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Infotainment & Telematic Systems: What Does Your Car Know?

Event data from vehicles has been accessed and analyzed by engineers for close to 25 years. Each year, technology progresses and the ability to access data stored in vehicles also expands. The seminar will provide the attendee with an understanding of the history/progression of event data in vehicles; the newest type of information that could be accessible; how to properly collect the data; and the engineering foundation upon which the data should be analyzed and utilized. The newest forms of event data including Telematics and Infotainment will be discussed along with lesser known, but potentially just as important, other sources of data. An understanding of how the information is utilized by the engineer and how it can be accepted by the courts will be reviewed using actual case examples.

Event Data

Event Data Progression

Initially proposed as a Federal Motor Vehicle Safety Standard (FMVSS), "Event Data Recorders" (EDRs) have become a voluntary inclusion in the vast majority of new passenger and light motor vehicles. As these devices have become more advanced, the data captured has become more ubiquitous in its availability from other devices within modern vehicles, including commercial and other heavy vehicles. Data can be captured (relevant to a collision event) by aftermarket dash cameras such as DriveCams, standard in-vehicle infotainment systems, and any cellular device in the vehicle at the time of a collision. While the EDR can still provide important, foundational data for a collision reconstruction – it is important to be aware not only of the data attainable through this device – but also of other data sources which can now be accessed and may, in some cases, contain additional and explanatory information than that which is captured by the EDR.

Equipped Vehicles

As mentioned previously, EDR's were initially intended to be a mandated component in new production vehicles. However, automakers, seeing the value in the data captured by these devices, voluntarily decided the inclusion of this device in almost all production vehicles. Other sources of data, such as cell phone data and DriveCam data, is dependent on the device being present in the vehicle when a collision occurs (present and active). A "new" (in terms of the ability to access it) type of data, which is now attainable from the vehicle's infotainment system, is present on most vehicles. The method for access, the data elements contained, and the frequency at which these data elements are recorded still varies between year, make, model, and manufacturer (at every trim level) and more information about the accessibility and enumeration of data elements is being discovered on a near monthly basis.

Infotainment & Telematics

Vehicle Communication Networks: Interacts with cars, devices and other networks

As cars developed, they could be driven for long periods of time, and roadway infrastructure supported and encouraged long distance travel. People began to spend an increasing amount of time in the car. Long drives meant boredom, leaving a new technology market niche to develop in-car entertainment. Car phones were popular assets to cars in the early 20th century and did not become wireless until 1946. Another big iteration was the commercial car radio. "Although commercial car radios hit the market in the late 1920s, it wasn't until Galvin Manufacturing Company (now known as Motorola) introduced the Motorola 5T71 radio that commercial car radios really became popular" **[1]**. AM/FM radio has surpassed the 8-track, cassette players, and mixtapes. It will soon surpass CD players as many car manufacturers are starting to discontinue them. Infotainment systems are the current trend, and they also broadcast AM/FM radio. Satellite radio has yet to take over the radio world, but it is also available in infotainment systems. Infotainment systems support their own type of car phone, as vehicle operators can now connect their smartphones via Bluetooth, Wi-Fi, or USB.

Supported Vehicles and Systems

While infotainment systems can be defined simply as an AM/FM radio, the term correlates more to the current systems in most modern vehicles that include navigation and phone connectivity capabilities. Infotainment systems made their first appearance in vehicles in 1990; however, they were not prevalent in vehicles until almost 20 years later. OnStar was popular during its heyday, running different generations from 2008-2015. OnStar was utilized by General Motors, equipped in Buick, Cadillac, Chevrolet, GMC, Hummer, Pontiac, and Saturn vehicles. Vehicles that fall under the following car manufacturers potentially contain infotainment systems: Audi; BMW; FCA; Ford; General Motors; Hyundai; Lexus; Mercedes; Nissan; Peugeot; Toyota; and Volkswagen. Not every vehicle has an infotainment system installed; car manufacturers did not incorporate infotainment systems in all of their cars.

