Correlation of Bendix® Data Recorder (BDR) versus Engine Control Module (ECM) Data

Numerous research papers, articles and publications have been written to validate the data within Engine Control Modules, specifically pertaining to the application of this data in relation to traffic crash investigation. This paper outlines the correlation of the data found within the Bendix® Data Recorder (BDR) and compares it against the data within Electronic Control Modules (ECM).

History:

Bendix® is a company which has been in business for over 85 years developing and manufacturing advanced active safety and braking system technologies. Currently Bendix® uses EC30, EC60 and EC80 Electronic Control Units (ECU's) in many commercial vehicle platforms. These Electronic Controllers are members of a family of electronic Antilock Braking System (ABS) devices designed to help improve the braking characteristics of air-braked vehicles – including heavy and medium duty bases, trucks and tractors.[i]

Bendix® ABS uses wheel speed sensors, ABS modulator valves, and an ECU to control either four or six wheels of a vehicle. By monitoring individual wheel turning motion during braking, and adjusting or pulsing the brake pressure at each wheel, the Bendix® EC-80 controller is able to optimize slip between the tire and the road surface.[ii]

Bendix® EC80 controllers are cab-mounted and vary in their mounting location. Typically, they are found in the center stack area and/or passenger side front dash (see red rectangles below).

Figure 1.1 – International Lone Star Tractor - typical mounting locations

Depending on the product type and version, Bendix® Electronic Control Units (ECU's) may store data related to troubleshooting, diagnostics, service needs, and vehicle system operating status and vehicle operator inputs.

The system calculates the rolling circumference between the steer and drive axle wheel sizes which it constantly monitors and updates at speeds greater than 12 mph (19 km/h). In addition, the ECU also receives data from the engine ECM regarding vehicle speed. When a system fault occurs, information is stored in the Bendix® ABS ECU which provides limited data recorded at the time of the event. The diagnostic record captures a single "freeze frame" image that includes the fault time in terms of engine hours and power up time (time range from key-on to fault onset).

Figure 1.2 – (Left) EC80, (Right) EC60

The two ECU's pictured above are the EC80 (left) and the EC60 (right). The EC80 is distinguishable by the module being deeper than the EC60. The EC80 is the latest ECU from Bendix® and is currently associated with the Bendix® Wingman/Fusion systems.

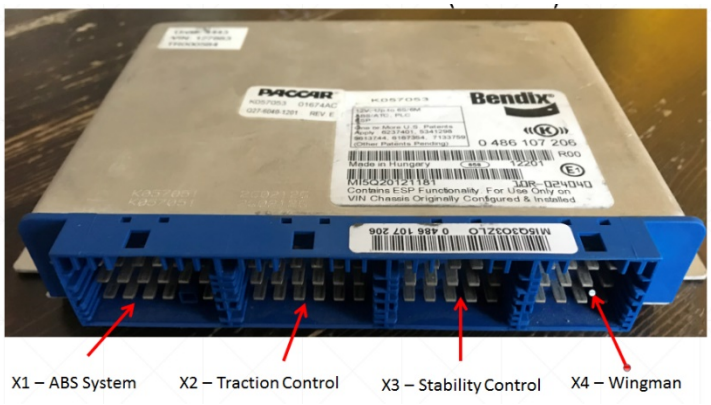


Figure 1.3 – EC80 "X" identifiers

There are four opening/connectors on the EC80 and each specific area is designated for a specific function. The author has seen EC80 modules with only two of the areas with pins which appear to be option specific for each owner/order. The four "X" openings are identified in figure 1.3.

The software required to image the in-cab ECU's is Bendix® ACOM, which is currently free (going to a pay model in the 4th quarter of 2019). With this software the user is able to communicate with the ECU via the Deutsch or ODBII connector (Mack and Volvo) and retrieve specific information. The data available through the Bendix® ACOM software relates to the system status, diagnostics, and system configuration.

Data can also be extracted in a direct to module type download. One way to complete this would be to use Synercon Technologies®, LLC Smart Sensor Simulator 2 (SSS2) which offers a forensically neutral process for obtaining data.

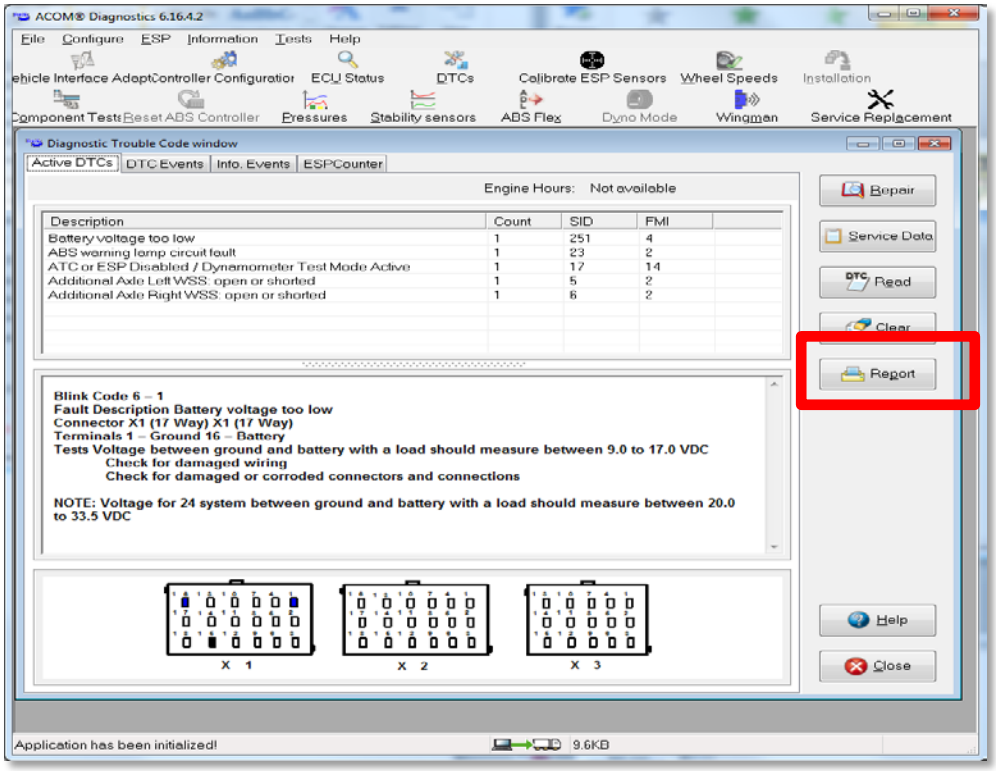


Figure 1.4 – Bendix®ACOM Software

Within the Bendix® ACOM program, clicking on the "report" button will allow the user to save an "htm" file.

See Appendix "A" (Request and Release of Bendix® ECU Data Download) for the process for submitting the "htm" file along with $1000 US dollars to Bendix®. Tabular data may be returned provided that the ECU is supported.

Once the Bendix® Data Report (BDR) is returned, the Bendix® EC-80 ECU Event-Based Header Information will be at the top left of the report.

