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An Introduction to the Forensic Acquisition of Passenger Vehicle Infotainment and Telematics Systems Data

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Abstract

The data obtained from event data recorders found in airbag control modules, powertrain control modules and rollover sensors in passenger vehicles has been validated and used to reconstruct crashes for years. Recently, a third-party system has been introduced that allows crash investigators and reconstructionists to access, preserve and analyze data from infotainment and telematics systems found in passenger vehicles. The infotainment and telematics systems in select vehicles retain information and event data from cellular telephones and other devices connected to the vehicle, vehicle events and navigation data in the form of tracklogs. These tracklogs provide a time history of a vehicle's geolocation that may be useful in investigating an incident involving an automobile or reconstructing a crash. This paper presents an introduction to the type of data that may be retained and the methods for performing data acquisitions. Finally, a case study is presented in which various vehicle events are examined and Global Positioning System (GPS) tracklog data imaged from a vehicle is compared to independent GPS instrumentation to analyze the accuracy of the retrieved tracklog data.

Introduction

The data obtained from event data recorders (EDRs) found in passenger vehicles has been extensively analyzed in peer-reviewed literature. Since the introduction of the commercially available Bosch Crash Data Retrieval tool in 2000, hundreds of vehicles have been tested and data from event data recorders has been validated. In 2016, Bortles, et al., provided a thorough review and analysis of all the known validation testing to date [1]. They concluded, "The analysis presented here supports the notion that original equipment EDRs tend to be accurate, and tend to underreport Pre-Crash speed and ΔV values… EDRs provide valid and useful data that can be used as a supplement to a thorough accident reconstruction."

Data extraction from GPS devices is currently not as prevalent as event data extraction from airbag control modules, powertrain control modules and roll-over sensors found in passenger vehicles. However, the data from GPS devices is equally beneficial, and in some cases, more information-rich than data found in event data recorders. GPS based data provides insightful information about a vehicle and its driver that can be used to investigate an incident involving an automobile and can be utilized as a supplement to a thorough accident reconstruction.

The GPS program was officially created in 1973 and consists of three parts: Space, Control and User [2]. The Space system consists of at least 24 satellites orbiting the Earth in six different orbital planes at approximately 12,550 miles above the Earth. Currently, the Control system consists of a Master Control Station, an Alternate Master Control Station, eleven Command and Control Antennas and fifteen Monitoring Sites. The control system tracks each satellite in order to determine accurate satellite orbit and clock information that is continually uploaded to each satellite for use in the GPS. The user system consists of various antennas, receivers and display units that utilize the satellites to provide location information.

In 2003, Nagle, et al., detailed the existing and future GPS and provided commentary on their current and future use in the automotive world [3]. Current GPS applications in the automotive industry include vehicle navigation, automatic vehicle location (AVL) applications such as fleet management networks, automatic collision notification and even autonomous vehicle operation in pit mining operations. Nagle, et al., believed that GPS technology had enormous potential for improving vehicle safety but realized that many future automotive safety improvements, such as collision avoidance, lane deviation and roadway path warnings, may be met with other more suitable technology solutions. However, the authors contend, "While this system may not be used as a primary sensor, it will come at a low enough cost that it should be considered as a complement to other technologies, thereby increasing reliability of many vehicle systems, and hence increasing vehicle safety."

In 2007, Butler, et al., tested the accuracy of a GPS-based data acquisition system for the purpose of reconstructing an accident. Butler performed longitudinal decelerating skid testing, steering

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response testing, steady state distance measurement testing and low speed dynamic crash testing [4]. For this study, the location data acquired using a GPS-based Traqmate system was compared to data collected using an accelerometer-based Vericom VC2000PC. The authors concluded that the GPS was able to determine location over a short time period at a resolution of 0.75 feet with 95% confidence.

In 2010, Reust tested five different consumer Garmin GPS units and compared the results to data obtained from a Racelogic VBOX III [5]. The testing procedure consisted of various maneuvers by the test vehicle including rapid acceleration, rapid deceleration, moderate acceleration, constant speed, changes in heading angle and short stop-and-go-and-stop events. According to Reust, the speed data recorded by the GPS units was in good agreement with the speed data that was recorded by the VBOX. The positional accuracy of the GPS coordinate locations was also analyzed by comparing the test vehicle's location at the end of a test with the physical location recorded by the GPS unit over two hour increments. This testing showed good initial coordinate location accuracy from the GPS unit data with increasing progressive error over time, with the error ranging from 3.5 to 7.5 feet.

Reust performed further testing in 2011 that was analyzed and published in a follow-up article [6]. During this testing, Reust determined that the GPS coordinates logged by the Garmin GPS units may vary over time by as much as 8 feet. Reust also determined that the leg length, or distance between two successive data points, affects the accuracy of the recorded data, with larger leg lengths generally leading to improved accuracy. It was reported that leg lengths between 20 and 30 feet had an accuracy of approximately 3.3% to 10% while distances between 100 feet and 0.1 miles had an accuracy of approximately 1.7% or better. Leg lengths given in tenths of a mile had an accuracy of approximately 2.3%.

In 2012, Bortolin, et al., analyzed the accuracy of consumer GPS models using speed and position aspects to determine the ability of GPS devices to correctly show a vehicle's traveled path [7]. In this testing, the authors used a Racelogic V-BOX III GPS-based data-collection unit to evaluate the positional accuracy of common consumer GPS models. The consumer GPS units evaluated during the testing included a Garmin Nuvi 265, Garmin Aera 510, Magellan eXplorists 210 and a TomTom One. Data from three test runs was analyzed during the study. After entering the roadway, the first test run consisted of a full lane change, the second test run consisted of a partial lane change and the final test run consisted of only straight-line travel. The positional accuracy of the consumer GPS models was determined to lack the accuracy shown by the V-BOX. In general, the authors noted, "The positional accuracy of hand-held GPS devices can vary based on its quality and features, but a simple model will likely be able to achieve an accuracy of 15 meters [49.2 feet]." The consumer GPS models showed offsets from the actual traveled path and were unable to show the subtle lane change maneuvers of the vehicle during the testing. Vehicle speed data from the units was fairly accurate with the Garmin Aera unit having the smallest error compared to the V-BOX baseline data. Some large singular errors were present in some of the data. The speed data computed by the GPS models is effectively the leg speed of the vehicle, or the speed calculated using only the change in position between two points with the time elapsed. Therefore, any inaccurate location data recorded by the GPS units lead to inaccurate speed recordings as well.

In 2013, Michener, et al., evaluated the ability of tablet computers and GPS surveying equipment to accurately measure and record vehicle kinematics [8]. For this testing, vehicle motion was captured by an Apple iPad 2, Topcon GPS surveying system, bumper gun, optical speed trap, test vehicle's powertrain control module (PCM), custom built tri-axial accelerometer, G-Cube racing accelerometer and high-speed, high-definition video. The testing procedure utilized by the authors consisted of three brake-to-stop tests on asphalt, one turning on asphalt test culminating in braking while turning and three brake-to-stop tests on gravel. The GPS surveying equipment used during this testing consisted of a Topcon HiPer Lite + Geodetic Receiver Rover. This equipment was utilized to perform Real Time Kinematic satellite navigation. The Auto Topo feature was configured to record data every 0.2 seconds. After analyzing the data, the authors concluded that the longitudinal and lateral acceleration curves generated by the GPS surveying equipment were comparable in magnitude and duration to the data captured using accelerometer-based equipment. However, the GPS surveying equipment lacked the ability to adequately record rapid changes in acceleration. The authors also concluded that, "The tested GPS survey equipment provides a more complete description of a vehicle's trajectory than is offered by some of the other devices and methods presented."

In 2016, Komatsu, et al., collected GPS data during a long duration test and analyzed the data in order to improve GPS simulation measurement accuracy and to partially validate satellite simulation using 3D maps [9]. This study was performed in the Nishi-Shinjuku district, a densely populated urban location in Tokyo, Japan, in order to study the multipath error that results when GPS signal waves reflect off of buildings and other structures when driving in urban areas. In this study a test vehicle, equipped with a POS LV 520 utilizing a Real Time Kinematics (RTK) system, was used to determine high-accuracy vehicle position in real time. This study showed that the positional ratio and positional accuracy of GPS simulations can be improved by analyzing the GPS signal to determine the wave state in order to ignore multipath signals. The reception state of a GPS signal can be classified as a direct wave, reflected wave, diffracted wave or a combination of these wave types. The authors concluded, "Achieving simultaneous improvement of positional ratio and positional accuracy will require more than just increasing the number of positioning satellites, which is insufficient. It will also be necessary to increase the number of positioning satellites from which direct waves can be received."