Navigation GPS

Similar to car phones, car GPS navigation systems trace their origins to the first half of the 20th century. In 1930, the Iter Avto was developed as the first automobile navigator. It used paper maps that scrolled as the vehicle operator drive. While it didn't use satellites to determine position, it did assist vehicle operators in figuring out routes to their destination. With the launch of Sputnik, the idea that satellites could help determine positioning on Earth was developed. While navigation systems appeared in vehicles as early as 1930, vehicle navigation systems that actually used GPS technology didn't develop until the 1990's. Today, GPS is increasingly included as part of the vehicle's software and is integrated with the existing infotainment systems. Vehicle GPS uses signals from orbiting satellites in order to determine location. GPS involves three different segments: the space segment, the control segment, and the user segment. The space segment is made up of a constellation of 24 satellites that receive data from car GPS devices. The control segment consists of various stations on Earth that monitor and maintain the satellites. The user segment involves the actual GPS device, which may be a standalone aftermarket device or integrated into the vehicle software itself.

When and What is Stored / Data Frequency and Duration

Typically, GPS-based Navigation systems document the latitude, longitude, and time-stamp at a pre-determined frequency (often 1 data point per second or greater) either within the unit itself or through communication with a cloud-based system which is accessible on the back-end by the manufacturer. This data is typically recorded in a continuous fashion and does not detail the occurrence of an "event" unless there is an in-built accelerometer in the in-vehicle device. For devices which do indeed record accelerations and document "events" – the recording and storage regime may either be event-based (where no data is recorded until an event is triggered and, upon triggering, only certain elements are detailed) or continuous depending on the manufacturer.

Cell Phones

Connection Methods

Cell phones can connect to a vehicle via Bluetooth, Wi-Fi, or USB. This allows vehicle operators to utilize hands-free calling and texting amongst other features. Vehicles with Android Auto and Apple Carplay will be granted access to additional voice-activated capabilities such as answering questions in response to the vehicle operator saying, "Ok Google" or "Hey Siri", followed by a question.

Unique Identifiers

Unique identifiers are MAC addresses or Bluetooth addresses. A MAC (Media Access Control) address is used in correspondence with network technologies like Wi-Fi and Bluetooth. It assigns a hardware identification number that uniquely identifies each device on a network. Bluetooth communicates via radio wave opposed to wires or cables. A Bluetooth address is used to determine the manufacturer of the device and to track the frequency pattern in radio communication between Bluetooth devices. The first portion of the Bluetooth address provides data about the manufacturer. If two Bluetooth devices are developed by the same manufacturer, the first half of their Bluetooth Address will be the same, while their frequency pattern may differ. In conclusion, all MAC addresses are unique, while Bluetooth Addresses have a chance of being the same, specifically the first half of the address.

What is Recorded

Cell phones already store so much user data, so it should be expected that vehicles will do the same. When it comes to cell phones, vehicles store call logs (who the call was from/to, whether the call was incoming/outgoing, when the call took place date/time, and how long the call was); contacts (name, phone number, home address, and email address); media files (songs on the device, album covers, and even when the songs were installed on the device); SMS (who the text was from/to, whether the text was incoming outgoing or read/unread, and the date/time of the text message); and unique identifiers (MAC address or Bluetooth address).

Vehicle Events

What events are logged?

Early infotainment systems were very limited as to what events were logged. Typically, only navigation data was logged, such as location data. Now with further advancements in technology, infotainment systems not only do more, they store more. Infotainment systems store anything from phone logs and text messages to vehicle events such as doors opening/closing, driver distraction, gear shifts, hard acceleration, and hard braking.