Event Completed	TRUE
Event Number	1
Event Lock Number	Not Locked
Engine Hours (min)	60
Powerup Time (min)	11.98
TriggerType	Hard Brake
FDA Table Index	255

Figure 1.5 – Sample of the Bendix®BDR Header Information

Within this event information is:

- Event Number (which is representative of the life of the ECU module) and will display if the event is locked or not
- Engine Hours in minutes
- Power up time (displayed in minutes) which relates to the period between the key "On" versus key "Off" position, and power is supplied to the system
- Trigger type (if recorded) and
- FDA Table Index

Time	Trigger	FLR Status	ABS Status	Trailer ABS Status	ESP Status	ABS Warning Lamp Request	ATC Warning Lamp Request	ATC Mud/Snow Switch	ABS Off-Road Switch	Vehicle Speed (mph)	Steering Angle (deg)	Accelerator Pedal Position (%)	CCVS Brake Light Request	Driver Service Brake Application	Park Brake Dash Ind. Request	Cruise Control Active Status	VDC Brake Lamp Request	FLR Audible Alert	FLR Intervention	ABS Activity	ESP Intervention	HSA Intervention
0.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
0.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
1.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
1.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
2.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
2.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
3.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
3.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
4.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
4.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
5.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
5.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
6.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
6.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
7.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
7.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
8.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
8.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
9.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
9.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
10.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
10.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
11.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
11.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
12.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
12.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
13.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
13.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
14.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
14.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
15.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
15.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
16.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
16.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
17.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
17.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
18.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
18.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
19.0	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1
19.5	1	3	1	1	1	1	1	1	1	140.93	-5.37	99.2	3	3	1	3	1	7	1	1	1	1

Figure 1.6 – Sample of the Bendix®BDR Tabular Information

The tabular information typically contains the following system recorded event-based data elements:[iii]

- Time
- Trigger (1 or 0 – indicates when the trigger occurred by a 1)

- FLR Status (Forward Looking Radar (normal operation when displayed by 1))
- ABS Status (normal operation when the value is 1)
- Trailer ABS Status (normal operation when the value is 1)
- ABS Warning Lamp Request (ABS active – 1)
- ATC Warning Lamp Request (active – 1)
- ATC Mud/Snow Switch (when on = 1)
- ABS Off-Road Switch (when on = 1)
- Vehicle Speed (MPH)
- Steering Angle (degrees) (provides driver steering angle input, clockwise and negative angle are synonymous, which is contrary to SAE J211)
- Accelerator Pedal Position (Percent) (how much throttle was requested)
- CCVS Light Request (brake light request)
    - 0 = no,
    - 1 = request
    - 2 = unknown
    - 3 = reserved for future use
- Driver Service Brake Application (brake pressure demanded by the driver, 1 bar = 14.5038 PSI)
    - 0 = < ½ bar
    - 1 = ½ bar to 2 bars
    - 2,3,4,5, bars
    - >= 6 bars
- Park Brake Dash Ind. Request (reports tractor park brake switch status)
    - 0 – not set
    - 1 = set
- Cruise Control Active Status (reports if cruise control was active or not)
    - 0 = CC not active
    - 1 = CC Active
    - 2 = Error
    - 3 = Not available
- VDC Brake Lamp Request (Reports when the brake lights were requested to be turned on by the Bendix®Active Safety Technology – ESP or Wingman)
    - 0 = off
    - 1 = on
- FLR Audible Alert (reports levels of audible warning given to the driver by the Wingman system)
    - 0 = No warning
    - 1 = Distance alert 1
    - 2 = Distance alert 2
    - 3 – Distance alert 3
    - 4 = System shutdown alert
    - 5 = Impact alert
    - 6 = Error

    - 7 = Not available
- FLR Intervention (Forward Looking Radar System Intervention – reports when there was a brake intervention by the Bendix® Wingman system
    - 0 = No intervention
    - 1 = System intervention
- ABS Activity (Reports when there was ABS activation)
    - 0 = No activation
    - 1 = ABS activation
- ESP Intervention (Reports when there was an intervention by the ESP system)
    - 0 = No intervention
    - 1 = ESP intervention
- HSA Intervention (Reports when there was intervention requested by the HSA feature)
    - 0 = HSA not active
    - 1 = HSA active

Event recording will typically be triggered by one or more of the following situations:

- Bendix® Wingman collision mitigation system brake activation
- High lateral acceleration
- High longitudinal acceleration; and/or
- Driver override of Bendix® Wingman collision mitigation system activation

The tabular data is recorded in half-second increments for a total of 20 seconds with approximately 10 seconds of pre and post trigger. It can store up to four different event logs with the oldest log overwritten as a new event log is captured.

All of this data is gathered from the J1939 network, or directly from ABS/ESP/Collision Mitigation Technology systems as well as other vehicle systems, as appropriate.

If a data element is not present at the time of recording, it will be indicated with NA, blank or a specific code.

Events deemed significant by the system, based on specific parameters in the system including acceleration change greater than 0.85 g or a vehicle speed change greater than 9 mph (14.5 km/h) within a second, the specific event is “locked” in the system and will not be overwritten until after the next 50 events are recorded. Only two events are able to be locked at a time. If a third “significant” event occurs that is deemed to be lockable, the oldest event will be overwritten.

Test Vehicle:

Figure 1.7 – 2019 Peterbilt 3 axle tractor

The vehicle used for the testing was a three axle day cab tractor, featuring a Cummins engine and ECM.

Test Location:

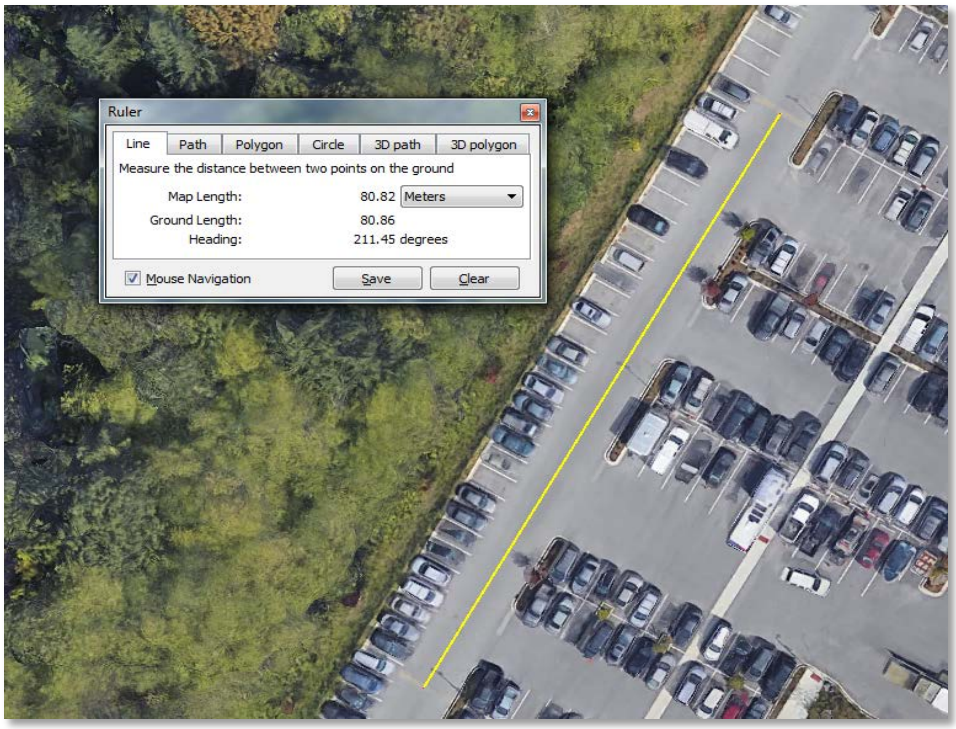


Figure 1.8 – Testing location – distance of testing

The testing took place in Vancouver, Canada in a parking lot. The testing consisted of the 2019 Peterbilt being driven along the yellow line and braked hard, then reversed back to the start again.

Google distance = 80.36 metres (one way) times two = 160.72 metres. Convering to miles (factor 0.000621) = 0.998 miles.

Figure 1.9 – 2019 Peterbilt Engine/ECM Identifiers

The 2019 Peterbilt was virtually brand new with 62.6 km (38.9 miles) on the dash.

A pre-testing download of the ECM was done to verify any pre-existing data events within the ECM.

Cummins PowerSpec® reported a Sudden Deceleration Rate of 7.0 mph/s (11.3 km/h/s).[iv]

The 2019 Peterbilt was equipped with a Bendix® EC80 ESP 6S/6M system. There were no active DTC's within the pre-testing download.