Applications of Infotainment and Telematics Systems Data

Cornetto, et al. [10], Schaub [11], LeMere [12] and Seffers [13] have written informational articles about the potential applications of infotainment and telematics data for reconstructing accidents or investigating a crime involving an automobile. The data could be beneficial to law enforcement, investigators and accident reconstructionists by:

- Linking a particular vehicle to a certain location at a specific date and time
- Identifying the general path of travel of a vehicle for a particular date and time
- Linking a particular vehicle to a sequence in question for events during a particular date and time

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- Establishing a general timeline of events for a period of time under investigation
- Linking a particular individual to a vehicle at a certain date and time
- Identifying potential sources for driver inattention
- Identifying the contacts and potential networks for individuals under investigation
- Identifying door open and close events to determine if someone had entered or exited a particular vehicle at a specific date and time

Acquiring Data from a Vehicle's Infotainment and Telematics System

This paper presents data that was acquired from the OEM installed infotainment and telematics systems. This data was acquired using the ***iVe*** hardware and software system created by the Berla Corporation of Annapolis, Maryland. In contrast to the EDR functionality of airbag control modules, powertrain control modules and rollover sensors, acquiring data from the infotainment and telematics systems is not authorized by any vehicle manufacturer. The ***iVe*** system was developed by digital forensic and cyber security experts who recognized that certain data elements are being recorded within certain vehicles and developed a method to extract and preserve the data.

According to the ***iVe*** user's manual [14]:

*"**iVe** is a vehicle system forensic tool that acquires user data from vehicles and allows forensic examiners and investigators a means to quickly and intuitively analyze it. Vehicle Infotainment systems store a vast amount of user related data such as recent destinations, favorite locations, call logs, contact lists, SMS messages, emails, pictures, videos, and the navigation history of everywhere the vehicle has been."*

The methods described in this paper were the culmination of Berla ***iVe*** system "Vehicle Systems Forensics" certification training associated with version 1.8 of the software (October 2015) [15]. The data acquisitions presented in this paper were performed using software versions 1.7.1 [14], 1.8.4 [16] and 1.9.2 [17] of the ***iVe*** software. References were made to the user's manuals for those versions of the software.

Data Acquisition Methods

There are two general processes for acquiring infotainment and telematics data: the 'physical' acquisition method and the 'logical' acquisition method. The physical acquisition method is intrusive and requires a significant amount of time and effort. This method requires physically removing the module in question, which is often installed within the dash of the vehicle. Once the module is removed from the vehicle, the cover of the module is removed. Next, the circuit board is removed from the module and various device interface boards are affixed to the circuit board from the module to perform the acquisition. A sample of the physical acquisition method is shown in Figure 1.

Figure 1. Sample Physical Acquisition2016 Ford Explorer: Ford Sync, Generation 2 Module

The logical acquisition method is substantially more straightforward than the physical acquisition method. Generally, the logical acquisition method simply requires inserting a series of wires and adapters into the existing USB ports in the center console or glovebox, or the OBDII port in the dash. A sample of the logical acquisition method is shown in Figure 2.

Figure 2. Sample Logical Acquisition2013 BMW X3: BMW Car Information Computer (CIC) Module

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For this study, seven vehicles were examined. Both the logical and physical data acquisition methods were utilized. The following vehicles were examined:

1. 2013 BMW X3
    - Car Information Computer (CIC)
    - Logical Acquisition
2. 2014 Dodge Durango
    - Uconnect 8.4A/8.4N
    - Logical Acquisition
3. 2013 Ford F-150
    - Ford Sync, Generation 1
    - Physical Acquisition
4. 2016 Ford Explorer
    - MyFord Touch, Ford Sync, Generation 2
    - Physical Acquisition
5. 2015 Ford F-350
    - MyFord Touch, Ford Sync, Generation 2
    - Physical Acquisition
6. 2014 GMC Sierra
    - OnStar, Generation 9
    - Physical Acquisition
7. 2015 GMC Canyon
    - OnStar, Generation 10 with GM Human Machine Interface (HMI)
    - Physical Acquisition

The specific procedure for each vehicle, organized by vehicle make, are provided in Appendices A, B, C and D. The remainder of this paper will focus on the data obtained during the examination, testing and analysis of the 2015 Ford F-350.

Case Study

Based on the amount recordable data, a 2015 model year Ford F-350 Super Duty 4x4 pickup was selected for a case study. The test pickup was configured with a crew cab, single rear-wheels and an eight-foot bed. The pickup was equipped with the Lariat trim package and the MyFord Touch infotainment system. This system was operated by the Generation 2 Ford Sync module. The Ford pickup is shown in Figure 3 and the vehicle specifications are listed in

Figure 3. 2015 Ford F-350: MyFord Touch, Ford Sync – Generation 2

Table 1. Case Study Vehicle: Ford F-350 Specifications

Model Year:	**2015**
Make:	**Ford**
Model:	**F-350, Super Duty**
Trim:	**Lariat**
Options:	**Crew cab, Styleside, Long Bed (8 ft.), Single Rear-Wheel, 4x4**
VIN:	**1FT8W3BT6FE********
Module:	**MyFord Touch, Ford Sync - Generation 2**

The Human Machine Interface (HMI) between the vehicle occupants and the MyFord Touch infotainment system consists of a touchscreen display in the center console. This interface is shown in Figure 4.

Figure 4. 2015 Ford F-350: MyFord Touch – Ford Sync, Generation 2 Module

Test Procedure

Testing for this case study was conducted on the morning of October 1, 2016, in the Mountain Daylight time zone. The ability of the vehicle's infotainment and telematics system to record the following data elements were examined:

- Door open/close events
- Gear shift events
- Parking light on/off events
- Telephone calls
- Short message service (SMS)
- Vehicle tracklogs

For this case study, the data acquisition for this vehicle was performed twice: initially as a baseline and once again after the testing. The testing was recorded using a camera mounted to the rear window inside the vehicle and a camera placed on a tripod with a view of the exterior of the vehicle. In order to analyze the events data accurately, the time and date stamps included in each data set downloaded from the Ford module were matched up to the time and date of the testing using the video recorded during the testing. Figure 5 shows the cameras used during the vehicle testing.

To test the vehicle tracklogs, a case study consisting of five routes were driven. The routes chosen for this case study closely resembled normal day-to-day driving conditions in which the vehicle was driven on a combination of interstate highway and surface streets.

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Figure 5. Video Cameras Used During Testing

For the dynamic vehicle tracklog testing, two independent instrumentation devices were used during the testing of the vehicle's navigation system. A Racelogic VBOX Sport and an iPhone running the Harry's Lap Timer application were mounted at to the front windshield of the test vehicle near the centerline. The Racelogic VBOX Sport is a GPS-based device that operates at 20 HZ with a stated accuracy of 0.1 km/h (0.06 mph) for velocity and 0.5% for acceleration data. Harry's Lap Timer is a commercially available iOS and Android data logging application featuring integrated video, GPS location, speed, acceleration and timing. For this testing, the application used an external GPS sensor collecting data at approximately 10 HZ. Figure 6 shows the mounting of the instrumentation and close-up views of the VBOX Sport (bottom left) and Harry's Lap Timer (bottom right).

Figure 6. Instrumentation Setup During Tracklog Testing

Test Vehicle Data Acquisition Procedure: Baseline and Post-Test Acquisitions

The data from the test vehicle's Ford Sync module was imaged using the physical acquisition method. The physical acquisition for the Ford F-350 required the removal of various vents, controls and trim pieces from the center dash in order to access the Ford Sync module. Figure 7 contains photographs documenting this process.

Figure 7. Physical Data Acquisition from the Ford F-350, Part 1

Once the module was removed from the vehicle, the main circuit board was removed from its housing. Next, the hardware acquisition kit was assembled and connected to the computer running the data acquisition software. Figure 8 contains photographs documenting this process.

After connecting the assembly to the computer, the data acquisition from the Ford Sync module was performed. The data download required approximately 4-1/4 hours to complete. The data that can be acquired from the test vehicle's Ford Sync Generation 2 module may include:

- Mobile telephone: Bluetooth and Wi-Fi connections, with the unique identifier for the connected cellular telephone
- Contact list from the cellular telephone
- Call logs from the cellular telephone while connected to the vehicle

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- Short Message Service (SMS) messages from the cellular telephone while connected to the vehicle
- Media files from the cellular telephone
- Mass storage device connections, with the unique identifier for the device
- Media files from the embedded device
- Vehicle Bluetooth connection events
- Vehicle odometer readings
- Vehicle door open/close events
- Vehicle gear shift events
- Vehicle light status (on/off) events
- Vehicle system updates
- Vehicle time updates
- Device USB connections and Wi-Fi connections
- Navigation System: Any user saved ‘Locations’
- Navigation System: Tracklogs
- System metadata

