

Minimizing the Risk of Losing Valuable Forensic Data When Downloading the Electronic Control Modules (ECMs) of Heavy Commercial Vehicles

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Introduction

Modern diesel engines have an Electronic Control Module (ECM) that controls elements such as engine operation and emissions. And it is well known that the ECMs of most modern heavy trucks—18-wheelers, commercial vehicles, and utility vehicles—contain a component often referred to as the Event Data Recorder (EDR), or “black box,” which captures data about the vehicle’s movement when certain events like crashes, rollovers, or other mishaps occur. [Learn more about EDRs.](#)

The most common method of accessing the ECM (and thereby the EDR as well) is by way of the vehicle’s diagnostic port, called the Deutsch connector. However, in order to use the Deutsch connector, the truck’s entire electrical system must be intact, and accessing the ECM via the Deutsch connector may be impossible after a truck has been involved in a serious crash, rollover, or other mishap.

Most engines with an EDR (“black box”) built into the ECM have a corresponding wiring harness that allows a technician to access the engine’s ECM directly. In this paper, we refer to these harnesses as “reprogramming harnesses.” This term best describes the original intent of the harnesses, which was to allow technicians to reprogram or recalibrate the ECM of an old or damaged truck. Detroit Diesel also refers to the wiring harnesses as “reprogramming harnesses,” whereas Caterpillar calls them “break-out cables,” and Cummins calls them “bench calibration cables.” Many technicians at large garages and truck shops use reprogramming harnesses for EDR data collection purposes, as do a number of accident reconstruction experts and forensic engineers.

However, in many cases, using a reprogramming harness to access the ECM and EDR data puts valuable forensic data at risk. Although “hard brake” data from the EDR are not affected by the use of a reprogramming harness, important “fault data” from the ECM *are affected*.

This paper discusses ECM and EDR data and the risk of losing valuable forensic evidence when using a reprogramming harness during an ECM download. In the event an investigator chooses not to perform an ECM download with a reprogramming harness, there are safe alternatives. This paper provides information about these safer methods for performing ECM downloads.

Definitions

Electronic Control Module (ECM) – sometimes referred to as the Engine Control Module, the ECM can be thought of as the diesel engine’s electronic “brain.”

Event Data Recorder (EDR) – refers to the “black box” component of an ECM, which can record vehicle speed and driver inputs when a crash, rollover, or other mishap occurs. EDR data from heavy trucks include Hard Brake reports, Last Stop Records, Sudden Deceleration Data, and Quick Stops.

Fault – sometimes referred to as a Diagnostic Trouble Code or DTC, a fault is an unexpected condition in the diesel engine that could affect or harm vehicle performance or cause damage, such as low oil pressure, high coolant temperature, and so on.

Reprogramming Harness – wiring that allows a diesel mechanic to reprogram or recalibrate an ECM when the ECM is not connected to an engine.

Snapshot – data about vehicle operation that is recorded when the ECM observes a fault or DTC; snapshot data can include vehicle speed, engine speed, throttle position, and many other attributes that describe the vehicle’s motion.

[Learn additional EDR-related definitions.](#)

EDR “Hard Brake” Data

The EDR (“black box”) is a component of many ECMs that stores event-specific data. In Detroit Diesel and Mercedes engines, EDR data are referred to as “Hard Brake reports” and the “Last Stop Record.” In Cummins engines, the EDR data are called “Sudden Deceleration Data,” and in Caterpillar engines, the EDR data are referred to as the “Quick Stop.” The data are usually saved when the vehicle’s speed changes by a specific amount or preset threshold. *These “hard brake” types of EDR records are not affected by the use of a reprogramming harness.*

Example of an Event Leading to the Creation of “Hard Brake” Data: A Freightliner tractor with a Detroit Diesel engine is traveling at 70mph. The driver perceives a hazard and brakes hard. If the truck decelerates by more than 7mph in one second (for example, a speed change from 70mph to 63mph, or lower, in one second), then a Hard Brake report will be created. The EDR will record the speed, brake use, clutch use, RPM (i.e., engine speed), engine load, percent throttle, cruise control status, and diagnostic trouble codes for about 75 seconds. These 75 seconds of recorded data are made up of the 60 seconds before the hard braking, and 15 seconds after.

Most ECMs employ another method of collecting event-specific data in addition to the EDR. This method involves the ECM’s collecting *fault data*. *Fault data can be erased or corrupted by using the reprogramming harness*, whether one is using a

reprogramming harness to perform a bench-top download (i.e., the ECM has been removed from the truck), or during an on-engine download (i.e., direct connection to the ECM on the side of the engine block).

