# Use of smart technologies to collect and retain crash information

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## Report for PENDANT (WP 1, task 1.1)

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# 1. Introduction and scope

Task 1.1 of Pendant Work Package 1 has a threefold objective: firstly to develop methods and guidelines for the reconstruction of road traffic accidents, secondly to develop a database of information about public domain crash tests, and thirdly to develop methods for determining the comparability and accuracy of reconstruction methods. As part of the third aim the *Description of work* (2001) states:

> Specific reference will be made to the use of smart technologies to collect and retain information about the crash ('black boxes', 'crash recorders'). The Task will examine current capabilities and identify the main obstacles to their wider implementation.

The purpose of this report is to provide an overview of the state of the art in recording information about the crash phase, including current capabilities and main obstacles to further implementation.

Smart technologies, as understood in this report, may be broadly characterised as systems that contain a microprocessor and sensors connected by a digital data network. Without drawing fine distinctions, the microprocessor may also be referred to as a microcomputer or an electronic control unit (ECU). Electronic fuel injection is an early example from the 1980s of a smart technology, where sensors for throttle position and oxygen content in the exhaust gas provide input to the ECU which in response issues a signal to control the quantity of fuel delivered to the engine. Later in the same decade anti-lock braking systems (ABS) were widely introduced, another smart technology, in which sensors for individual wheel speeds provide input to an ECU which reduces brake fluid pressure to wheels that are locking up. The 1990s saw the general introduction of supplemental restraint systems (SRS), typically air bags and seat belt pretensioners. These employ accelerometers (including inertia switches) to sense the onset of an impact which may be recognised by the ECU as severe enough to warrant actuation of the pyrotechnic devices that provide power to deployable restraint components. It is conventional also to have diagnostic logic in the microprocessor, so that a warning is displayed when a circuit problem or other malfunction is detected.

The current trend is towards the rapid development and introduction of new and enhanced smart technologies. Anti-lock braking for example is being enhanced as a vehicle control system by traction control, which prevents wheel spin, and by stability control, which counteracts over- or under-steer by momentary, selective braking of individual wheels. Enhanced supplemental restraint systems (SRS) are capable of sensing such factors as the occupant's presence or absence, weight and proximity the to air bag and modulating the power of the air bag or pretensioner accordingly—or suppressing activation entirely. Other advanced systems such as adaptive cruise control and pre-impact deployment of restraint systems require the installation of sensors and microprocessor intelligence capable of detecting and recognising objects in the environment of the vehicle. There are many other smart technologies already conceived and under development that are yet to appear in production vehicles. The new and existing types of sensors required for these systems provide an opportunity to record information about road accidents by sampling the data flow through the digital network and storing the results to ECU memory.

In considering the potential of smart technologies it is useful to make a clear distinction between how often (a) a sensor issues a digital signal, (b) the microprocessor reads the signal and (c) the microprocessor stores the reading. These can be referred to as measurement, sampling and recording respectively. An operational system could for example have a sensor that issues a digital measurement 1000 times per second, where the microprocessor reads the value from the data network 10 times per second but writes it to memory only once per second. In this case the measurement rate would be 1000 Hz, the sampling rate 10 Hz and the recording rate 1 Hz. The frequency of measurement and sampling is likely to be mainly determined by the operational requirements of the system; a manufacturer may also record data in order that faults can be diagnosed and performance checked. Beyond this there are cost implications to installing recording capability that may not be justifiable from the manufacturer's or purchaser's point of view. For this reason the introduction of smart technologies provides the *potential* for collecting and recording information about a crash, but it does not follow that such information will be recorded or accessible.

There are many applications and uses of recorded data. Its role for the manufacturer in system diagnostics and performance feedback, as already mentioned, stands in the forefront. Accident reconstruction and the related effort to reduce road casualties would benefit greatly from the measurement of velocity, acceleration, braking, steering, restraint use, timing of air bag deployment and so on. At the moment it is usually necessary draw inferences about the crash from indirect evidence: residual vehicle damage, tyre marks, debris, vehicle rest positions, road layout, seat belt webbing marks and so on. Much is difficult or impossible to deduce, for example the acceleration-time history during impact (crash pulse), braking and steering before impact, occupant out of position, pre-impact speed of travel and the timing of advanced restraint system deployment. Automated crash notification is a further application for recorded data. Upon crashing the vehicle itself would issue an emergency call identifying itself and stating among other things the location, date, time and severity of impact. This is intended to allow the fastest and most appropriate delivery of emergency services, recognising the benefits of early medical treatment and the limited availability of the emergency services. Insurance companies and fleet managers also have an interest in crash information from the risk management or health and safety perspective. Both suffer financially from fraudulent claims or misleading accident accounts and would benefit from an objective electronic record. This applies equally to the handling of traffic accidents in courts of law and other legal processes.