Data retention – where does the data go and what is stored?
While EDR's only record the seconds prior to an "event" and are limited in the number of events they can capture and the details which they can provide about said events – there is essentiallly no limit to the breadth of that which is documented by the infotainment system. Inside modern vehicles, there is what's known as an External Computing Unit (ECU). This unit serves as the "hub" of vehicle data and receives inputs from the vehicles systems themselves (that is the systems which physically move the vehicle), the in-vehicle entertainment systems, and any external devices connected to the vehicle (among other systems). While our cell phones and home computers have a certain amount of storage capacity – this capacity is necessarily exceeded by the modern automobile which must be far more robust given the different inputs and the need to have fast, reliable access to the data received.

Data Extraction

Module Locations
The module for infotainment systems is located in the center of the dashboard behind the screen or display of the infotainment system. By disassembling the dashboard and removing the screen, the module can be removed for data extraction.

Methods to Image the Available Data
Event Data can be imaged from a vehicle's Event Data Recorder (EDR) by connecting to the vehicle's Diagnostic Link Connector (DLC), usually found below the steering column. If the DLC is unreachable, the data can be imaged with the Airbag Control Module (ACM) still bolted to the vehicle. The module can also be extracted, with the data being imaged after being completely removed from the vehicle. For most newer vehicles, the Bosch Crash Data Retrieval Tool is utilized to image the data from the EDR. Some vehicle manufacturers have proprietary systems that require other tools to download event data. As infotainment systems grow increasingly complex and contain more information, a relatively new area of data extraction involves the imaging of data from the infotainment system.

Extracted Data Examples: Cell Phone Data, Device Connections, GPS Track Points, Vehicle Events
There is a wide variety of data available in infotainment systems, but this data varies between each system. Each car manufacturer has their own unique modules and additionally may have multiple versions or upgraded modules over time. In general, data is collected from: connections (Bluetooth, Wi-Fi), CD/DVD or mass storage devices (media files, unique identifiers), phones or embedded devices (call logs, contacts, media files, SMS, unique identifiers), events (light status, GPS warnings, seat belts, Android Auto, Apple Carplay, etc.), navigation (location, routes, and tracklogs), and system metadata. There is a lot of other data available, but again, it depends on what module you are extracting data from. Some modules might just have a few data types stored on them, while others store close to everything listed above.

Other Data: Voice Recording, Media, Warnings

Other data being documented by the infotainment system includes any and all in-vehicle warnings the system communicates to the operator, any voice commands the operator gives the vehicle throughout the (conceivable) lifetime of the vehicle, and any median data/connections not detailed to this point such as those which are directly connected to the vehicle via a USB-type hookup or any direct-to-system input.

Data Privacy

Who "owns" the data?

The current vehicle OWNER, not the OPERATOR (think rental cars) owns the data in the vehicle. The vehicle is the property of the owner, and any data created by the vehicle or stored within it is theirs as well. This data falls under the user's fourth amendment rights and can only be downloaded with consent or a warrant.

Vehicle Data in the Future

Crash Avoidance Systems

Increasingly, newer vehicles come equipped with various collision avoidance systems. These can include warnings such as lane departure warnings, blind-spot monitoring, and forward-collision warnings, or features like automatic braking or lane keep assist. In order to function, these systems use a combination of cameras, lasers, GPS, and/or other sensors in order to monitor the vehicle's position and its relationship to other vehicles and objects that may be on the roadway. These types of warnings and active processes undertaken by the vehicle provide another type of event data that can be monitored and analyzed.

What Parameters to Expect

Of the new data elements which will likely become accessible in vehicles with these advanced features, the most notable (perhaps) are photographs and video data recorded by the camera-based systems. That is, if the advanced safety system is indeed camera-based (either still images or recordings), this image data will need to be recorded, and stored, within the vehicles' memory. As such, this data will presumably be accessible through the same avenues that other infotainment data is obtained. As these systems become more prevalent and further determinations are made with regard to the method of accessing the vehicles infotainment systems, there will be a more robust picture of exactly how these data elements will be realized by the end user performing the download. In addition, information contained in the vehicle storage will necessarily define the sense-plan-act stages of the robotic control loop allowing for determination of how, if at all, an automated vehicle system may or may not have contributed to the happenings of a collision event.