<u>Testing Equipment:</u>

- Cummins PowerSpec® ECM software
- Synercon Technologies Forensic Link Adapter (RP1210 compliant device)
- Samsung Cell Phone Video
- Bendix® ACOM Software
- Bendix® BDR
- Apple iPhone Cell Phone Video/Time

During the testing, the truck was driven by the same person to ensure the driving style was consistent. The dash was videotaped using a Samsung cellular device and after each run, the ECM and Bendix® ECU were imaged. Tests 1, 2, 3, and 4 were driven in a forward direction while tests 4a and 5 were driven in

reverse. During test 4a, the 2019 Peterbilt was driven in reverse, but it was initially thought that the 11.8 mph (19 km/h) speed was not achieved to record any potential data. As such, the ECM, ACOM and BDR files were not imaged and we proceeded onto test 5. For an unknown reason, test 5 did not show up in the Bendix® BDR data.

Test Data Analysis:

The 2019 Peterbilt was accelerated and then decelerated rapidly. According to Bendix®, the *Event Number* will increase with each successive event. This was confirmed during testing where each completed event advanced the counter by one (n + 1).

	Pre-Testing Download	Test 1	Test 2	Test 3	Test 4	Test 4a	Test 5
Bendix ACOM Data							
Engine Hours	5.5	5.65	5.75	5.8	5.9	n/a	6
Input voltage	12.6	n/a	12.9	12.5	12.6	n/a	12.4
Active DTC	no	n/a	no	no	no	n/a	no
Event History	51	n/a	53	53	54	n/a	54
DTC window - ABS	18	19	20	21	22	n/a	24
DTC window - ABS during XBR	0	0	0	0	0	n/a	0
DTC window - ATC Brake	9	9	9	9	9	n/a	9
DTC window - ATC Engine	1	1	1	1	1	n/a	1
DTC window - Brake fade	0	0	0	0	0	n/a	0
DTC window - Hard Brake	2	2	2	2	2	n/a	2
Bendix BDR Data							
Event Numnber	2	3	4	5	6	7	n/a
Engine Hours (Minutes)	315	333	339	348	351	357	n/a
Converted to Hours	5.25	5.55	5.65	5.8	5.85	5.95	n/a
Power-up Time (min)	7.39	13.88	11.9	10.06	13.75	8.57	n/a
Trigger	>0.5 g	>0.5 g	>0.5 g	>0.5 g	>0.5 g	>0.5 g	n/a
FDA Table Index	255	255	255	255	255	255	n/a
Lock Numnber	Locked (52)	Locked (53)	Locked (54)	Not Locked	Not Locked	Not Locked	n/a

Figure 1.10 – Bendix® Tabular Data

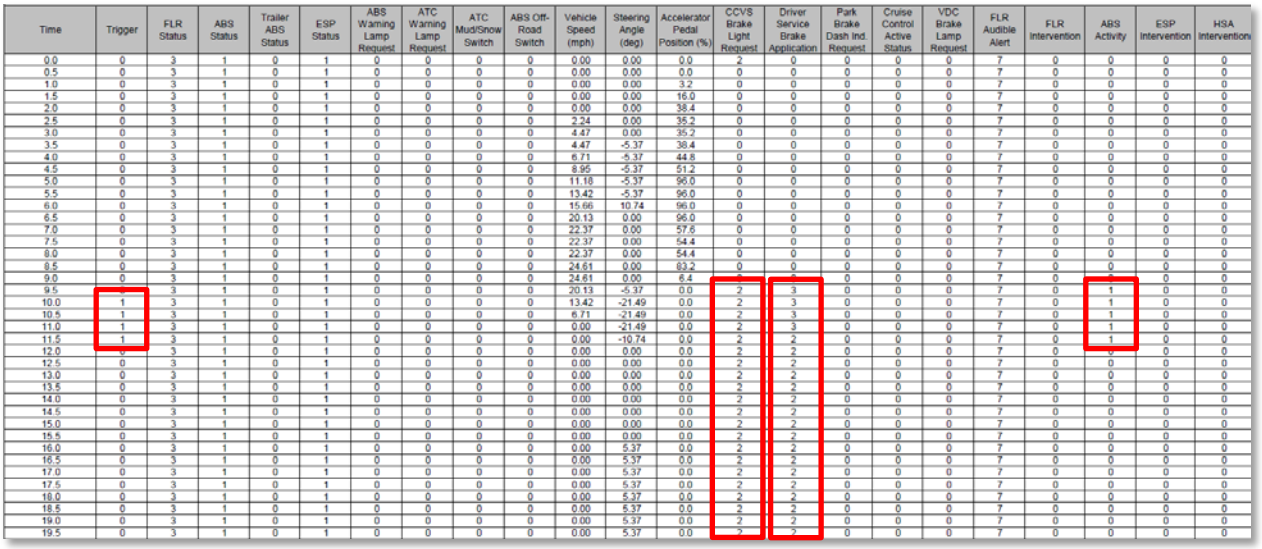
With each test, the *Engine Hours within the ACOM* data increased, although the resolution is in hours and without more decimal places it is impossible to correlate for this testing. Regardless, the values were increasing. The *Bendix® BDR data Engine Hours* (remember it is displayed in minutes) also increased but due to the 2019 Peterbilt being shut off after tests, correlation of the time to the exact minute was not achievable.

The *DTC window – ABS* within the Bendix® ACOM software increased with each brake application performed.

	Pre-Testing Download	Test 1	Test 2	Test 3	Test 4	Test 4a	Test 5
Dash Video							
Speed (Km/h)			40	39	40	25	30
Speed (MPH)			24.85	24.23	24.85	15.53	18.64
RPM			1820	1790	1810	1810	1810
PowerSpec							
Speed (MPH)		25	25	24	25	16	19
Speed (km/h)		40.23	40.23	38.62	40.23	25.75	30.58
RPM		1811	1831	1786	1840	1751	1830
Bendix BDR							
Record #		3	4	5	6	7	n/a
Speed (MPH)		24.61	24.61	22.37	24.61	15.66	n/a
Speed (Km/h)		39.61	39.61	36.00	39.61	25.20	n/a

Figure 1.11 – Tabular Analysis

In test 1, the 2019 Peterbilt was accelerated forward with the ECM recording 25 mph (40.23 km/h) and the Bendix® BDR data recording 24.61 mph (39.61 km/h). The video recording of the speedometer was not done during this test.