ECM Fault Data

When most ECMs sense that a serious fault (sometimes referred to as a Diagnostic Trouble Code, or DTC) has occurred, they record information about how the truck was being used at or around the time the fault was activated. Fault data often include vehicle speed, RPM, engine load, and throttle percentage, as well as the status of many other onboard sensors. This information can be very valuable evidence for the collision investigator.

Example of an Event Leading to the Creation of Fault Data: A Peterbilt tractor with a Caterpillar C-15 engine is traveling at 70mph when the truck's driver becomes incapacitated. The tractor strikes a passenger vehicle without braking, and it overrides the passenger vehicle's bumper. This rips the oil pan off the Peterbilt's Caterpillar engine, and the engine experiences a "Very Low Oil Pressure" fault as the oil drains onto the roadway. This condition can cause the Caterpillar's ECM to record 13 seconds of valuable data, including the vehicle's speed and RPM, beginning at approximately nine seconds before the fault and continuing for four seconds after the fault.

Fault data can also be extremely useful in cases where the electrical and mechanical condition of the tractor may have contributed to the crash. For example, if a truck is losing oil pressure, overheating, or experiencing other problems, it can become partially or completely disabled. The records associated with these faults can provide valuable evidence about the time surrounding a crash or mishap.

ECM Fault Data in EDR-Equipped Engines

All major engine manufacturers have ECMs that can capture fault data. However, the differences between different engines' ECMs include how much fault data are stored, when they are stored, and how the data are erased or overwritten by new fault data.

Detroit Diesel (1998-2006) and Mercedes Benz (2000-2006) ECMs have the capacity to record fault data as 55-second-long "snapshots" of event data (one sample every five seconds). Detroit Diesel and Mercedes Benz refer to these fault snapshots as "diagnostic records." These engines' ECMs can store three diagnostic records at a time and record 15 different parameters, including vehicle speed, engine speed, and braking. (Note: Detroit Diesel and Mercedes Benz engines produced after late-2007 do record information about fault codes, but they do not store vehicle speed information with the fault data.)

Caterpillar ECMs (1995 – present) can record up to four fault snapshot records. These snapshots contain up to 13 seconds of data. Unlike the other types of ECMs

discussed in this paper, the Caterpillar ECM's Quick Stop feature is turned off by default on all engines manufactured prior to the 2008 model year. As a result, it can be the case that the fault snapshots in Caterpillar engines are the only available event data. This is significant because it means that the vehicle speed data associated with a fault code is often the only "event" data available from a Caterpillar ECM.

Cummins ECMs (1998 – present) are able to record fault code snapshots of data for up to 40 different parameters. Unlike Detroit Diesel and Mercedes Benz ECMs, the fault code snapshots recorded by Cummins ECMs only capture a single, one-second sample. Due to this small sample, Cummins fault code snapshots are generally less useful than those from Detroit Diesel, Mercedes Benz, and Caterpillar ECMs.

How ECM Fault Data Can Be Affected by the Use of a Reprogramming Harness

In situations where a vehicle has been seriously damaged or its electrical system has been compromised, often a reprogramming harness is used to retrieve ECM data. This typically involves disconnecting the vehicle harness and then connecting the reprogramming harness directly to the ECM. The reprogramming harness is powered from an external source (outside the vehicle), and the ECM is downloaded. This type of download is most commonly referred to as a "bench-top" or "direct" download.

The problem with using reprogramming harnesses in bench-top or direct ECM downloads is that new fault codes are almost always created due to the fact that the ECM has been separated from its native environment. These newly created data are completely unrelated to the crash. In some cases, using a reprogramming harness to access the ECM may even *overwrite*, crash-related event data. In cases where the mechanical and electrical integrity of a vehicle have been compromised, the use of a reprogramming harness can almost guarantee that relevant data will be lost completely.