Newer Technologies

How do they function?

New technologies are not all predictable; however, there's a few that are developing currently. Adaptive headlights, or an adaptive frontlight system (AFS), is a safer and more efficient way for drivers to use their high beams. By using cameras and sensors, the headlights are able to determine the location of other vehicles and, as a result, will adapt their light distribution accordingly. If a vehicle appears in front of the adaptive headlights, the headlights "use sensors and cameras to continuously shape a vehicle's high beam so that it illuminates only areas without oncoming traffic, while throwing light elsewhere far down the road" **[2]**. In the case of an approaching vehicle, adaptive headlights respond by first creating a "tunnel" of reduced light intensity around the approaching vehicle, followed by the activation of low beams specifically for the left headlight as the oncoming vehicle passes.

Adaptive headlights are not the only form of intelligent light technology available on vehicles. Adaptive brake lights help the driver of the following vehicle understand how hard the person in front of them is braking. The brake lights exhibit the sensitivity of how hard the brakes are being applied. If the brakes are lightly tapped, the brake lights will glow dimly; however, if the brakes are slammed, the brake lights will glow extremely bright and will flash in order to alert surrounding vehicle operators.

Adaptive brakes are the next step up. Adaptive brakes are able to predict when the vehicle operator will need to quickly slam on the brakes by sensing how fast they removed their foot from the gas pedal. The adaptive brakes will then alert the brake lights to light up before the brakes have even been applied. Adaptive brakes can determine if it is raining by sensing the use of windshield wipers. When it is raining, adaptive brakes will keep themselves "ready for action, automatic brake drying periodically squeezes the brakes just enough to sweep away water buildup" **[3].** When a vehicle is on an incline, the adaptive brakes are notified and activate a hill assist that prevents the vehicle from rolling backwards. This feature holds the brake for a few extra seconds so the vehicle operator can focus on accelerating. Providing two long, consecutive pushes on the adaptive brakes in a standstill traffic situation activates a hold feature that allows the vehicle operator to take their foot off the brake pedal while the vehicle stays in place and the brake lights remain illuminated. This only works when the vehicle is at a complete stop. This feature helps reduce driver fatigue and prevents vehicles rolling into others if the vehicle operator dozes off or takes their foot off the brake accidentally.

What Parameters to Expect

The data elements expected from these systems are similar to those detailed in the previous section. However, there is an additional emphasis with these specific technologies in the detailed storage and delineation of the sense-plan-act elements that detail the operator of the advanced systems of the future.

Can manufacturers obtain additional data?

There is a tremendous leap of faith that the travelling public is going to need to make in "trusting" that the auto manufacturers are providing the full, detailed data elements via infotainment, EDR, or post-collision cloud-based access when these events occur. Companies such as Tesla have already demonstrated the pitfalls in this "trust-based" approach and there may need to be some regulatory structure in place with regard to what is proprietary information and what is the objective data that should be available to ensure the safety of the travelling public.

[1] Tran, Anne Le. "The History of the Car Radio: From Morse Code to Mixtapes." *Esurance On*, Esurance Insurance Services, Inc., 24 Aug. 2016, blog.esurance.com/history-of-the-car-radio/.

[2] Taub, Eric A. "Smart Headlights Inch Closer to American Roads." *The New York Times*, The New York Times, 21 Nov. 2018, www.nytimes.com/2018/11/21/business/headlights-adb-high-beams.html. [4] https://www.popularmechanics.com/cars/g1195/10-car-options-the-law-wont-let-you-have/

[3] Mercedes-Benz Canada. *YouTube*, YouTube, 27 May 2013, www.youtube.com/watch?v=GUXidhOg3_I.