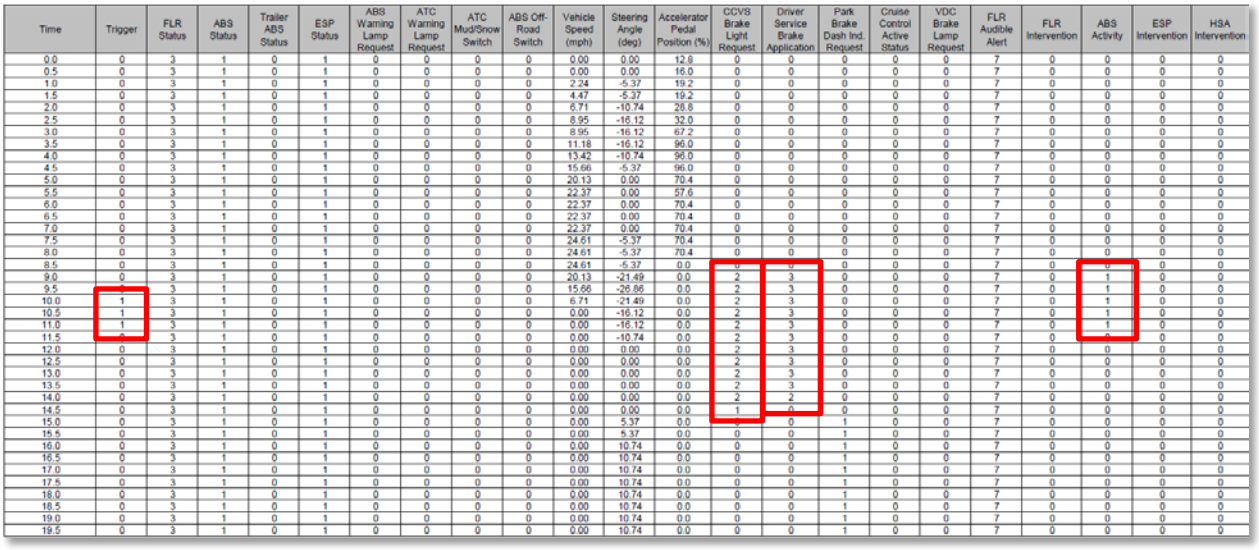


Time	Trigger	FLR Status	ABS Status	Trailer ABS Status	ESP Status	ABS Warning Lamp Request	ATC Warning Lamp Request	ATC Mud/Snow Switch	ABS Off-Road Switch	Vehicle Speed (mph)	Steering Angle (deg)	Accelerator Pedal Position (%)	CCVS Brake Light Request	Driver Service Brake Application	Park Brake Dash Ind. Request	Cruise Control Active Status	VDC Brake Lamp Request	FLR Audible Alert	FLR Intervention	ABS Activity	ESP Intervention	HSA Intervention
0.0	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	0	0	0	0	7	0	0	0	0
0.5	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	0	0	0	0	0	7	0	0	0	0
1.0	0	3	1	0	1	0	0	0	0	0.00	0.00	3.2	0	0	0	0	0	7	0	0	0	0
1.5	0	3	1	0	1	0	0	0	0	0.00	0.00	16.0	0	0	0	0	0	7	0	0	0	0
2.0	0	3	1	0	1	0	0	0	0	0.00	0.00	38.4	0	0	0	0	0	7	0	0	0	0
2.5	0	3	1	0	1	0	0	0	0	2.24	0.00	35.2	0	0	0	0	0	7	0	0	0	0
3.0	0	3	1	0	1	0	0	0	0	4.47	0.00	35.2	0	0	0	0	0	7	0	0	0	0
3.5	0	3	1	0	1	0	0	0	0	4.47	-5.37	38.4	0	0	0	0	0	7	0	0	0	0
4.0	0	3	1	0	1	0	0	0	0	6.71	-5.37	44.8	0	0	0	0	0	7	0	0	0	0
4.5	0	3	1	0	1	0	0	0	0	8.95	-5.37	51.2	0	0	0	0	0	7	0	0	0	0
5.0	0	3	1	0	1	0	0	0	0	11.18	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
5.5	0	3	1	0	1	0	0	0	0	13.42	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
6.0	0	3	1	0	1	0	0	0	0	15.66	10.74	96.0	0	0	0	0	0	7	0	0	0	0
6.5	0	3	1	0	1	0	0	0	0	20.13	0.00	96.0	0	0	0	0	0	7	0	0	0	0
7.0	0	3	1	0	1	0	0	0	0	22.37	0.00	57.6	0	0	0	0	0	7	0	0	0	0
7.5	0	3	1	0	1	0	0	0	0	22.37	0.00	54.4	0	0	0	0	0	7	0	0	0	0
8.0	0	3	1	0	1	0	0	0	0	22.37	0.00	54.4	0	0	0	0	0	7	0	0	0	0
8.5	0	3	1	0	1	0	0	0	0	24.61	0.00	83.2	0	0	0	0	0	7	0	0	0	0
9.0	0	3	1	0	1	0	0	0	0	24.61	0.00	6.4	0	0	0	0	0	7	0	0	0	0
9.5	0	3	1	0	1	0	0	0	0	20.13	-5.37	0.0	2	3	0	0	0	7	0	1	0	0
10.0	1	3	1	0	1	0	0	0	0	13.42	-21.49	0.0	2	3	0	0	0	7	0	1	0	0
10.5	1	3	1	0	1	0	0	0	0	6.71	-21.49	0.0	2	3	0	0	0	7	0	1	0	0
11.0	1	3	1	0	1	0	0	0	0	0.00	-21.49	0.0	2	3	0	0	0	7	0	1	0	0
11.5	1	3	1	0	1	0	0	0	0	0.00	-10.74	0.0	2	2	0	0	0	7	0	1	0	0
12.0	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	2	0	0	0	7	0	0	0	0
12.5	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	2	0	0	0	7	0	0	0	0
13.0	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	2	0	0	0	7	0	0	0	0
13.5	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	2	0	0	0	7	0	0	0	0
14.0	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	2	0	0	0	7	0	0	0	0
14.5	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	2	0	0	0	7	0	0	0	0
15.0	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	2	0	0	0	7	0	0	0	0
15.5	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	2	0	0	0	7	0	0	0	0
16.0	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	2	0	0	0	7	0	0	0	0
16.5	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	2	0	0	0	7	0	0	0	0
17.0	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	2	0	0	0	7	0	0	0	0
17.5	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	2	0	0	0	7	0	0	0	0
18.0	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	2	0	0	0	7	0	0	0	0
18.5	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	2	0	0	0	7	0	0	0	0
19.0	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	2	0	0	0	7	0	0	0	0
19.5	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	2	0	0	0	7	0	0	0	0

Figure 1.12 – Bendix® BDR Data from Test 1

The tabular data from test 1 revealed that the Trigger was met (type - >0.5g), as it changed from 0 to 1. The CCVS Brake light request also changed from 0 to 2, meaning unknown. The Driver Service Brake Application changed from 0 to 3 meaning 3 bars, and the ABS activity changed from 0 to 1 meaning the ABS was activated. Between time samples 9 to 9.5, the vehicle reached an acceleration of -0.4g. Between time samples 9.5 to 10 and 10 to 10.5, the vehicle reached -0.61g on both, confirming that the trigger of >0.5g was accurate.

In test 2, the 2019 Peterbilt was accelerated forward to 40 km/h (24.85 mph) and 1820 RPM as displayed on the dash, while the ECM recorded 25 mph (40.23 km/h) and 1831 RPM and the Bendix® BDR data recording 24.61 mph (39.61 km/h).