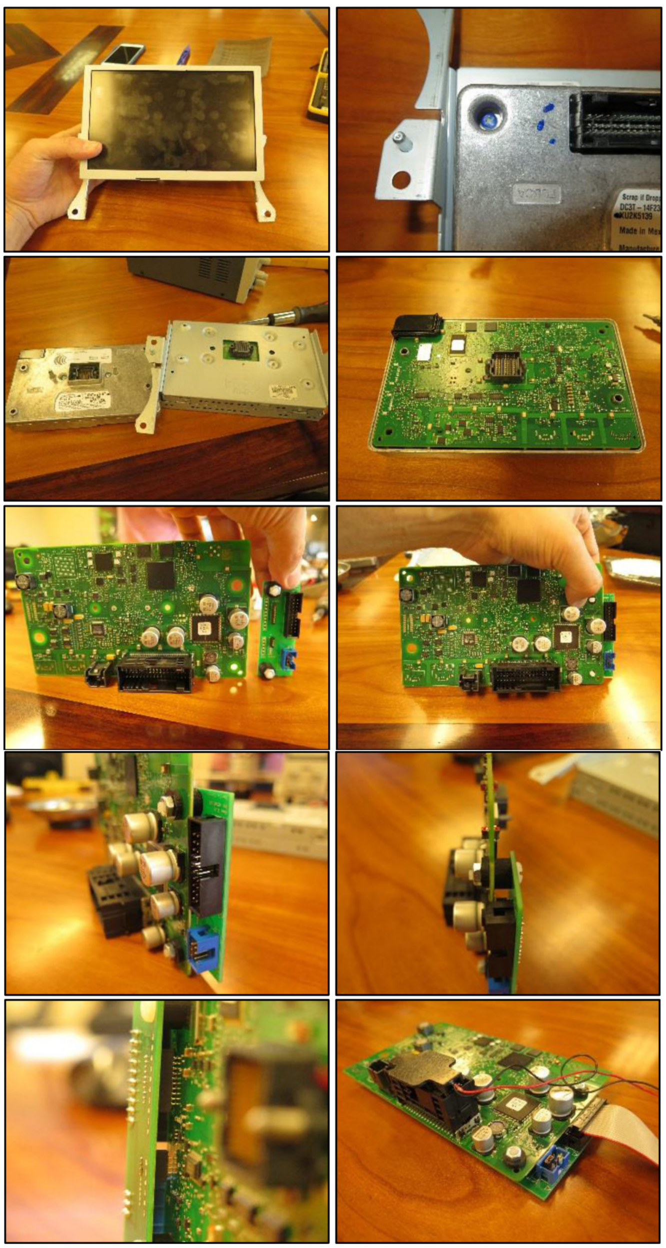

Figure 8. Physical Data Acquisition from the Ford F-350, Part 2

Acquired Data Review: Reinstallation of the Module and Power Loss Events

After the initial baseline acquisition was performed, the module was reinstalled in the vehicle prior to testing. The module experienced a loss of electrical power because it had been removed from the vehicle for an extended period of time. As a result, there was a period of time when the module was reinstalled in the vehicle before the system automatically updated to the correct date and time. During this period of time before the automatic time update, the system reverted to just after midnight on the first day of this decade (00:00 on 01/01/2010). After the automatic time update, the vehicle reset itself to the correct date and time in the appropriate local time zone. The module is capable of recording vehicle system updates, including power loss events, under the heading of *Reboot Events*. In this instance, the vehicle recorded a *Reboot Event*. At the time of the power loss, the module recorded the date, time, and GPS location of the power loss.

Acquired Data Review: Door Events

The Ford Sync Generation 2 module recorded door open and close events. These door events recorded an identifier that stated if a passenger or driver door was opened or closed, the action of the door, date/time and a GPS location of the event. Door testing was performed in various power configurations: key out of ignition, key in the ignition, key turned to the on position with the engine off, key turned to the auxiliary position with the engine off, and key in the on position with the engine running. For each power configuration, a door opening and closing cycle was performed. The cycle consisted of the following procedure:

- Each door was opened
- Door left open for approximately five seconds
- Door closed

It was observed that the module would record door events regardless of the key position and engine status, but the module did not record all of the events. A total of 98 recorded door events were retrieved from the data acquisition. During the door testing, the doors were opened a total of 38 times. Of the 38 times the doors were opened during testing, 16 of those events were recorded. The system did not record rear door open or close events on either side of the vehicle. There was one door event recorded by the module that did not match the test documentation or procedure. The time stamps associated with recorded door events were accurate within the appropriate local time zone.

Acquired Data Review: Gear Shift Events

Gear shift events was another data element that was recorded by the Ford module. Similar to the door events, the module recorded the event type, identifier, action, date/time and GPS location of the event. To test the gear shift events, a consistent gear shift procedure was performed. This procedure consisted of:

- Test vehicle was started and idled for approximately 1 minute
- Test vehicle placed in a forward gear and driven forward for approximately 5 seconds
- Test vehicle was then stopped, placed into reverse and moved backwards to the original starting position, stopped and placed into park

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The test vehicle's transmission consisted of four forward gears: first, second, manual mode, and drive. This procedure was repeated in each of the test vehicle's forward gear options. After all the forward gears were tested and the vehicle was reversed to the starting point and placed in park, it was shifted into neutral and idled for approximately 10 seconds. During this testing, 30 total gear shift events were performed.

There were a total of 55 gear shift events recorded by the module and retrieved from the data acquisition. These 55 events consisted of events recorded prior to the day of the testing and from the day of the testing. Of the 30 gear shifts performed, 17 events were successfully recorded. There was one recorded anomaly in the data where the event recorder did not give a gear selection, but instead recorded "*GearShift to ?7*". It was observed that if the gear shifts were made quickly the module did not record the gears that were passed through, but correctly recorded the beginning and end shift positions. For example, when shifting quickly from park to drive, both reverse and neutral are passed but were not recorded in the gear shift events. If the gear shift was made more slowly, then the gears that were passed through were correctly recorded. From the testing performed, if the module recorded data pertaining to gear shift events, that data was accurate and reliable. The time stamp that was recorded with each gear shift event was accurate within the appropriate local time zone.

Acquired Data Review: Parking Light Events

Parking light activity was another data element that can be recorded by the Ford module. For this testing, the parking lights were activated using the key fob or the physical light switch inside the vehicle. When lock or unlock is pressed on the key fob, the test vehicle parking lights turn on and remain on for a set period of time depending on if lock or unlock was pressed. The physical light switch can be set to off, parking lights, on or automatic. To test the ability of the module to record parking light events, lock and unlock was pressed on the key fob and the physical light switched was cycled through the available positions with the ignition in various positions.

A total of 146 parking light events were recorded and retrieved from the data acquisition. The lights were turned on and off 19 times (a total of 38 events) during testing. From the specific testing performed, the module did not record any parking light events associated with the key fob or physical light switch tests. However, parking light events were recorded by the module during the door open/close testing. Of the 38 door open/close events, 17 parking light events were recorded. Parking light events were recorded when any of the doors opened, not just the front doors. The parking light events that were recorded by the module were recorded at the correct local time zone.

Acquired Data Review: Telephone Call Events/Call Log Entries

The Ford module has the ability to record incoming and outgoing mobile telephone calls while a telephone is connected to the vehicle. To test this aspect of the module, a test telephone was synced to the system. Outgoing and incoming calls were placed using the physical telephone and the in-vehicle infotainment system. When a telephone is synced to the system, the system records the telephone under attached devices and logs the phone's unique ID number. The testing procedure for telephone call events consisted of first placing calls using the telephone directly, with the outgoing calls being answered, not answered, and ignored. Calls were then received by the telephone that were answered, not answered (went to voicemail), and ignored. The same process was performed using the hands-free in-vehicle system (controls on the steering wheel) to place and receive calls.

Telephone calls are recorded and can be reported by the ***iVe*** system under two headings: 'Phonecall Events' and 'Call Log Entries.' The data acquired from the module disclosed that none of the twelve calls, regardless of the source, physical telephone or in-vehicle system, were recorded by the module as phonecall events. Three of the test calls made during the testing were recorded as call log entries. These three calls consisted of two incoming calls, both answered using the in-vehicle steering wheel controls, and one outgoing call placed by the mobile phone. In addition to the three test calls that were successfully recorded, the data acquisition contained numerous calls that were made prior to testing. The authors of this study spoke to the owner of the vehicle and confirmed the veracity of the telephone call events that were recorded by the vehicle. The owner of the vehicle confirmed that the recorded calls that occurred prior to testing were recorded in the telephone call events log at the same time as the matching call from call log within the owner's actual mobile telephone. It was determined that not all calls made or received are recorded. The telephone call events that were recorded by the module were recorded accurately in the Coordinated Universal Time (UTC) time zone.

Acquired Data Review: Short Message Service (SMS

The ability of the module to record SMS messages, or text messages, was also tested. The system was tested by sending outgoing text messages and receiving incoming text messages with the vehicle running and with the engine off while the key was in the on position. The data acquired from the module after testing revealed that only incoming text messages were recorded by the module; none of the sent messages, regardless of the ignition or engine status, were recorded in the module. There were also two inadvertent text messages sent by parties unaware of the testing that were received and successfully recorded by the module. Any predefined or "canned" messages that are programmed into the telephone will be recorded, regardless of whether or not those messages were actually sent. Examples of canned messages include, "I'll call you back in a few minutes," "I just left, I'll be there soon," and "Can you give me a call?" The data elements included in the acquirable SMS data include the date and time of the message, name of contact, message contents, read status and the device identifier. The SMS events that were recorded by the module were recorded accurately in the UTC time zone.

Acquired Data Review: Vehicle Tracklogs

The tracklogs recorded by the Ford module contain data elements for time, date, GPS longitude and latitude coordinates, distances and bearing at a rate of approximately once per second (1 Hz). For the tracklog testing, the vehicle was driven on five routes with and without the assistance from the test vehicle's GPS navigation system. The tracklog testing performed included driving while adhering to the GPS navigated suggested route from the MyFord system, driving but deviating from the suggested navigated guided route and driving a route with no GPS navigation at all. These test runs were performed while driving on mixed use business streets, residential side streets and interstate highways. The GPS tracklogs obtained from the Ford

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Module were compared to independent instrumentation in order to analyze the location of the vehicle and calculate vehicle speed. Table 2 contains a summary of the five routes driven during the case study.