In the context of Task 1.1 ‘Accident reconstruction and collision severity assessment guidelines’ the focus is on accident reconstruction and the assessment of impact severity. The concept of accident reconstruction potentially embraces a very wide range of road environment, vehicle and human factors, and recorded data could applied to many aspects of these areas. The discussion in this report concentrates on the movement of vehicles shortly before, during and after the impact phase. Vehicle movement is described mainly by velocity and acceleration parameters, and less directly braking or steering actions for example. Where occupant and occupant restraint use data is available, this is also considered because of its relevance to secondary safety.

A extensive array of terms are used to describe or name vehicle devices or systems that record digital data. These include ‘black box’, ‘crash recorder’, ‘accident data recorder’, ‘UDS (Unfalldatenspeicher)’, ‘data logger’, ‘sensing and diagnostic module’, ‘restraints control module’ and ‘powertrain control module’. These are by no means equivalent and it is convenient to have a general term to express the general concept of recording electronic data. The expression ‘event data recorder’ (EDR) seems to have established itself for this purpose, especially in the USA. In this report an EDR is understood to be a device or system capable of recording digital data obtained from vehicle sensors. This is a functional definition: as long as the vehicle is capable of recording data, no specific presumption is made about the physical components used in the device or system.

In practice there are two categories of EDRs that are worth distinguishing because of their very different characteristics and capabilities. In this report they are referred to as ‘production’ or ‘aftermarket’. An aftermarket EDR is an independent device designed and fitted to a vehicle for the specific purpose of measuring the acceleration pulse and other data during an impact, i.e. it is a custom-made crash recorder or ‘black box’. The UDS manufactured by VDO and the Folksam crash pulse recorder are examples of aftermarket EDRs. When an intrinsic vehicle system such as the air bag or powertrain control module is capable of recording crash-related data, this is referred to as a ‘production’ EDR. An example is the GM supplemental restraint system, recent versions of which in the USA have been modified to compute and record change of speed during impact. In general terms, to date, production EDRs have emerged by modification or enhancement of vehicle systems that the manufacturer has installed for completely separate reasons such as electronic fuel injection, anti-lock braking, air bags or adaptive cruise control.

**Figure 1 Aftermarket EDR (VDO Unfalldatenspeicher)**

**Figure 2 Smart technology (occupant sensing)**

## 2. Current activities

This section provides a selective overview of activities in Europe and North America that aim to collect data from passenger car EDRs and that have been detailed in the literature.

### 2.1 General Motors

Like other manufacturers, GM production vehicles equipped with air bags have recorded air bag status and crash-related data for many years. Unlike other manufacturers, with the exception of Ford, GM have licensed a company, Vetronix Corporation, to supply the general public with the hardware and software required to access this data (Figure 3). Vetronix began selling its ‘crash data retrieval system’ (CDR) in 2000. As the data is stored in the air bag sensing and diagnostic module and the system as a whole may be regarded as an enhancement of the supplemental restraint system, the GM system is an example of a production EDR.


**Figure 3 Vetronix crash data retrieval equipment**

An extensive range of GM models have been fitted with EDRs. The list of 2004 models includes: Buick Century, Buick LeSabre, Buick Park Avenue, Buick Rainier, Buick Regal, Buick Rendezvous, Cadillac Commercial, Cadillac CTS, Cadillac Deville, Cadillac Escalade, Cadillac EXT, Cadillac XLR Roadster, Cadillac Seville, Cadillac SRX, Chevrolet Avalanche, Chevrolet Astro, Chevrolet Blazer, Chevrolet Colorado, Chevrolet Cavalier, Chevrolet Corvette, Chevrolet Express, Chevrolet Impala, Chevrolet Kodiak, Chevrolet Monte Carlo, Chevrolet S10, Chevrolet Silverado, Chevrolet SSR, Chevrolet Suburban, Chevrolet Tahoe, Chevrolet Tracker, Chevrolet TrailBlazer, Chevrolet Venture, GMC Envoy, GMC Safari, GMC Savana, GMC Sierra, GMC Sonoma, GMC Suburban, GMC Top Kick, GMC Yukon, Hummer H2, Oldsmobile Alero, Oldsmobile Bravada, Oldsmobile Silhouette, Pontiac Aztek, Pontiac Bonneville, Pontiac Grand Am, Pontiac Grand Prix, Pontiac Montana, Pontiac Sunfire, Saturn ION and Saturn VUE. A complete tabulation of make and model by year of manufacture (over 500 entries) is available on the Vetronix website [Vetronix Corporation, 2004]. These models are primarily directed toward the North American market. Documentation on whether the Vetronix crash data retrieval system would function on vehicles marketed in Europe under the Opel, Vauxhall or other GM brands, and if so which, has not been identified.