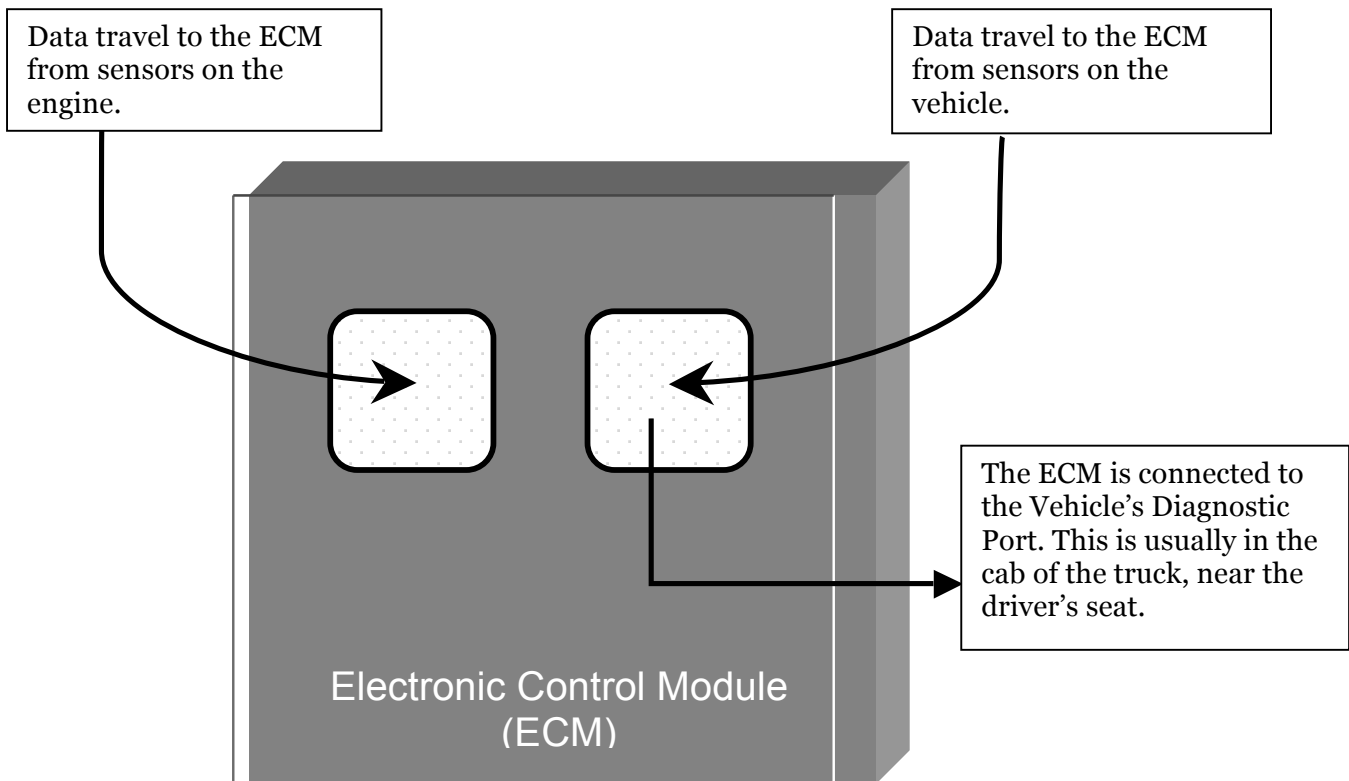
The following steps explain how using a reprogramming harness can lead to data loss:

1. A severe crash occurs, and the engine sensors and/or vehicle sensors detect "fault codes."
2. A "snapshot" is written in the ECM that records information about how the vehicle was operated shortly before and after the fault was detected.
3. The ECM is removed from the crashed vehicle.
4. Then a reprogramming harness is connected so that investigators can download the ECM directly.
5. The ECM receives power though the reprogramming harness, but it does not receive the expected signals from vehicle and engine sensors.

- 6. New fault codes and snapshots are written at this time.
- 7. These new fault codes and snapshots overwrite the crash-related fault codes and snapshots.

Why the ECM Records New Faults

One of the ECM's main functions is to perform diagnostic checks on the engine sensors and vehicle sensors, which feed important information to the ECM. Some examples of these sensors include the throttle position sensor, the barometric pressure sensor, and the oil pressure sensor. Because information from the sensors is what the ECM uses to control emissions, fuel injection, and basic vehicle operation, the ECM performs diagnostic checks of the sensors to make sure they are working properly each time the ECM is powered on. Whenever a sensor provides the ECM with unexpected information, the ECM records the information as a "fault." In many cases, when the ECM records a "fault," it also writes a "snapshot." Snapshots are like mini-EDR reports that can show information about vehicle speed, engine speed, and engine usage at the time that the fault was created.



When a reprogramming harness is used, the engine sensor harness and vehicle sensor harness are disconnected, and the reprogramming harness is connected in their place. Because of this, the ECM does not receive the signals that it's expecting from sensors on the truck; the ECM then records these pieces of unexpected information as new "faults." Using a reprogramming harness causes the ECM to write new "faults" that are *related to the download*. Since the ECM can only store a

limited amount of data, it has to delete older faults in order to accommodate these new ones. When the older faults are overwritten, the snapshot associated with them is also overwritten.