Table 2. Case Study: Summary of Routes

Route	GPS Navigation System Status	Tracklog Recorded?
Route 1: Generally Southbound Interstate and Surface Streets	Activated	No
Route 2: Generally Westbound Surface Streets	Activated	No
Route 3: Generally Westbound Surface Streets	Activated	No
Route 4: Generally Northbound Surface Streets	Activated	No
Route 5: Round Trip Interstate and Surface Streets	Not Activated	Partially: Final Portion of Route

During the entirety of the vehicle testing (door events, phone call events, etc.) multiple tracklogs were recorded by the Ford module. Some of the tracklogs showed the vehicle stationary, which occurred during the door, light and phone testing. Another tracklog was recorded during the gear shift testing and multiple tracklogs were recorded consisting of events prior to any testing. The Ford module only recorded one of the five driven routes performed during the designated tracklog testing portion of the case study. This recorded tracklog contained data from only a portion of the fifth and final route. This route was driven without GPS navigation. The total length of this round-trip route was 5.5 miles, but the module only recorded tracklog data during the last half of the route. The tracklog data was recorded by the module in predominantly one second intervals with a few data points recorded at longer intervals. A sample of the data from the module during tracklog test run five is shown in Figure 9.

TRACK: RECOVERED0121

6503	10/1/2016 11:00:35 AM	39.62416	-104.89254		
6504	10/1/2016 11:00:36 AM	39.62416	-104.89276	39.37 m	180°
6505	10/1/2016 11:00:37 AM	39.62416	-104.89298	39.37 m	180°
6506	10/1/2016 11:00:38 AM	39.62416	-104.8932	39.37 m	180°
6507	10/1/2016 11:00:39 AM	39.62416	-104.89342	39.37 m	180°
6508	10/1/2016 11:00:41 AM	39.62416	-104.89384	75.16 m	180°

Figure 9. Sample Tracklog from iVe Report

As seen in Figure 9, the GPS latitude and longitude coordinates are recorded in degree-seconds at a resolution of 1/100000 of a degree. At first glance this seems to be very precise data, but the resolution in latitude and longitude translates to a potential positional error of approximately 3.5 feet.

GPS Data Location Analysis

Data collected by the test vehicle and the VBOX sport instrumentation during tracklog test route five was downloaded and analyzed using Google Earth software. Data was captured over an approximately 2.5-mile path that consisted of both arterial roadway and freeway driving. The beginning and end of route five is shown in Figure 10, as well as the location where the vehicle tracklog began to record data.

Figure 10. Case Study: Route 5

Figure 11 shows the tracklog data acquired from the vehicle as well as the VBOX Sport data pertaining to the fifth route from the case study overlaid onto the overall route map. For the figures that follow, the yellow line represents data from the VBOX Sport while the red line represents the tracklog data acquired from the vehicle as recorded by the vehicle's module.

Figure 11. Case Study: Vehicle Tracklog Data Versus VBOX Sport Data

Analysis of this data showed that the accuracy and reliability of both the VBOX and Ford Sync tracklog data was within the range of accuracy described in previous literature. The positional accuracy of the tracklog data acquired from the vehicle is well within the 15-meter (49.2 feet) range found in aftermarket GPS devices described by Bortolin [7]. Review of the data collected showed that the tracklog data generally positioned the vehicle in the area of its appropriate lane of travel. The results of this case study are consistent with the 3.5 to 7.5-foot range of potential error described by Reust [5].

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As described by Komatsu, et al., underpasses, trees and other large structures have been known to block or reduce GPS signals and negatively affect accuracy [9]. During the case study, the vehicle crossed under an overpass just prior to the vehicle turning onto the freeway, as seen in Figure 12. During this sequence, the test vehicle crossed through an intersection prior to the underpass and subsequently changed lanes into the leftmost turn lane before traveling under the underpass. Both the vehicle tracklog data and the VBOX data accurately showed the lane change just prior to the underpass, but only the vehicle tracklog data correctly showed the test vehicle's travel path as it traveled beneath the underpass. Figure 13 shows the tracklog data and VBOX data in the area of this underpass.

Figure 12. Case Study: Test Vehicle Approaching Underpass

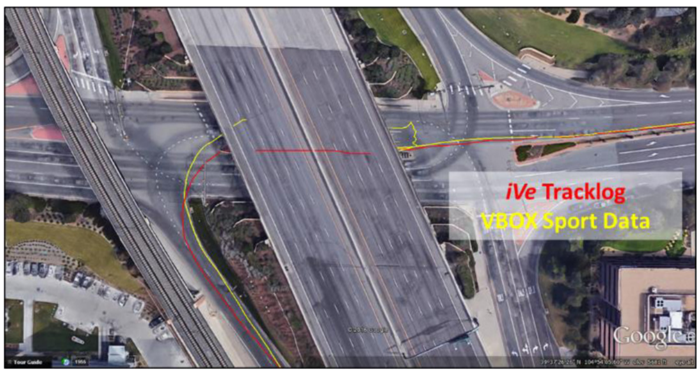

Figure 13. Vehicle Tracklog and VBOX Data in Area of Underpass

After merging onto the freeway, the test vehicle traveled for approximately one mile before exiting the freeway. During this one-mile stretch, the test vehicle was driven in an approximate straight line in the furthest travel lane to the right for the entire sequence. During this sequence, the test vehicle was accelerated to highway speeds, maintained highway speed with the flow of traffic, decelerated, then exited the freeway. Figure 14 shows the vehicle as it was being driven during this portion of the case study, as well as the travel paths derived from the recorded GPS data for the vehicle tracklog and VBOX Sport.

During this entire straight-line sequence on the freeway both the vehicle tracklog and VBOX data properly located the test vehicle in its correct lane of travel. It should be noted, however, that the vehicle travel paths do not depict the straight-line path down the center of the lane that the test vehicle traveled during the testing. Analysis of the specific travel paths during this sequence show that the vehicle tracklog and VBOX data deviated laterally from one another on average approximately 2 feet with a standard deviation of 1.4 feet. Figure 15 shows the entire travel paths during the straight-line sequence of freeway driving.

Figure 14. Comparison of Testing to GPS Data Vehicle Paths

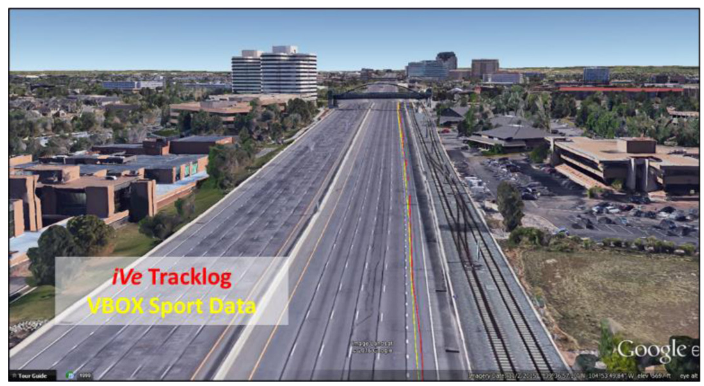

Figure 15. Vehicle Travel Paths During Straight-line Freeway Testing

Towards the end of the fifth route of the case study, the test vehicle performed a few sweeping turns on an arterial roadway. One of these turns was performed on a slightly downhill section of roadway, as seen in Figure 16.

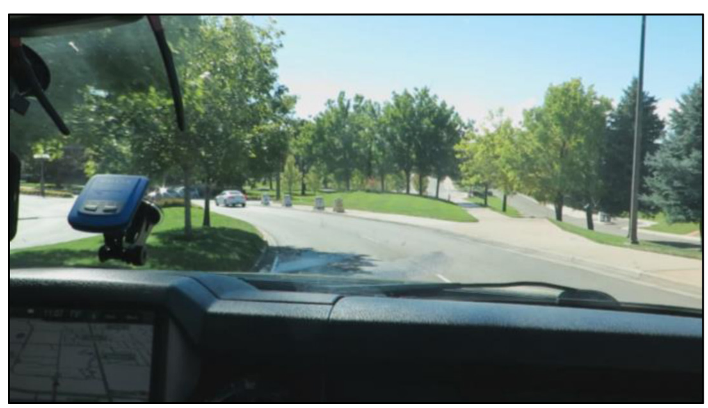

Figure 16. Case Study – Downhill Sweeping Left-Hand Turn

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During this turn sequence, maximum lateral deviations of approximately six to seven feet between both the vehicle tracklog and VBOX data were observed. As seen in Figure 17, the VBOX data tended to place the location of the vehicle near the center lane line of the roadway while the vehicle tracklog data tended to place the location of the vehicle near the inside curb.