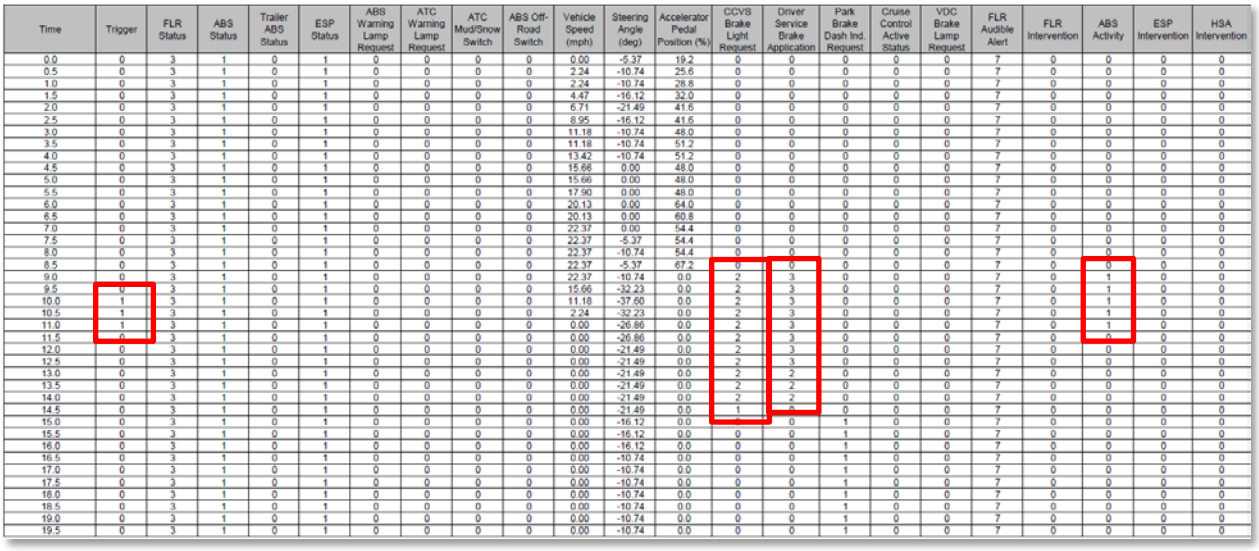


Time	Trigger	FLR Status	ABS Status	Trailer ABS Status	ESP Status	ABS Warning Lamp Request	ATC Warning Lamp Request	ATC Mud/Snow Switch	ABS Off-Road Switch	Vehicle Speed (mph)	Steering Angle (deg)	Accelerator Pedal Position (%)	CCVS Brake Light Request	Driver Service Brake Application	Park Brake Dash Ind. Request	Cruise Control Active Status	VDC Brake Lamp Request	FLR Audible Alert	FLR Intervention	ABS Activity	ESP Intervention	HSA Intervention
0.0	0	3	1	0	1	0	0	0	0	0.00	0.00	12.8	0	0	0	0	0	7	0	0	0	0
0.5	0	3	1	0	1	0	0	0	0	0.00	0.00	16.0	0	0	0	0	0	7	0	0	0	0
1.0	0	3	1	0	1	0	0	0	0	2.24	-5.37	19.2	0	0	0	0	0	7	0	0	0	0
1.5	0	3	1	0	1	0	0	0	0	4.47	-5.37	19.2	0	0	0	0	0	7	0	0	0	0
2.0	0	3	1	0	1	0	0	0	0	6.71	-10.74	28.8	0	0	0	0	0	7	0	0	0	0
2.5	0	3	1	0	1	0	0	0	0	8.95	-16.12	32.0	0	0	0	0	0	7	0	0	0	0
3.0	0	3	1	0	1	0	0	0	0	8.95	-16.12	67.2	0	0	0	0	0	7	0	0	0	0
3.5	0	3	1	0	1	0	0	0	0	11.18	-16.12	96.0	0	0	0	0	0	7	0	0	0	0
4.0	0	3	1	0	1	0	0	0	0	13.42	-10.74	96.0	0	0	0	0	0	7	0	0	0	0
4.5	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
5.0	0	3	1	0	1	0	0	0	0	20.13	0.00	70.4	0	0	0	0	0	7	0	0	0	0
5.5	0	3	1	0	1	0	0	0	0	22.37	0.00	57.6	0	0	0	0	0	7	0	0	0	0
6.0	0	3	1	0	1	0	0	0	0	22.37	0.00	70.4	0	0	0	0	0	7	0	0	0	0
6.5	0	3	1	0	1	0	0	0	0	22.37	0.00	70.4	0	0	0	0	0	7	0	0	0	0
7.0	0	3	1	0	1	0	0	0	0	22.37	0.00	70.4	0	0	0	0	0	7	0	0	0	0
7.5	0	3	1	0	1	0	0	0	0	24.61	-5.37	70.4	0	0	0	0	0	7	0	0	0	0
8.0	0	3	1	0	1	0	0	0	0	24.61	-5.37	70.4	0	0	0	0	0	7	0	0	0	0
8.5	0	3	1	0	1	0	0	0	0	24.61	-5.37	0.0	0	0	0	0	0	7	0	0	0	0
9.0	0	3	1	0	1	0	0	0	0	20.13	-21.49	0.0	2	3	0	0	0	7	0	1	0	0
9.5	0	3	1	0	1	0	0	0	0	15.66	-26.86	0.0	2	3	0	0	0	7	0	1	0	0
10.0	1	3	1	0	1	0	0	0	0	6.71	-21.49	0.0	2	3	0	0	0	7	0	1	0	0
10.5	1	3	1	0	1	0	0	0	0	0.00	-16.12	0.0	2	3	0	0	0	7	0	1	0	0
11.0	1	3	1	0	1	0	0	0	0	0.00	-16.12	0.0	2	3	0	0	0	7	0	1	0	0
11.5	1	3	1	0	1	0	0	0	0	0.00	-10.74	0.0	2	3	0	0	0	7	0	1	0	0
12.0	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	3	0	0	0	7	0	0	0	0
12.5	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	3	0	0	0	7	0	0	0	0
13.0	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	3	0	0	0	7	0	0	0	0
13.5	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	3	0	0	0	7	0	0	0	0
14.0	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	2	0	0	0	7	0	0	0	0
14.5	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	1	0	0	0	0	7	0	0	0	0
15.0	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	0	0	1	0	0	7	0	0	0	0
15.5	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	0	0	1	0	0	7	0	0	0	0
16.0	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
16.5	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
17.0	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
17.5	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
18.0	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
18.5	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
19.0	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
19.5	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0

Figure 1.13 – Bendix® BDR Data from Test 2

The tabular data from test 2 revealed that the Trigger was met (type - >0.5g), as it changed from 0 to 1. The CCVS Brake light request also changed from 0 to 2, meaning "unknown". The Driver Service Brake Application changed from 0 to 3 meaning 3 bars, followed by a single 2 at time sample 14, and the ABS activity changed from 0 to 1 meaning the ABS was activated. Between time samples 9 to 9.5, the vehicle reached an acceleration of -0.4g. Between time samples 9.5 to 10 the vehicle reached -0.81 and time samples 10 to 10.5, the vehicle reached -0.61g, confirming that the trigger of >0.5g was accurate.

In test 3, the 2019 Peterbilt was accelerated forward to 39 km/h (24.23 mph) and 1790 RPM as displayed on the dash, while the ECM recorded 24 mph (38.62 km/h) and 1786 RPM and the Bendix® BDR data recording 22.37 mph (36 km/h).



