper PCB 1-2007, Rudy Limpert, Ph.D., PC-Brake, Inc. www.pcbrakeinc.com
9. Numerical Methods for Evaluating ECM Data in Accident Reconstruction and Vehicle Dynamics, Roland L. Ruhl, C. Adam Senalik and Ericka J. Southcombe, Ruhl Forensic, Inc., SAE Technical Paper Series 2003-01-3393

10. The Application and Reliability of Commercial Vehicle Event Data Recorders for Accident Investigation and Analysis, Sebastian A. B. van Nooten and James R. Hrycay, Hrycay Consulting Engineers Inc., SAE Technical Paper Series 2005-01-1177
11. Validating Speed Data from Cummins Engine Sudden Deceleration Data Reports, Roger Bortolin, Sebastian A. B. van Nooten, Marc Scodeller, Danny Alvar, Jeff Gervais and James Hrycay, Hrycay Consulting Engineers Inc., SAE Technical Paper Series 2009-01-0876
12. The accuracy of Speed Captured by Commercial Vehicle Event Data Recorders, Timothy J. Reust, SAE Technical Paper Series 2004-01-1199
13. An Examination of Snapshot Data in Caterpillar Electronic Control Modules, Timothy P. Austin Wisconsin State Patrol, Michael J. Farrell Fox Valley Technical College, SAE Technical Paper Series 2011-01-0807

Contact Information:

Dennis F. Andrews

fox@trilobyte.net