Figure 17. Lateral Deviation During Left-Hand Turn

GPS Data Speed Analysis

The speed of the vehicle during the case study was analyzed by comparing the vehicle speed calculated from vehicle tracklog data with the speed reported by the VBOX Sport and Harry's Lap Timer application. GPS latitude, longitude and time steps recorded in the tracklog were used to calculate the speed of the vehicle based on the GPS positional data [18]. This method utilizes the angular latitude and longitude data along with the measurement of the radius of the Earth to determine the distance between any two points along the surface of the Earth:

$$D = Rc \tag{1}$$

Where:

$$D = The\ distance\ between\ to\ GPS\ points$$

$$R = the\ Radius\ of\ the\ Earth$$

$$c = 2\ x\ atan2(\sqrt{a}, \sqrt{1-a}) \tag{2}$$

$$a = sin^2\left(\frac{lat_2 - lat_1}{2}\right) + \cos(lat_1)\cos(lat_2)sin^2\left(\frac{long_2 - long_1}{2}\right) \tag{3}$$

The speed calculated from the raw vehicle tracklog data has been plotted along with the speed reported by the VBOX Sport instrument and Harry's Lap Timer application in Figure 18.

As seen in Figure 18, the raw tracklog data contains potentially anomalous data resulting in spikes and drops in the calculated vehicle speed. Improved results were seen when the spikes and drops were reduced from the data by utilizing a 6-point center moving average filtering routine, as shown in Figure 19.

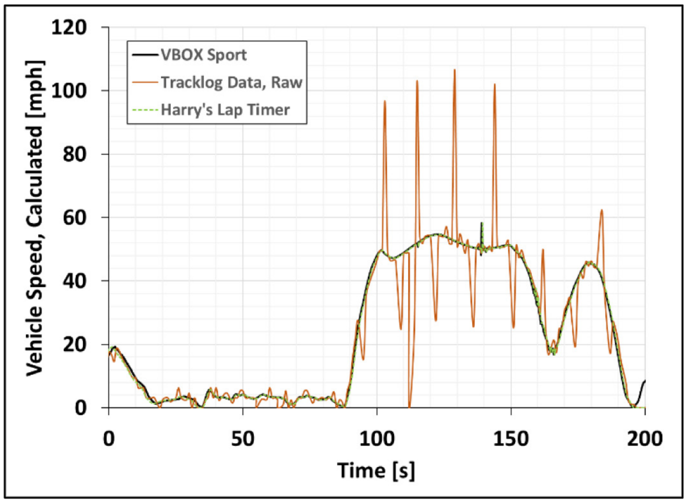

Figure 18. Speed Calculated from Raw Vehicle Tracklog Data with Speed from VBOX Sport and Harry's Lap Timer

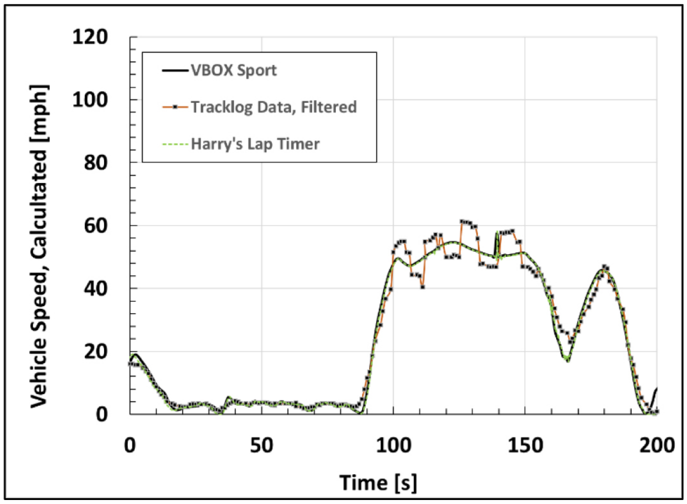

Figure 19. Filtered Vehicle Speed from Tracklog Data with Speed from VBOX Sport and Harry's Lap Timer

As seen in Figure 19, the filtered tracklog data can provide insight into the general driving patterns of the vehicle. At low speeds and during modest acceleration and deceleration, the tracklog data appears to accurately record the motion of the vehicle. However, at high speeds, the speed calculated by the tracklog data may contain anomalous spikes or drops in the calculated vehicle speed. These spikes or drops in vehicle speed were shown to produce overestimations as high as 8.9 mph (at t = 166 sec, VBOX Sport calculated speed is 16.84 mph, tracklog calculated speed 25.77 mph) or underestimates as much as 10.8 mph (at t = 139 sec, VBOX Sport calculated speed is 57.55 mph, tracklog calculated speed 46.75 mph). On average, the error of the filtered vehicle calculated speed was less than 1 mph when compared to the VBOX sport and Harry's Lap Timer.

Based on the limitations of the data sampling rate, GPS coordinate precision and inherent error, vehicle speeds calculated from tracklog data may be insufficient to accurately determine the instantaneous speed of a vehicle, especially during a rapidly dynamic event (i.e. aggressive pre-impact braking). However, the tracklog data can be valuable to quantify the general motion of the vehicle over long periods of driving.

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Summary

The data presented in this paper represents the results, observations and analysis of a single case study involving only one vehicle. This case study may not replicate the entire population of vehicles equipped with infotainment and telematics modules with retrievable data. The findings of this case study indicate that not every vehicle event, telephone event or tracklog is recorded. There appear to be limits to the amount of data that can be recorded by the vehicle. The circumstances surrounding why a particular event might be recorded and why another similar event may not be recorded at a different time require further investigation. However, this case study has shown that if the infotainment and telematics system has recorded a particular data element, that data element is expected to be reliable.

The tracklogs recorded by the vehicle can accurately record the general motion and speed of the vehicle. However, the tracklog data does not contain the precision or accuracy to pinpoint small path deviations and may imply drifts within a lane of travel that did not occur. Overall, on average the filtered calculated vehicle speed for this case study was accurate within 1 mph, but could contain anomalous spikes or drops in the calculated vehicle speed.

Recommendations for Future Work

Further research should be completed to further validate the GPS tracklog data from a wider sample of vehicles. This testing should be done on a closed course, under a variety of vehicle operational conditions using differential GPS instrumentation.

Further testing should also investigate the extent to which the act of syncing a device to a vehicle transfers data, specifically Call Logs and SMS Messages, from the device to the vehicle. It is possible that telephone calls and SMS messages can occur while the device is outside of the vehicle, but transferred recorded by the module in the vehicle after the device was synced.

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APPENDIX

APPENDIX A – BMW DATA ACQUISITION METHODS

CONNECTEDDRIVE: CAR INFORMATION COMPUTER MODULE (CIC

BMW offers three separate modules for the infotainment systems in their vehicles depending on the model and options: Car Communication Computer (CCC), Car Information Computer (CIC) and the Next Big Thing (NBT). Currently, only vehicles equipped with the CIC system in select model year 2008 and newer vehicles is supported by the ***iVe*** data acquisition system.

A 2013 model year BMW X3 was examined. This vehicle is equipped with the xDrive28i option package and the BMW ConnectedDrive infotainment system, operated by the Car Information Computer (CIC) module. The vehicle is shown in Figure 20 and the vehicle specifications are listed in Table 3.

Figure 20. 2013 BMW X3: BMW Car Information Computer (CIC) Module

Table 3. BMW Specifications

Model Year:	**2013**
Make:	**BMW**
Model:	**X3**
Package:	**xDrive28i**
Options:	**AWD, 4-Door SUV**
VIN:	**5UXWX9C55D0********
Module:	**BMW Car Information Center (CIC)**

The Human Machine Interface (HMI) between the vehicle occupants and the BMW ConnectedDrive infotainment system consists of a display in the dash with controls in the console near the shifter. This interface is shown in Figure 21.

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Figure 21. BMW ConnectedDrive Interface

The data acquisition for the BMW CIC module is relatively straightforward. A personal computer running the acquisition software is connected to the main USB port, which is located in the glovebox of the vehicle, using a series of Ethernet cables. This type of connection method is referred to as a ‘logical’ acquisition. Figure 22 contains photographs of this logical acquisition method using USB cables. Once connected, the data acquisition takes approximately 10 minutes to complete.

Figure 22. Logical Data Acquisition from the BMW X3 using USB Port

Data acquisitions from BMW vehicles can also be performed using a cable kit that accesses the On-Board Diagnostic (OBD) port from the vehicle. Figure 23 contains photographs depicting this logical acquisition method using the OBD port.

Figure 23. Logical Data Acquisition from the BMW X3 using OBD Port

Once connected, the data that can be acquired from BMW vehicles with the CIC module may include:

- Mobile telephone: Bluetooth connections, with the unique identifier for the connected cellular telephone
- Contact list from the cellular telephone
- Mass storage device connections, with the unique identifier for the device
- Media files from the embedded device
- Contact list from embedded device
- Vehicle odometer readings
- Navigation System: Any user saved ‘Locations’ or ‘Routes’
- System metadata

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APPENDIX B – FIAT CHRYSLER DATA ACQUISITION METHODS

UCONNECT® 8.4 & 8.4N, 8.4A/8.4N, AND 6.5 SYSTEMS

Fiat Chrysler (FCA) vehicles branded under the Dodge, RAM, Jeep, Chrysler, Fiat, SRT, Lancia, Alfa Romeo, Maserati and Ferrari makes may be supported by the ***iVe*** data acquisition system for select vehicles from model year 2011 to 2013. It should be noted that due to security concerns surrounding cyber-attacks on some Jeep vehicles, FCA released a software update in 2014 that prevents access to the data from select 2014 model year FCA vehicles. At the time of this paper, model year 2015 and 2016 FCA vehicles are not supported by the data acquisition software.