Time	Trigger	FLR Status	ABS Status	Trailer ABS Status	ESP Status	ABS Warning Lamp Request	ATC Warning Lamp Request	ATC Mud/Snow Switch	ABS Off-Road Switch	Vehicle Speed (mph)	Steering Angle (deg)	Accelerator Pedal Position (%)	CCVS Brake Light Request	Driver Service Brake Application	Park Brake Dash Ind. Request	Cruise Control Active Status	VDC Brake Lamp Request	FLR Audible Alert	FLR Intervention	ABS Activity	ESP Intervention	HSA Intervention
0.0	0	3	1	0	1	0	0	0	0	0.00	-5.37	19.2	0	0	0	0	0	7	0	0	0	0
0.5	0	3	1	0	1	0	0	0	0	2.24	-10.74	25.6	0	0	0	0	0	7	0	0	0	0
1.0	0	3	1	0	1	0	0	0	0	2.24	-10.74	28.8	0	0	0	0	0	7	0	0	0	0
1.5	0	3	1	0	1	0	0	0	0	4.47	-16.12	32.0	0	0	0	0	0	7	0	0	0	0
2.0	0	3	1	0	1	0	0	0	0	6.71	-21.49	41.6	0	0	0	0	0	7	0	0	0	0
2.5	0	3	1	0	1	0	0	0	0	8.95	-16.12	41.6	0	0	0	0	0	7	0	0	0	0
3.0	0	3	1	0	1	0	0	0	0	11.18	-10.74	48.0	0	0	0	0	0	7	0	0	0	0
3.5	0	3	1	0	1	0	0	0	0	11.18	-10.74	51.2	0	0	0	0	0	7	0	0	0	0
4.0	0	3	1	0	1	0	0	0	0	13.42	-10.74	51.2	0	0	0	0	0	7	0	0	0	0
4.5	0	3	1	0	1	0	0	0	0	15.66	0.00	48.0	0	0	0	0	0	7	0	0	0	0
5.0	0	3	1	0	1	0	0	0	0	15.66	0.00	48.0	0	0	0	0	0	7	0	0	0	0
5.5	0	3	1	0	1	0	0	0	0	17.90	0.00	48.0	0	0	0	0	0	7	0	0	0	0
6.0	0	3	1	0	1	0	0	0	0	20.13	0.00	64.0	0	0	0	0	0	7	0	0	0	0
6.5	0	3	1	0	1	0	0	0	0	20.13	0.00	60.8	0	0	0	0	0	7	0	0	0	0
7.0	0	3	1	0	1	0	0	0	0	22.37	0.00	54.4	0	0	0	0	0	7	0	0	0	0
7.5	0	3	1	0	1	0	0	0	0	22.37	-5.37	54.4	0	0	0	0	0	7	0	0	0	0
8.0	0	3	1	0	1	0	0	0	0	22.37	-10.74	54.4	0	0	0	0	0	7	0	0	0	0
8.5	0	3	1	0	1	0	0	0	0	22.37	-5.37	67.2	0	0	0	0	0	7	0	0	0	0
9.0	0	3	1	0	1	0	0	0	0	22.37	-10.74	0.0	2	3	0	0	0	7	0	1	0	0
9.5	0	3	1	0	1	0	0	0	0	15.66	-32.23	0.0	2	3	0	0	0	7	0	1	0	0
10.0	1	3	1	0	1	0	0	0	0	11.18	-37.60	0.0	2	3	0	0	0	7	0	1	0	0
10.5	1	3	1	0	1	0	0	0	0	2.24	-32.23	0.0	2	3	0	0	0	7	0	1	0	0
11.0	1	3	1	0	1	0	0	0	0	0.00	-26.86	0.0	2	3	0	0	0	7	0	1	0	0
11.5	1	3	1	0	1	0	0	0	0	0.00	-26.86	0.0	2	3	0	0	0	7	0	1	0	0
12.0	0	3	1	0	1	0	0	0	0	0.00	-21.49	0.0	2	3	0	0	0	7	0	0	0	0
12.5	0	3	1	0	1	0	0	0	0	0.00	-21.49	0.0	2	3	0	0	0	7	0	0	0	0
13.0	0	3	1	0	1	0	0	0	0	0.00	-21.49	0.0	2	2	0	0	0	7	0	0	0	0
13.5	0	3	1	0	1	0	0	0	0	0.00	-21.49	0.0	2	2	0	0	0	7	0	0	0	0
14.0	0	3	1	0	1	0	0	0	0	0.00	-21.49	0.0	2	2	0	0	0	7	0	0	0	0
14.5	0	3	1	0	1	0	0	0	0	0.00	-21.49	0.0	1	0	0	0	0	7	0	0	0	0
15.0	0	3	1	0	1	0	0	0	0	0.00	-16.12	0.0	0	0	1	0	0	7	0	0	0	0
15.5	0	3	1	0	1	0	0	0	0	0.00	-16.12	0.0	0	0	1	0	0	7	0	0	0	0
16.0	0	3	1	0	1	0	0	0	0	0.00	-16.12	0.0	0	0	1	0	0	7	0	0	0	0
16.5	0	3	1	0	1	0	0	0	0	0.00	-10.74	0.0	0	0	1	0	0	7	0	0	0	0
17.0	0	3	1	0	1	0	0	0	0	0.00	-10.74	0.0	0	0	1	0	0	7	0	0	0	0
17.5	0	3	1	0	1	0	0	0	0	0.00	-10.74	0.0	0	0	1	0	0	7	0	0	0	0
18.0	0	3	1	0	1	0	0	0	0	0.00	-10.74	0.0	0	0	1	0	0	7	0	0	0	0
18.5	0	3	1	0	1	0	0	0	0	0.00	-10.74	0.0	0	0	1	0	0	7	0	0	0	0
19.0	0	3	1	0	1	0	0	0	0	0.00	-10.74	0.0	0	0	1	0	0	7	0	0	0	0
19.5	0	3	1	0	1	0	0	0	0	0.00	-10.74	0.0	0	0	1	0	0	7	0	0	0	0

Figure 1.14 – Bendix® BDR Data from Test 3

The tabular data from test 3 revealed that the Trigger was met (type - >0.5g), as it changed from 0 to 1. The CCVS Brake light request also changed from 0 to 2, meaning “unknown”. The Driver Service Brake Application changed from 0 to 3 meaning 3 bars, and the ABS activity changed from 0 to 1 meaning the ABS was activated. Between time samples 9 to 9.5, the vehicle reached an acceleration of -0.61g. Between time samples 9.5 to 10 the vehicle reached -0.4 and time samples 10 to 10.5, the vehicle reached -0.81g, confirming that the trigger of >0.5g was accurate.

In test 4, the 2019 Peterbilt was accelerated forward to 40 km/h (24.85 mph) and 1810 RPM as displayed on the dash, while the ECM recorded 25 mph (40.23 km/h) and 1840 RPM and the Bendix® BDR data recording 24.61 mph (39.61 km/h).

Time	Trigger	FLR Status	ABS Status	Trailer ABS Status	ESP Status	ABS Warning Lamp Request	ATC Warning Lamp Request	ATC Mud/Snow Switch	ABS Off-Road Switch	Vehicle Speed (mph)	Steering Angle (deg)	Accelerator Pedal Position (%)	CCVS Brake Light Request	Driver Service Brake Application	Park Brake Dash Ind. Request	Cruise Control Active Status	VDC Brake Lamp Request	FLR Audible Alert	FLR Intervention	ABS Activity	ESP Intervention	HSA Intervention
0.0	0	3	1	0	1	0	0	0	0	0.00	5.37	9.6	0	0	0	0	0	7	0	0	0	0
0.5	0	3	1	0	1	0	0	0	0	0.00	5.37	28.8	0	0	0	0	0	7	0	0	0	0
1.0	0	3	1	0	1	0	0	0	0	2.24	5.37	35.2	0	0	0	0	0	7	0	0	0	0
1.5	0	3	1	0	1	0	0	0	0	2.24	0.00	38.4	0	0	0	0	0	7	0	0	0	0
2.0	0	3	1	0	1	0	0	0	0	4.47	0.00	41.6	0	0	0	0	0	7	0	0	0	0
2.5	0	3	1	0	1	0	0	0	0	6.71	0.00	44.8	0	0	0	0	0	7	0	0	0	0
3.0	0	3	1	0	1	0	0	0	0	8.95	0.00	60.8	0	0	0	0	0	7	0	0	0	0
3.5	0	3	1	0	1	0	0	0	0	11.18	0.00	96.0	0	0	0	0	0	7	0	0	0	0
4.0	0	3	1	0	1	0	0	0	0	13.42	0.00	96.0	0	0	0	0	0	7	0	0	0	0
4.5	0	3	1	0	1	0	0	0	0	15.66	0.00	96.0	0	0	0	0	0	7	0	0	0	0
5.0	0	3	1	0	1	0	0	0	0	17.90	0.00	96.0	0	0	0	0	0	7	0	0	0	0
5.5	0	3	1	0	1	0	0	0	0	20.13	0.00	70.4	0	0	0	0	0	7	0	0	0	0
6.0	0	3	1	0	1	0	0	0	0	22.37	0.00	57.6	0	0	0	0	0	7	0	0	0	0
6.5	0	3	1	0	1	0	0	0	0	24.61	0.00	54.4	0	0	0	0	0	7	0	0	0	0
7.0	0	3	1	0	1	0	0	0	0	24.61	0.00	54.4	0	0	0	0	0	7	0	0	0	0
7.5	0	3	1	0	1	0	0	0	0	24.61	-5.37	54.4	0	0	0	0	0	7	0	0	0	0
8.0	0	3	1	0	1	0	0	0	0	24.61	-10.74	54.4	0	0	0	0	0	7	0	0	0	0
8.5	0	3	1	0	1	0	0	0	0	24.61	-5.37	54.4	0	0	0	0	0	7	0	0	0	0
9.0	0	3	1	0	1	0	0	0	0	24.61	-5.37	0.0	2	2	0	0	0	7	0	0	0	0
9.5	0	3	1	0	1	0	0	0	0	17.90	-5.37	0.0	2	3	0	0	0	7	0	1	0	0
10.0	1	3	1	0	1	0	0	0	0	13.42	-10.74	0.0	2	3	0	0	0	7	0	1	0	0
10.5	1	3	1	0	1	0	0	0	0	4.47	-5.37	0.0	2	3	0	0	0	7	0	1	0	0
11.0	1	3	1	0	1	0	0	0	0	0.00	-10.74	0.0	2	3	0	0	0	7	0	1	0	0
11.5	1	3	1	0	1	0	0	0	0	0.00	-10.74	0.0	2	3	0	0	0	7	0	1	0	0
12.0	0	3	1	0	1	0	0	0	0	0.00	0.00	0.0	2	3	0	0	0	7	0	0	0	0
12.5	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	3	0	0	0	7	0	0	0	0
13.0	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	3	0	0	0	7	0	0	0	0
13.5	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	3	0	0	0	7	0	0	0	0
14.0	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	2	2	0	0	0	7	0	0	0	0
14.5	0	3	1	0	1	0	0	0	0	0.00	5.37	0.0	1	1	0	0	0	7	0	0	0	0
15.0	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
15.5	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
16.0	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
16.5	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
17.0	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
17.5	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
18.0	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
18.5	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
19.0	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0
19.5	0	3	1	0	1	0	0	0	0	0.00	10.74	0.0	0	0	1	0	0	7	0	0	0	0