Recently, research has been published that compared different methods for downloading Detroit Diesel and Mercedes Benz ECMs. Plant, Austin, and Smith ([SAE 2011-01-0808](#)) found that bench-top downloads of Detroit Diesel and Mercedes Benz ECMs *always* overwrote at least one fault. *However, the authors found that downloading by way of the diagnostic port (the Deutsch connector) did not create any faults.* There is no evidence or testing that suggests that EDR data are affected by the reprogramming harness downloads. In addition, the authors found that Hard Brake records and Last Stop Records were not altered in Detroit Diesel and Mercedes Benz engines whether they were downloaded through the diagnostic port or by way of reprogramming harness.

Appropriate Versus Inappropriate Times for Using Reprogramming Harnesses

In general, accessing the ECM by way of the vehicle's Deutsch connector (i.e., the vehicle's diagnostic port) is the most appropriate option. However, vehicle damage or wiring damage from a collision can create situations where it is not possible to conduct an ECM download using this method. In situations where one must select an alternative download method, it is important to consider the type of crash as well as the ECM manufacturer. Also, the pros and cons of using a reprogramming harness in general must be taken into account. Bench-top downloads, while often very convenient, can overwrite important fault code snapshots.

Detroit Diesel and Mercedes Benz: Detroit Diesel and Mercedes Benz ECMs produced before 2007 are likely to record crash-related Hard Brake and Last Stop Records, and there are situations when downloading these ECMs with a reprogramming harness is appropriate. If the Detroit Diesel or Mercedes Benz engine was produced in 2007 or later, there is less risk involved with using a reprogramming harness because there are no fault snapshots to overwrite in these engines. However, the type of crash must be carefully considered when deciding on a download method. If there is any reasonable chance that a Hard Brake or Last Stop Record *was not created*, then a surrogate vehicle or Truck in a Box should be used instead of the reprogramming harness. Regardless of the year or engine model, in any case involving a Detroit Diesel or Mercedes Benz engine where the mechanical or electrical integrity of the tractor is a potential issue in the investigation, a reprogramming harness should not be used.

Caterpillar: Caterpillar ECMs produced between 1995 and 2007 require the use of extreme caution when considering which download method is the most appropriate. The Quick Stop function in these ECMs is turned off by default and is rarely available. Consequently, fault code snapshots are often the only available event data; therefore, using reprogramming harnesses to download these ECMs will

almost always overwrite the only event data that may be present. As a general rule, *Caterpillar ECMs should not be downloaded with reprogramming harnesses*. Also, regardless of the year or engine model, in any case involving a Caterpillar engine where the mechanical or electrical integrity of the tractor is a potential issue in the investigation, a reprogramming harness should not be used. Whenever possible, Caterpillar engines should be downloaded either using the vehicle's Deutsch connector, via a surrogate vehicle, or by using a "truck in a box."

Cummins ECMs: There are several reasons why downloading a Cummins ECM using a reprogramming harness appears to be a suitable option. For example, after 2005, there is a good chance that a sudden deceleration event will be recorded during a crash, and ECM testing and prior downloads have shown that reprogramming harness downloads do not alter sudden deceleration event data. Also, the very small fault code snapshot sample (one-second) is typically far less useful than fault snapshots from other engines. Additionally, Cummins ECMs do not simply erase old fault data in favor of newer fault data; instead, Cummins uses a more sophisticated algorithm for saving old fault records. This means that even with the use of a reprogramming harness, important fault data in Cummins ECMs may be preserved. However, it is likely that a large amount of new fault code data will be created when bench-top downloading a Cummins ECM. The party who is responsible for the downloaded vehicle should be aware of this likelihood before any download attempt is made.

Alternative, Safe Methods for Downloading ECMs

There are two main methods for downloading ECMs that eliminate any need to use reprogramming harnesses. The first method is what is referred to as a "surrogate vehicle download." In this method, the ECM is removed from the crash vehicle and is placed into an undamaged, virtually identical surrogate vehicle and then downloaded via the Deutsch connector. Assuming that the surrogate vehicle is in proper working condition, this method is very reliable. However, the main obstacle with this method is finding the surrogate vehicle because it has to be virtually identical to the crash vehicle. Finding available surrogate vehicles can be very difficult and expensive.

The second alternative to using a reprogramming harness to download an ECM is using what is commonly referred to as a "truck in a box." The "truck in the box" is a device that simulates the normal connections between a vehicle and an ECM. It allows the ECM to be properly downloaded *off* of the damaged vehicle, without the concern of creating new fault code snapshots. While these devices are less common at the current time, using a "truck in the box" to download the ECM is much easier and more convenient than trying to locate a proper surrogate vehicle.