A 2014 model year Dodge Durango was examined. This vehicle is equipped with the Limited trim package and the Chrysler Uconnect 8.4A/8.4N infotainment system. The vehicle is shown in Figure 24 and the specifications of the vehicle are listed in Table 4.

Figure 24. 2014 Dodge Durango: Chrysler Uconnect 8.4A/8.4N Module

Table 4. Dodge Specifications

Model Year:	**2014**
Make:	**Dodge**
Model:	**Durango**
Package:	**Limited**
Options:	**AWD, 4-Door SUV**
VIN:	**1C4RDJDGXEC*********
Module:	**Uconnect 8.4A/8.4N**

The HMI between the vehicle occupants and the Dodge Uconnect infotainment system consists of a touchscreen control in the center of the dash. Figure 25 contains photographs of this interface.

Figure 25. Dodge Uconnect Interface

Similar to the BMW, the data acquisition for the Chrysler Uconnect is performed by the 'logical' acquisition method. A personal computer running the acquisition software is connected to the main USB port, which is located in the center console of the vehicle, using a series of Ethernet cables. Figure 26 contains photographs depicting this logical acquisition method using the USB port. Once connected, the data acquisition takes approximately 10 minutes to complete.

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Figure 26. Logical Data Acquisition from the Dodge Durango

Once connected, the data that can be acquired from Fiat Chrysler vehicles with the 8.4A/8.4AN module may include:

- Mobile telephone: Bluetooth and Wi-Fi connections, with the unique identifier for the connected cellular telephone
- Contact list from the cellular telephone
- Call logs from the cellular telephone while connected to the vehicle
- Short Message Service (SMS) messages from the cellular telephone while connected to the vehicle
- Mass storage device connections, with the unique identifier for the device
- Media files from the embedded device
- Vehicle odometer readings
- Device connections and Wi-Fi connections
- Navigation System: Any user saved ‘Locations’ or ‘Routes’
- Navigation System: Tracklogs
- System metadata

APPENDIX C – FORD DATA ACQUISITIONS METHODS

Ford vehicles branded under the Ford, Lincoln and Mercury makes may be supported by the data acquisition system for select vehicles from model year 2008 and newer. The specific modules within Ford vehicles that are supported include:

- Generic Radio Interface with Sync (Sync, Generation 1)
- Touch Screen Radio Interface with Sync (Sync, Generation 2)
- Ford Navigation Radio (Generation 2)

FORD SYNC, GENERATION 1 MODULE

A 2013 model year Ford F-150 4x4 pickup was examined. This pickup was configured with a SuperCrew cab and a five-and-a-half-foot bed. The pickup was equipped with the XLT trim option package and the Ford Sync infotainment system, operated by the Ford Sync, Generation 1, Version 3 module. The Ford pickup is shown in Figure 27 and the vehicle specifications are listed in Table 5.

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Figure 27. 2013 Ford F-150: Ford Sync, Generation 1 Module

Table 5. Ford F-150 Specifications

Model Year:	**2013**
Make:	**Ford**
Model:	**F-150**
Trim:	**XLT**
Options:	**SuperCrew, Styleside, Short Bed (5.5 ft.), 4x4**
VIN:	**1FTFW1EF8DK********
Module:	**Ford Sync, Generation 1**

The HMI between the vehicle occupants and the Ford Sync infotainment system of this F-150 consists of a screen and a series of push-buttons in the dash. This interface is shown in Figure 28.

Figure 28. 2013 Ford F-150: Ford Sync Interface

Unlike the logical acquisition method found in the BMW and Fiat Chrysler vehicles, the data acquisition method required for the Ford vehicles is more labor intensive. For the 2013 Ford F-150, the data acquisition procedure required physically extracting the Sync module from the dash of the vehicle. This method is referred to as the 'physical' acquisition method. The photographs in Figure 29 show this process. As seen in Figure 29, the Sync module is accessible by removing a tray on the dashboard of the vehicle. This tray is secured by tabs to the dashboard of the vehicle and is passively covered by a rubber mat. With the mat removed, the tray can be removed from the dashboard by removing two 7-mm machine screws. Once the tray has been removed from the dashboard, the Ford Sync module can be removed from the vehicle by removing two additional 7-mm machine screws and disconnecting the existing cables.

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Figure 29. Physical Data Acquisition from the Ford F-150, Part 1

With the Ford Sync module removed from the vehicle, it is necessary to remove the printed circuit board from the module. With the printed circuit board removed from the module, a pair of smaller device interface boards, which are part of the data acquisition hardware package, are attached above and below the main circuit board from the module. These device interface boards contain spring loaded pogo pins that protrude from the device interface boards to make contact with the pads on the main circuit board. The two device interface boards are attached to the main board using nuts, bolts and nylon spacers. Once the two device interface boards are attached to the main board, 12.0 volts of direct current are supplied to the device interface boards using an external power supply. In addition to the two device interface boards, the data acquisition hardware kit contains a series of ribbon cables, adapters and a USB cable that are used to connect the circuit board assembly to a computer running the data acquisition software. Figure 30 contains a series of photographs depicting the removal of the main circuit board from the module and the connection method.

It should be noted that precise alignment of the spring loaded pogo pins between the data acquisition hardware and the pads of the circuit board is required to achieve a successful connection and data acquisition. This requires a considerable amount of patience and attention. The authors of this study found that over or under torqueing of the nuts from the acquisition hardware can induce small amounts of rotation that may influence the alignment (or misalignment) between the pogo pins and the pads on the circuit board.

Once connected, the data acquisition from the Ford Sync, Generation 1 module takes approximately 12-1/2 hours to complete. The data that can be acquired from the Ford Sync Generation 1 module may include:

- Mobile telephone: Bluetooth connections, with the unique identifier for the connected cellular telephone
- Contact list from the cellular telephone
- Call logs from the cellular telephone while connected to the vehicle
- Vehicle odometer readings
- Vehicle power readings
- System metadata

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Figure 30. Physical Data Acquisition from the Ford F-150: Ford Sync, Generation 1 Module

MYFORD TOUCH - FORD SYNC, GENERATION 2 MODULE

A 2016 model year Ford Explorer was examined. This 4-door SUV was equipped with four-wheel drive, the Limited trim package and the MyFord Touch infotainment system, operated by the Ford Sync, Generation 2 module. The Ford Explorer is shown in Figure 31 and the vehicle specifications are listed in Table 6.

Figure 31. 2016 Ford Explorer: Ford Sync, Generation 2 Module

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Table 6. Ford Explorer Specifications

Model Year:	**2016**
Make:	**Ford**
Model:	**Explorer**
Trim:	**Limited**
Options:	**4WD, 4-Door SUV**
VIN:	**1FM5K8F87GG********
Module:	**MyFord Touch, Ford Sync - Generation 2**

The HMI between the vehicle occupants and the MyFord Touch infotainment system consists of a touchscreen display in the dash. This interface is shown in Figure 32.

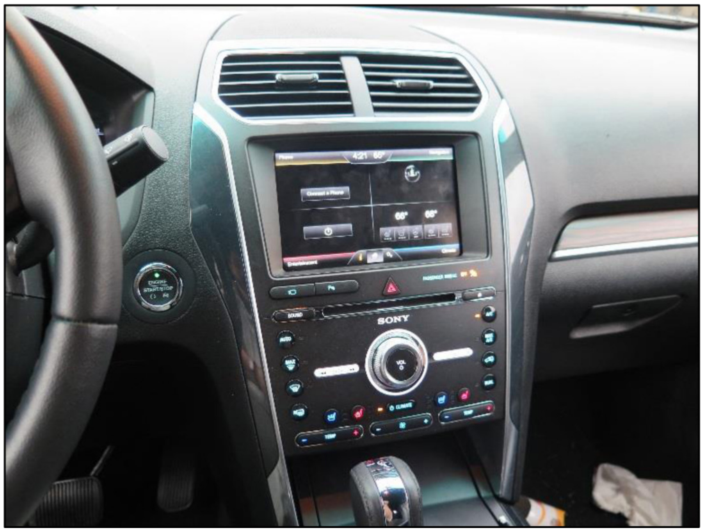

Figure 32. 2016 Ford Explorer: MyFord Touch, Sync Generation 2 Module

Like the Ford Sync Generation 1 module found in the 2013 Ford F-150, the module from the 2016 Ford Explorer requires the "physical" acquisition method. This requires physically extracting the Sync Generation 2 module from the dash of the vehicle. The photographs in Figure 33 show this process. As seen in Figure 33, the Sync module is accessible by first removing a speaker on the top of the dashboard of the vehicle using nylon pry tools. Once the speaker is removed, the trim pieces and vents in the dash can be removed from the center console. Once the trim pieces and vents have been removed from the dashboard, the touch-screen display and module can be removed from the vehicle by removing machine screws and disconnecting the existing cables.

With the Ford Sync Generation 2 module removed from the vehicle, it is necessary to remove the printed circuit board from the module by removing a series of machine screws that complete the housing assembly. The hardware from the acquisition system kit consists of a single device interface board that is attached below the main circuit board using two nylon bolts, nylon spacers and nuts. Once the device interface board is attached to the main board, 12.0 volts of direct current are supplied to the device interface board using an external power supply. The device interface board is connected to the computer running the acquisition software with a series of ribbon cables, adapters and a USB cable. Figure 34 contains a series of photographs depicting the removal of the main circuit board from the module and the connection method.