Figure 1.15 – Bendix® BDR Data from Test 4

The tabular data from test 4 revealed that the Trigger was met (type - >0.5g), as it changed from 0 to 1. The CCVS Brake light request also changed from 0 to 2, meaning “unknown”. The Driver Service Brake Application changed from 0 to 3 meaning 3 bars, and the ABS activity changed from 0 to 1 meaning the ABS was activated. Between time samples 9 to 9.5, the vehicle reached an acceleration of -0.61g. Between time samples 9.5 to 10 the vehicle reached -0.4 and time samples 10 to 10.5, the vehicle reached -0.81g, confirming that the trigger of >0.5g was accurate.

In test 4a, the 2019 Peterbilt was accelerated in reverse to 25 km/h (15.53 mph) and 1810 RPM as displayed on the dash, while the ECM recorded 16 mph (25.75 km/h) and 1751 RPM and the Bendix® BDR data recording 15.66 mph (25.20 km/h). Of note, within Cummins PowerSpec® the variable speed sensor (VSS) on the output shaft does not differentiate positive or negative rotation of the output shaft which is also the same for the Bendix® BDR sensors at each wheel.

Time	Trigger	FLR Status	ABS Status	Trailer ABS Status	ESP Status	ABS Warning Lamp Request	ATC Warning Lamp Request	ATC Mud/Snow Switch	ABS Off-Road Switch	Vehicle Speed (mph)	Steering Angle (deg)	Accelerator Pedal Position (%)	CCVS Brake Light Request	Driver Service Brake Application	Park Brake Dash Ind. Request	Cruise Control Active Status	VDC Brake Lamp Request	FLR Audible Alert	FLR Intervention	ABS Activity	ESP Intervention	HSA Intervention
0.0	0	3	1	0	1	0	0	0	0	6.71	0.00	96.0	0	0	0	0	0	7	0	0	0	0
0.5	0	3	1	0	1	0	0	0	0	8.95	0.00	96.0	0	0	0	0	0	7	0	0	0	0
1.0	0	3	1	0	1	0	0	0	0	11.18	0.00	96.0	0	0	0	0	0	7	0	0	0	0
1.5	0	3	1	0	1	0	0	0	0	13.42	0.00	89.6	0	0	0	0	0	7	0	0	0	0
2.0	0	3	1	0	1	0	0	0	0	15.66	-10.74	80.0	0	0	0	0	0	7	0	0	0	0
2.5	0	3	1	0	1	0	0	0	0	15.66	-16.12	80.0	0	0	0	0	0	7	0	0	0	0
3.0	0	3	1	0	1	0	0	0	0	15.66	-5.37	80.0	0	0	0	0	0	7	0	0	0	0
3.5	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
4.0	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
4.5	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
5.0	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
5.5	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
6.0	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
6.5	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
7.0	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
7.5	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
8.0	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
8.5	0	3	1	0	1	0	0	0	0	15.66	-5.37	96.0	0	0	0	0	0	7	0	0	0	0
9.0	0	3	1	0	1	0	0	0	0	15.66	-10.74	0.0	0	2	0	0	0	7	0	0	0	0
9.5	0	3	1	0	1	0	0	0	0	8.95	0.00	0.0	2	3	0	0	0	7	0	1	0	0
10.0	1	3	1	0	1	0	0	0	0	2.24	0.00	0.0	2	3	0	0	0	7	0	1	0	0
10.5	1	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	3	0	0	0	7	0	1	0	0
11.0	1	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	3	0	0	0	7	0	1	0	0
11.5	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	3	0	0	0	7	0	0	0	0
12.0	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	3	0	0	0	7	0	0	0	0
12.5	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	3	0	0	0	7	0	0	0	0
13.0	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	3	0	0	0	7	0	0	0	0
13.5	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	3	0	0	0	7	0	0	0	0
14.0	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	3	0	0	0	7	0	0	0	0
14.5	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	3	0	0	0	7	0	0	0	0
15.0	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	3	0	0	0	7	0	0	0	0
15.5	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	2	0	0	0	7	0	0	0	0
16.0	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	2	0	0	0	7	0	0	0	0
16.5	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	2	1	0	0	0	7	0	0	0	0
17.0	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	1	0	1	0	0	7	0	0	0	0
17.5	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	0	0	1	0	0	7	0	0	0	0
18.0	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	0	0	1	0	0	7	0	0	0	0
18.5	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	0	0	1	0	0	7	0	0	0	0
19.0	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	0	0	1	0	0	7	0	0	0	0
19.5	0	3	1	0	1	0	0	0	0	0.00	-5.37	0.0	0	0	1	0	0	7	0	0	0	0

Figure 1.16 – Bendix® BDR Data from Test 4a

The tabular data from test 4a revealed that the Trigger was met (type - >0.5g), as it changed from 0 to 1. The CCVS Brake light request also changed from 0 to 2, meaning “unknown”. The Driver Service Brake Application changed from 0 to 3 meaning 3 bars, and the ABS activity changed from 0 to 1 meaning the ABS was activated. Between time samples 9 to 9.5, the vehicle reached an acceleration of -0.61g. Between time samples 9.5 to 10 the vehicle reached -0.61 and time samples 10 to 10.5, the vehicle reached -0.2g, confirming that the trigger of >0.5g was accurate.

In test 5, the 2019 Peterbilt was accelerated in reverse to 30 km/h (18.64 mph) and 1810 RPM as displayed on the dash, while the ECM recorded 19 mph (30.58 km/h) and 1830 RPM. There was no Bendix® BDR data for this test.

	Test 1	% of ECM Data	Test 2	% of ECM Data	Test 3	% of ECM Data	Test 4	% of ECM Data	Test 4a	% of ECM Data	Test 5	% of ECM Data	Minimum	Average	Maximum
Dash Video															
Speed (Km/h)			40	99.42%	39	100.97%	40	99.42%	25	97.09%	30	98.11%	97.09%	99.00%	100.97%
Speed (MPH)			24.85	99.42%	24.23	100.97%	24.85	99.42%	15.53	97.09%	18.64	98.11%	97.09%	99.00%	100.97%
RPM			1820	99.40%	1790	100.22%	1810	98.37%	1810	103.37%	1810	98.91%	98.37%	100.05%	103.37%
PowerSpec															
Speed (MPH)	25		25		24		25		16		19				
Speed (km/h)	40.23		40.23		38.62		40.23		25.75		30.58				
RPM	1811		1831		1786		1840		1751		1830				
Bendix BDR															
Record #	3		4		5		6		7		n/a				
Speed (MPH)	24.61	98.44%	24.61	98.44%	22.37	93.21%	24.61	98.44%	15.66	97.88%	n/a		93.21%	96.99%	98.44%
Speed (Km/h)	39.61	98.44%	39.61	98.44%	36.00	93.21%	39.61	98.44%	25.20	97.88%	n/a		93.21%	96.99%	98.44%

Figure 1.17 – Tabular Analysis

An analysis of the data as it relates to the ECM data revealed that the average dash needles displayed an average of 99% of the recorded speed and 100.05% of the RPM of the ECM, while the BDR data reported an average of 96.99% of the ECM recorded speed data.

Summary:

The following data points within the Bendix® BDR, data engine hours, DTC window, record number, trigger, ABS activity, speed and trigger threshold type are in good agreement when compared against ECM data, and therefore could be relied upon with confidence, if this was the only data that was available for analysis. More testing is planned with different engine manufacturers and an attempt to corroborate other data points.