[Messerschmidt Safety Consultants \(MSC\)](#) and [Great Lakes Crash Analysis \(GLCA\)](#) have developed and tested a "truck in a box" device, which can access Detroit Diesel and Caterpillar ECMs without setting new fault codes.

MSC's Truck in a Box

After nearly five years of research and hundreds of heavy truck ECM downloads, MSC joined forces with [Tim Austin of GLCA](#) and Mike Farrell of Fox Valley Technical College to construct a Truck in a Box that will prevent diagnostic codes from being written in Detroit Diesel, Mercedes, and Caterpillar ECMs.

Using our Truck in a Box, along with original equipment supplied by the engine manufacturers, MSC is able to download Detroit Diesel and Caterpillar ECMs on the bench-top without creating new faults or overwriting incident or crash data. MSC, Mr. Austin of GLCA, and Mr. Farrell of Fox Valley are currently working on creating similar technology for downloading Mercedes and Cummins ECMs as well.

Conclusions

The safest way to download any heavy truck or commercial vehicle ECM is by way of the Deutsch connector (i.e., the vehicle's diagnostic port). All research to-date indicates that this method presents the smallest chance of creating new fault data or overwriting potentially significant older data. When a heavy commercial vehicle ECM cannot be downloaded via the Deutsch connector, it is important to consider alternate methods for downloading the ECM safely.

The following considerations should be taken into account regarding the following engines' ECMs:

Detroit Diesel and Mercedes:

- If the electrical and mechanical condition of the tractor may be an issue in the investigation, you should use a Truck in a Box or a surrogate vehicle, regardless of the year and engine model.
- If the electrical and mechanical condition of the tractor is not an issue, then it is important to determine whether a Hard Brake or Last Stop Record was written, and/or if any damage might have led to a Diagnostic Trouble Code being written. If there is any reasonable chance that a Hard Brake or Last Stop Record *was not created*, then a surrogate vehicle or Truck in a Box should be used instead of the reprogramming harness.

Caterpillar:

- It is almost NEVER safe to perform an on-engine or bench-top download of a Caterpillar ECM. Only one Caterpillar ECM type will preserve Fault Snapshots; these snapshots can contain 13 seconds of valuable pre-event data. If downloading the ECM by way of the Deutsch connector (i.e., the vehicle's diagnostic port) is not possible, then using a surrogate vehicle or Truck in a Box will almost always be the best method of dealing with a Caterpillar ECM.

Cummins:

- In most cases, Cummins ECM data will not be affected by the use of a reprogramming harness. However, if the pre-crash electrical and mechanical condition of the truck is very important, then a surrogate vehicle should be considered.

For all ECM types, a download through the vehicle's Deutsch connector (i.e., the vehicle's diagnostic port) is the preferred method. When this is impossible or impractical, then investigators should consider the facts and circumstances of the case before performing an ECM download. In some cases, a bench-top download may be appropriate. However, in many cases, a surrogate vehicle or Truck in a Box will be the best alternative so that all fault codes are preserved and no new data are written during the download process.

About the Authors

William Messerschmidt developed and is the co-instructor of "[How to Interpret Commercial Vehicle EDRs](#)," the country's first formal training class on the forensic use of ECM data. The course is taught through the University of Tulsa's Continuing Engineering and Science Education (CESE) division.

Messerschmidt is also the author of several papers on ECM technology. These include "[A Statistical Analysis of Data from Heavy Vehicle Event Data Recorders](#)," published in the *SAE International Journal of Commercial Vehicles*, and "Simulating the Effect of Collision-Related Power Loss on the Event Data Recorders of Heavy Trucks," published as [SAE Technical Paper 2010-01-1004](#).

Messerschmidt will be an invited speaker at the [2011 SAE EDR Symposium](#), where he will present his latest research, *Driver Braking Performance as Reported by Heavy Vehicle EDRs*.

Benjamin Smith has been involved in Heavy Vehicle Event Data Recorder (HVEDR) research for four years and has co-authored peer-reviewed research for *Collision Magazine* and SAE. Smith's research includes co-authoring the first technical research on data loss during bench-top, on-engine, and diagnostic port downloads. Ben's other papers include [Testing the Last Stop Record in the MBE 4000](#), a paper that demonstrates how Mercedes Benz's EDR function differs from Detroit Diesel's EDR function, and *Applying Heavy Vehicle EDR Data in the Real World*, which was presented at the [2011 CDR Summit](#).

Kelly Messerschmidt is a technical communications specialist at MSC. Messerschmidt completed her graduate studies in Technical and Professional Communication ([MTPC](#)) at Auburn University, where her research included the impact of communication on systems safety. She has reviewed, edited, and written technical reports, research papers, safety manuals, and other media, including many documents on the subject of EDRs.