The General Motors system has been modified since its introduction in the early 1990s. The data recorded depends on the vehicle make, model and year. For recent GM models some or all of the following information may be available:

vehicle speed
engine speed

brake status

throttle position

driver's seat belt switch on/off

passenger's air bag enabled/disabled

warning lamp on/off

time from vehicle impact to air bag deployment

ignition cycle count at event time

ignition cycle count at investigation

maximum delta-V for non-deployment event

delta-V versus time for frontal air bag deployment event

time from vehicle impact to time of maximum delta-V

time between non-deployment and deployment event (if within 5 seconds)

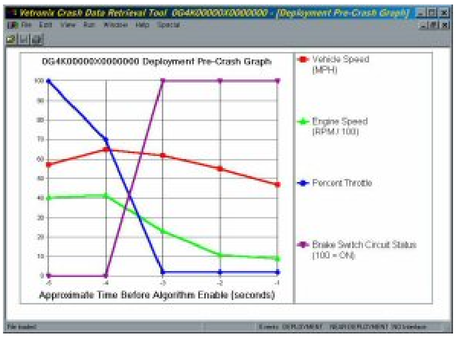


**Figure 4 GM pre-crash information**

Here 'delta-V' refers to the change of velocity on the vehicle's longitudinal axis during impact. The first four parameters, vehicle speed, engine speed, brake status and throttle position are recorded at approximately five one-second intervals before impact as illustrated in Figure 4. This chart shows release of the throttle, application of the brakes and a reduction of engine speed in the five seconds preceding impact; vehicle speed is recorded as approximately 57, 65, 62, 55 and 47 mph.

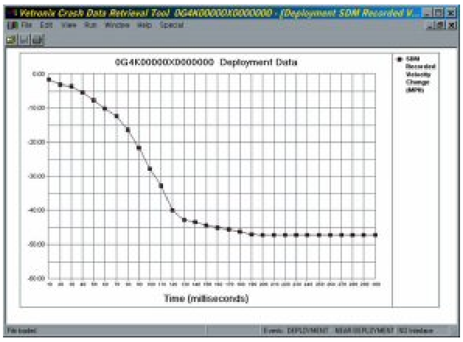


**Figure 5 GM velocity-time history during impact**

The change of velocity versus time history during impact is recorded at 10 milliseconds intervals (100 Hz) for 300 milliseconds in the example shown in Figure 5. (This appears to be from the earlier version of the GM EDR system. Since 1999-2000 the duration of recording has been reduced to 150 milliseconds.) This chart shows a reduction in velocity of 40 mph over the first 120 milliseconds which from the 190 milliseconds mark reaches a plateau at 47 mph. It is worth noting that the change of velocity during impact derives from a high-frequency output of an accelerometer aligned with the longitudinal axis of the vehicle. It follows that lateral and vertical velocity changes relative to the car are not detected and that the (longitudinal) velocity-time curve is ‘smoother’ than it would be if more frequent measurements were recorded.

## 2.2 Ford

Ford Motor Company is the second motor manufacturer to allow public access to the data stored in its air bag module, the ‘restraints control module’. Like GM, Ford has licensed Vetronix Corporation to supply the required hardware and software.

The range of Ford vehicles fitted with electronic data recording capability is less extensive than for GM. The list of 2001-2004 models for which data may be available from the current or next version of the Ford-Vetronix system includes: Ford Crown Victoria, Ford Escape, Ford Escort, Ford Excursion, Ford Explorer, Ford F-Series, Ford Mustang, Ford Ranger, Ford Sable, Ford Taurus, Ford Thunderbird, Ford Windsor, Mercury Grand Marquis, Lincoln Continental, Lincoln LS, Lincoln Navigator and Lincoln Town Car. A complete tabulation of make and model by year of manufacture (over 500 entries) is available on the Vetronix website [Vetronix Corporation, 2004]. Like GM, these models are primarily directed toward the North American market and it is difficult to establish to what extent, if any, the Vetronix crash data retrieval system would function on Ford vehicles marketed in Europe.

Ford vehicles currently record data during the crash phase. Inputs to and outputs from the air bag module are recorded in order that the performance of the unit can be monitored after the event. The data is not intended to record an event for accident reconstruction—although it may have some incidental value for this purpose—and on this ground it is fair to note that Ford resists classification of the system as an EDR. In this report, as explained above, the term ‘EDR’ is understood to encompass the notion of recording crash-related data without the presumption that the data meets the general requirements of accident reconstruction.