Special Thanks To:

- Tony Becker, Forensic Training Group LLC
- Corporal Rick Neger, Royal Canadian Mounted Police (ICAARS)
- Pierre Brideau - T/SM Ontario Region - Bendix®

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[i] Sourced from Bendix.com
[ii] Bendix® Service Data – SD-13-4983, Bendix EC80 ABS/ATC Controllers
[iii] Sourced from The Bendix Technical Bulletin (TCH-013-026) Effective Date – October 26, 2015, Subject – *Bendix® EC80 Electronic Control Unit Data Storage*
[iv] Sourced from Cummins PowerSpec®, Trip Information – Sudden Deceleration Rate

Bendix Commercial Vehicle Systems LLC
901 Cleveland Street, Elyria, Ohio 44035
Tel: 440.329.9000 • Fax: 440.329.9203

Appendix "A"

REQUEST AND RELEASE OF BENDIX ECU DATA DOWNLOAD

Section 1: Overview

This form is used to request and release Bendix ECU data download and track custody of the components removed from the vehicle to Bendix Commercial Vehicle Systems. A copy of this completed form must accompany the components when sent. Once removed from the vehicle, send this form completely filled out, component and check for $1000 to:

Bendix Commercial Vehicle Systems
Event Log Reporting Location # 4138
901 Cleveland Street
Elyria, Ohio 44035
440-326-9843

NOTE: Data extraction fee $1000.

EXCLUSION OF INCIDENTAL, CONSEQUENTIAL AND CERTAIN OTHER DAMAGES:

TO THE MAXIMUM EXTENT PERMITTED BY APPLICABLE LAW, IN NO EVENT SHALL BENDIX, ITS SUBSIDIARIES, AFFILIATES, SUPPLIERS OR APPROVED SERVICE PROVEDER BE LIABLE FOR ANY SPECIAL, INCIDENTAL, INDIRECT, OR CONSEQUENTIAL DAMAGES WHATSOEVER (INCLUDING, BUT NOT LIMITED TO, DAMAGES FOR LOSS OF PROFITS OR CONFIDENTIAL OR OTHER INFORMATION, FOR BUSINESS INTERRUPTION FOR PERONSAL INJURY, FOR LOSS OF PRIVACY, FOR FAILURE TO MEET ANY DUTY INCLUDING THOSE OF GOOD FAITH OR REASONABLE CARE FOR NEGLIGENCE, OR FOR ANY OTHER PECUNIARY OR OTHER TYPE OF LOSS WHATSOEVER) ARISING OUT OF OR IN ANY WAY RELATED TO THE LOSS OF THE ECU, THE USE OF OR INABILITY TO USE THE DATA DOWNLOAD, THE PROVISION OF OR FAILURE TO PROVIDE EVENT REPORTS, OR OTHERWISE UNDER OR IN CONNECTION WITH ANY PROVISION OF THIS AGREEMENT, EVEN IN THE EVENT OF THE FAULT, TORT (INCLUDING NEGLEGENCE), STRICT LIABILITY, BREACH OF CONTRACT OR BREACH OF WARRANTY OF BENDIX OR ANY SUBSIDIARY, AFFILIATE, OR SUPPLIER, AND EVEN IF BENDIX OR ANY SUCH SUBSIDIARY, AFFILIATE, SUPPLIER OR APROVED SERVICE PROVIDER HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

Section 2: Contact Information (All Fields Mandatory, Please **TYPE** all information to avoid processing delays)

	Requestor Information *(The person requesting the data download.)*	**Vehicle Owner** *(The person/ company that owns the vehicle.)*	**Report / ECU(s) Recipient** *(The person Bendix will return the report(s) and ECU(s).*
Name			
Company			
Full Mailing Address			
Phone			
Email			

Rev D

Bendix Commercial Vehicle Systems LLC
901 Cleveland Street, Elyria, Ohio 44035
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ATTENTION

Depending on the product type and version, Bendix Electronic Control Units (ECUs) may store data related to troubleshooting, diagnostics, service needs, vehicle system operating status and vehicle operator inputs. No personally identifying data (e.g. name, gender or age) is recorded. Bendix will not access stored ECU data or share it with others except: with the consent of the vehicle owner; in response to an official request by law enforcement or other governmental agency; as part of Bendix's defense of litigation; or, as otherwise required by law. Data that Bendix receives may also be used for research purposes or made available to others for research purposes, where a need is shown and the data is not linked to a specific vehicle or owner.

Bendix®-brand ECUs are not designed to store data for purposes of accident reconstruction and Bendix® ACom® Diagnostic Software is not intended to retrieve data for purposes of accident reconstruction. Bendix makes no representations as to the accuracy of data retrieved and interpreted from ECUs for purposes of accident reconstruction. Bendix does not offer accident reconstruction services or interpretation of stored data. Bendix ECUs are not protected from fire, loss of power, impact damage, or other conditions that may be sustained in a crash situation and may cause data to be unavailable or irretrievable.

Section 3: Vehicle & Component Information (all fields mandatory; TYPE to avoid processing delays)

When requesting ECU Data Download from Bendix components, a single form can be used when sending in multiple components for download. It is extremely important that this form be filled out completely. Please list serial number for each component you are sending on the form below. It is also strongly recommended to send in a picture of the label of each component.

ABS ECU: It is not required to send in the brake ECU if you are requesting a BDR report. You only need to email the ABS DTC report in HTML format (address at end of form) to be able to have the BDR report generated. This will reduce the time needed to process the information.

AutoVue 3G Camera (Grey): Please do **not** send this camera in as there is no data that can be extracted

FLR-21 (Forward Looking Radar): The only data that is available is the DTC report from the radar. There is no need to send in the component.

AutoVue/SDP ECU: If video capture is not enabled, there is no data/video that can be extracted

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Vehicle & Component Information (All Fields Mandatory; TYPE to avoid processing delays)

	Vehicle VIN	
	Vehicle Truck Number	
	Vehicle Make & Model	

DTC Report(s) Sent in	ABS DTC Report (HTML)	☐		**Photo of Component(s) Sent to Bendix**
	Check All That Apply		**ECU Serial Number**	You can add pictures to the end of this form
Component(s) Removed	SafetyDirect Processor (SDP)	☐		
	AutoVue ECU	☐		
	ABS ECU	☐		
	FLC20 Camera (Black)	☐		
	3G Camera (Gray)		Do not send in	
	Forward Looking Radar (FLR)		Do not send in	
Component removed from vehicle	**Removed from Vehicle by**			
	Removal Date & Time			
Component sent to Bendix **MUST BE SENT VIA FEDEX OR UPS FOR TRACKING**	**Date Sent to Bendix**			
	Sender Name			
	Sender Signature			**Tracking Number**
	Carrier	FedEx ☐	UPS ☐	

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Tel: 440.329.9000 • Fax: 440.329.9203

Section 4: Accident Information

If the requested extraction request is the result of an accident, the following information is REQUIRED.

Incident Information - Required			
	***Is this request the result of an accident**	Yes ☐	No ☐
	***Current SafetyDirect Customer**	Yes ☐	No ☐
***All Fields are Required**	***Date of Incident**		
	***Time of Incident**		
	***Time Zone of Incident Time Above**		

Customer	
*Name	
*Address	
*Contact	
*Phone	
*Email	
Customer Reference Number	

Ship To	
Name	Bendix CVS
Address	Event Log Reporting # 4138
	901 Cleveland Street
	Elyria, Ohio 44035
Phone	440-326-9843
Email	EventLogReporting@Bendix.com
Bendix Reference Number	

After the components/reports are received, expected processing times is 2-4 weeks from when received. During times of high volume, expected processing time may be greater.

***Customer**	
***Signed**	
***Printed**	
***Date**	

***All Fields are Required**

Email this form to EventLogReporting@Bendix.com prior to shipping the ECU **AND** attach a copy with the shipment.

This form is required to accompany any product returned to Bendix. If this form is not included with shipment, it may result in shipment contents to be lost and long processing delays.

Please package unit carefully to prevent damage during transit.