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Figure 33. Physical Data Acquisition from the Ford Explorer, Part 1

Figure 34. Physical Data Acquisition from the Ford Explorer: Ford Sync Generation 2, Part 2

Once connected, the data acquisition from the Ford Sync, Generation 2 module takes approximately 4-1/4 hours to complete. The data that can be acquired from the Ford Sync Generation 2 module may include:

- Mobile telephone: Bluetooth and Wi-Fi connections, with the unique identifier for the connected cellular telephone
- Contact list from the cellular telephone
- Call logs from the cellular telephone while connected to the vehicle

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- Short Message Service (SMS) messages from the cellular telephone while connected to the vehicle
- Media files from the cellular telephone
- Mass storage device connections, with the unique identifier for the device
- Media files from the embedded device
- Vehicle Bluetooth connection events
- Vehicle odometer readings
- Vehicle door open/close events
- Vehicle gear shift events
- Vehicle parking light status (on/off) events
- Vehicle system updates
- Vehicle time updates
- Device USB connections and Wi-Fi connections
- Navigation System: Any user saved 'Locations'
- Navigation System: Tracklogs
- System metadata

MYFORD TOUCH - FORD SYNC, GENERATION 2 MODULE

A 2015 model year Ford F-350 Super Duty 4x4 pickup was examined and tested. This pickup was configured with a crew cab, single rear-wheels and an eight-foot bed. The pickup was equipped with the Lariat trim package and the MyFord Touch infotainment system, operated by the Ford Sync, Generation 2 module. The Ford pickup is shown in Figure 35 and the vehicle specifications are listed in Table 7.

Figure 35. 2015 Ford F-350: MyFord Touch, Ford Sync, Generation 2

Table 7. Ford F-350 Specifications

Model Year:	**2015**
Make:	**Ford**
Model:	**F-350, Super Duty**
Trim:	**Lariat**
Options:	**Crew cab, Styleside, Long Bed (8 ft.), Single Rear-wheel 4x4**
VIN:	**1FT8W3BT6FE********
Module:	**MyFord Touch, Ford Sync - Generation 2**

The HMI between the vehicle occupants and the MyFord Touch infotainment system consists of a touchscreen display in the center console. This interface is shown in Figure 36.

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Figure 36. 2013 Ford F-150: MyFord Touch, Ford Sync, Generation 2 HMI

The physical acquisition for the Ford F-350 resembles the process described for the F-150 and the Explorer. Various vents, controls and trim pieces must be removed from the center dash in order to access the Ford Sync module from within the dash. Figure 37 contains photographs documenting this process.

Figure 37. Physical Data Acquisition from the Ford F-350, Part 1

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Once the module was removed from the vehicle, the main circuit board was removed from its housing, the hardware acquisition kit was assembled, similar to the Explorer, and connected to the computer running the data acquisition software. Figure 38 contains photographs documenting this process.

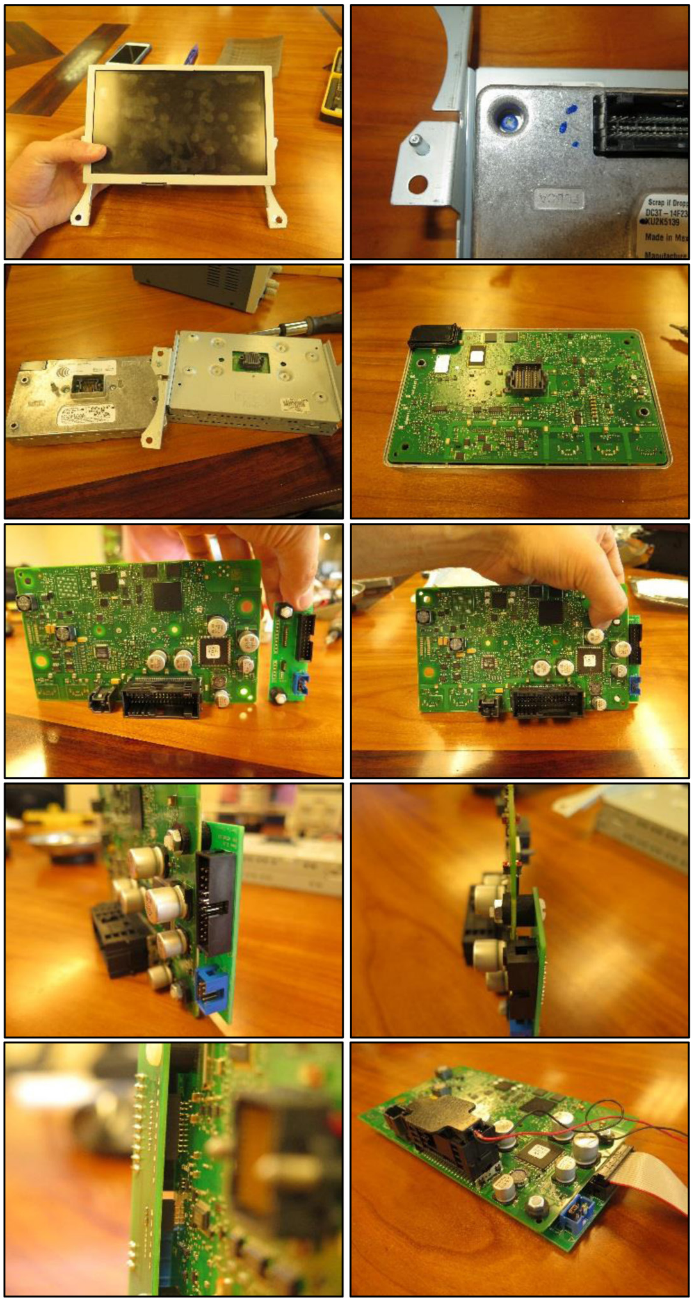

Figure 38. Physical Data Acquisition from the Ford F-350, Part 2

Once connected, the data acquisition from the Ford Sync, Generation 2 module takes approximately 4-1/4 hours to complete. The data that can be acquired from the Ford Sync Generation 2 module may include:

- Mobile telephone: Bluetooth and Wi-Fi connections, with the unique identifier for the connected cellular telephone
- Contact list from the cellular telephone
- Call logs from the cellular telephone while connected to the vehicle
- Short Message Service (SMS) messages from the cellular telephone while connected to the vehicle
- Media files from the cellular telephone
- Mass storage device connections, with the unique identifier for the device
- Media files from the embedded device
- Vehicle Bluetooth connection events
- Vehicle odometer readings
- Vehicle door open/close events

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- Vehicle gear shift events
- Vehicle parking light status (on/off) events
- Vehicle system updates
- Vehicle time updates
- Device USB connections and Wi-Fi connections
- Navigation System: Any user saved 'Locations'
- Navigation System: Tracklogs
- System metadata

APPENDIX D – GENERAL MOTORS DATA ACQUISITION METHODS

General Motors vehicles branded under the Chevrolet, GMC, Cadillac, Buick, Vauxhall, Opel, Holden, Pontiac, Hummer and Saturn makes may be supported by the data acquisition system for select vehicles from model year 2007 and newer. The specific modules within General Motors vehicles that are supported include:

- OnStar, Generation 7 (model years 2007-2008)
- OnStar, Generation 8 (model years 2008-2011)
- OnStar, Generation 9 (model years 2010-2014, some 2015)
- OnStar, Generation 10/HMI (2015 and newer)

GENERAL MOTORS, ONSTAR GENERATION 9

A 2014 model year GMC Sierra 3500HD 4x4 pickup was tested. This pickup was configured with a crew cab, dual rear-wheels and the SLT trim package. The GMC Sierra was equipped with the OnStar Generation 9 module. The GMC pickup is shown in Figure 39 and the vehicle specifications are listed in Table 8.

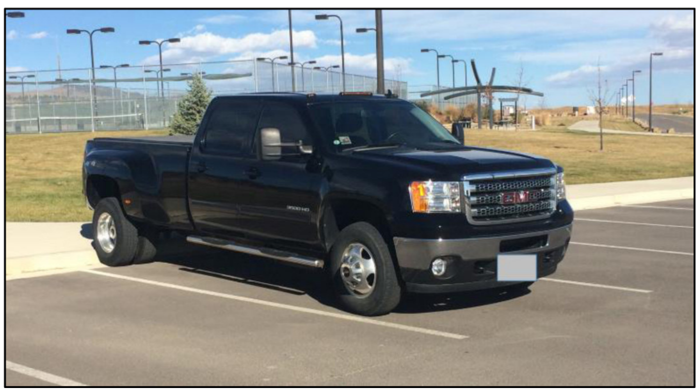

Figure 39. 2014 GMC Sierra 3500 HD: OnStar Generation 9

Table 8. Chevrolet Sierra Specifications

Model Year:	**2014**
Make:	**GMC**
Model:	**Sierra 3500 HD**
Trim:	**SLT**
Options:	**4-Door, Crew cab ,4x4, Dual Rear-Wheels**
VIN:	**1GT424C84EF********
Module:	**OnStar, Generation 9**

The HMI between the vehicle occupants and the infotainment system of this GMC Sierra consists of a basic radio screen and a series of push-buttons in the dash. This interface is shown in Figure 40.

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Figure 40. 2015 Chevrolet Sierra 3500 HD HMI and Radio Controls

General Motors vehicles require the physical acquisition method. This method requires physically extracting the OnStar module from the center dash of the vehicle. For the GMC Sierra examined in this study, removal of the OnStar module required the disassembly of the entire dash, including vents, controls and trim pieces, as well as the removal of the glovebox and the trim pieces covering the A-pillar. Figure 41 contains photographs documenting this process.

Figure 41. Physical Data Acquisition from GMC Sierra, Part 1

With the OnStar module removed from the vehicle, it is necessary to remove the printed circuit board from the module. Figure 42 contains photographs documenting the removal of the circuit board from the module housing. Unlike the Sync modules found in Ford vehicles, some OnStar modules require the removal of solder mask from specific portions of the circuit board, revealing the underlying pads. This can be done by carefully scratching the solder mask from the board using a fiberglass scratch pen. This process is shown in the fourth, fifth and sixth photographs in Figure 42. Once the solder mask has been scratched away, the hardware acquisition kit can be attached to the circuit board and connected to the computer running the data acquisition software, as seen in the final images on Figure 42.

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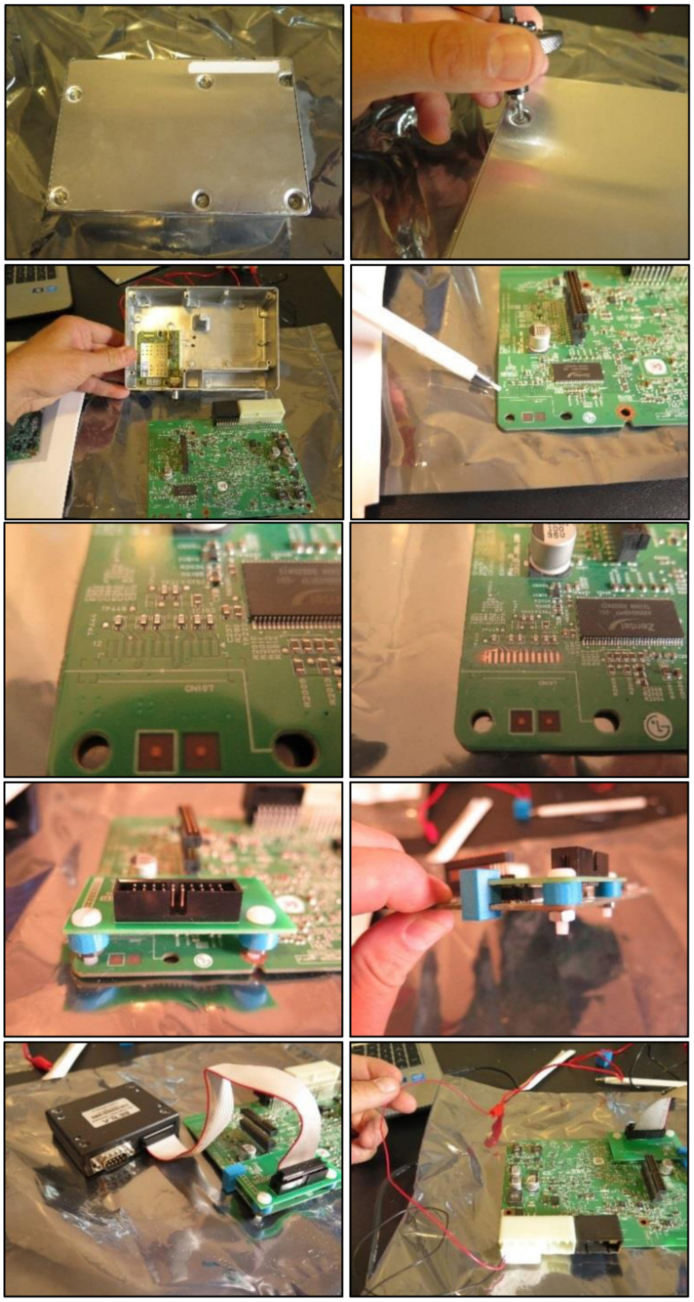

Figure 42. Physical Data Acquisition from the GMC Sierra/OnStar Generation 9, Part 2

Once connected, the data acquisition from the OnStar Generation 9 module takes approximately 2-2/3 hours to complete. The data that can be acquired from the OnStar Generation 9 module may include:

- Mobile telephone: Bluetooth connections, with the unique identifier for the connected cellular telephone
- Embedded device connections
- Contact list from the cellular telephone
- Vehicle system updates
- Navigation System: Any user saved ‘Locations’
- Navigation System: Tracklogs
- System metadata

ONSTAR, GENERATION 10/GENERAL MOTORS HMI INFOTAINMENT MODULE

A 2015 model year GMC Canyon 4x4 pickup was examined. This pickup was configured with a crew cab and a short bed. The pickup was equipped with the SLE trim package and an infotainment system operated by the GM HMI module. In this particular instance, the interface was branded with the GMC Intellilink platform. The GMC Canyon pickup is shown in Figure 43 and the vehicle specifications are listed in Table 9.

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Figure 43. 2015 GMC Canyon: OnStar Generation 10/GM HMI Module

Table 9. GMC Canyon Specifications

Model Year:	**2015**
Make:	**GMC**
Model:	**Canyon**
Trim:	**SLE**
Options:	**Crew cab, Short Bed, 4WD**
VIN:	**1GTG6BE34F1********
Module:	**OnStar Generation 10/GM HMI**

The touchscreen user interface for the GMC Intellilink system is shown in the photographs in Figure 44.

Figure 44. 2015 GMC Intellilink/HMI: Interface

The GMC Canyon utilizes the physical acquisition method that requires the removal of the GM HMI module from the vehicle. For the GMC Canyon examined in this study, the HMI module was located on the passenger side foot-well of the vehicle, in the area of the interior fuse panel. Figure 45 contains photographs documenting the removal of the GM HMI module from the vehicle. Figure 46 documents the data acquisition process once the module has been removed from the vehicle.

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Figure 45. Physical Data Acquisition from the GMC Canyon, Part 1

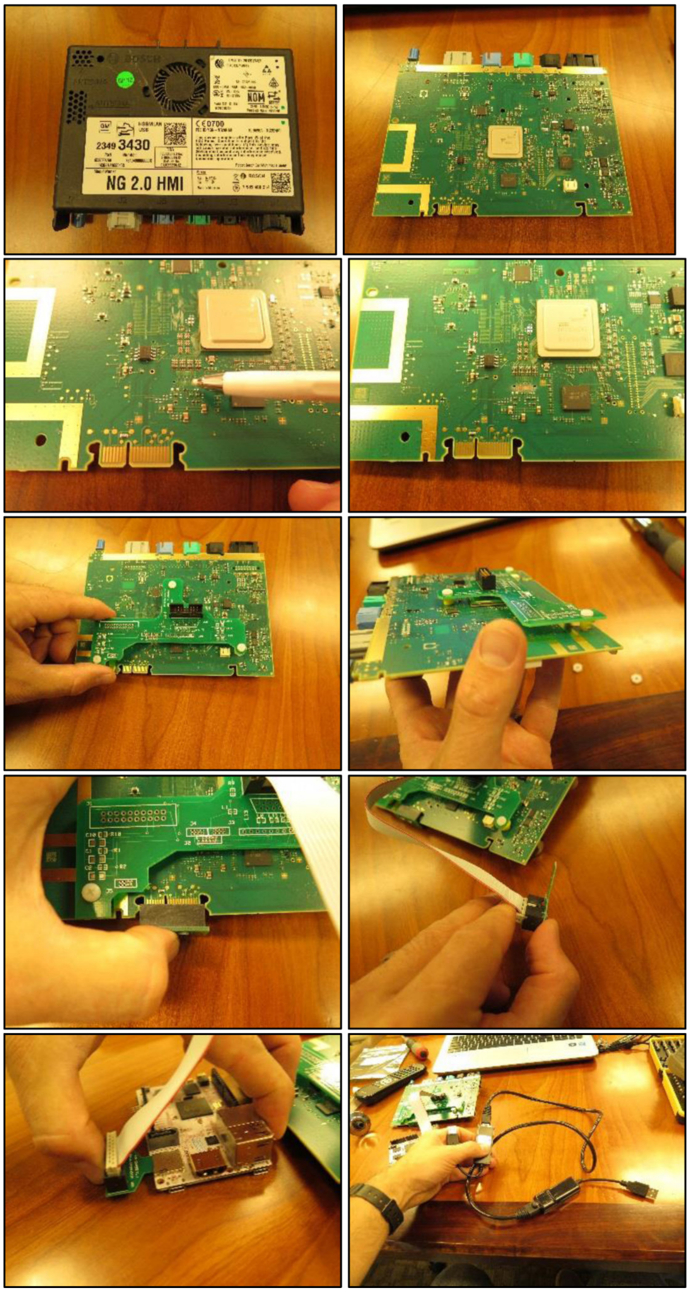

Figure 46. Physical Data Acquisition from the GMC Canyon, Part 2

The Engineering Meetings Board has approved this paper for publication. It has successfully completed SAE's peer review process under the supervision of the session organizer. The process requires a minimum of three (3) reviews by industry experts.

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