The Ford-Vetronix system dates from 1998. The data recorded depends on the vehicle make, model and year. For recent models some or all of the following information may be available:

data validity check
EDR model version
safing decision time (multiple)
diagnostic codes active when event occurred
algorithm wake-up time (multiple)
driver seat belt engaged/not engaged
passenger seat belt engaged/not engaged
driver seat track in forward position
run time
longitudinal acceleration
lateral acceleration

Of particular interest among these items are seat belt use, driver seat position and especially longitudinal and lateral acceleration. Acceleration and a derived value of velocity change is recorded every millisecond (1000 Hz) for 78 milliseconds as illustrated in Figure 6. Acceleration and change of velocity are shown by the solid and dashed lines respectively. Acceleration relative to the longitudinal axis of the vehicle in this example is generally in the 5-10 g band for the first 40 milliseconds then peaks at about 23 g at 60 milliseconds, as shown on the left chart. The corresponding velocity change is 20 mph over the period of recording.

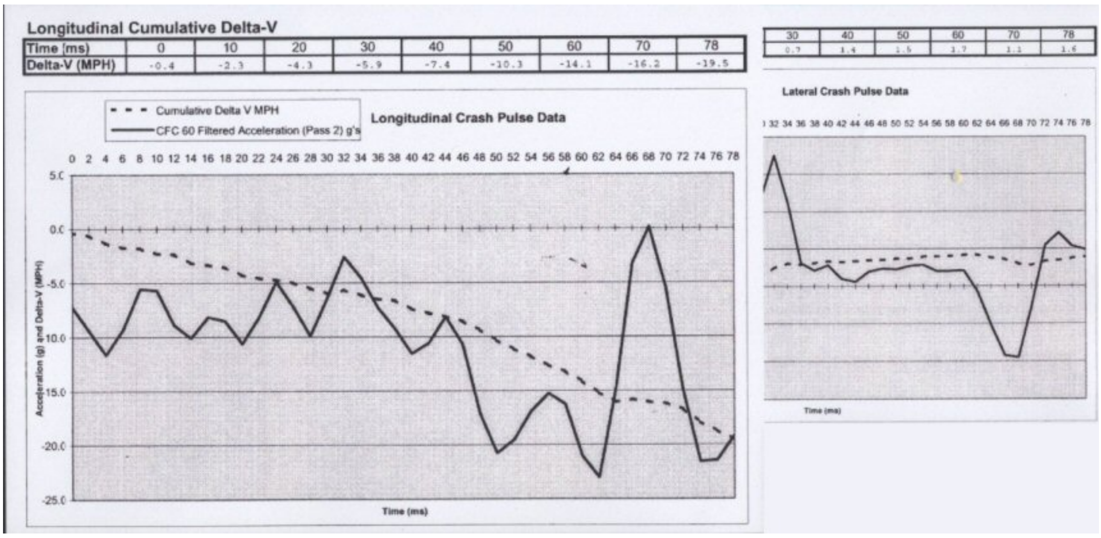


**Figure 6 Ford acceleration-time trace during impact**

This is a more frequent but shorter record than the GM system (100 Hz, 150 ms). Many impacts endure for longer than 78 milliseconds and are therefore not fully recorded by the Ford restraints control module—as indicated in the example shown, where neither the acceleration nor velocity lines have stabilised by the end of the record.

### 2.3 Volvo

Volvo Car Corporation has released some information on two proprietary EDR systems, the 'digital accident research recorder' (DARR) and the 'pre-crash recorder' (PCR). As the DARR and PCR systems are integrated or highly associated with other independent, intelligent vehicle systems—the air bag sensor unit and brake control module respectively—they count as production EDRs. Public documentation on the systems is limited and no privileged sources were available for this report. The hardware and software required to access the data are proprietary and the EDR information is therefore not available to the general public.

(1) The digital accident research recorder has been installed in all new Volvo cars sold in Europe since 1994. The system uses an accelerometer aligned with the longitudinal axis of the vehicle. After an impact is detected 64 readings are stored. Originally the

duration of recording was 107 milliseconds, later this was increased to nearly 180 milliseconds (333 Hz).

The data recorded by the digital accident research recorder (DARR) is:

longitudinal acceleration

(2) The pre-crash recorder was first installed or evaluated on the Volvo S80 during the period 1998-2001. Public documentation on the range of models to which it has subsequently been installed, if any, and the nature of any modifications since 2001 have not been identified. The system stores data from the 5 seconds preceding impact. For the main PCR variables, 11 readings are recorded (2 Hz).

The data available from the pre-crash recorder (PCR) includes:

outdoor temperature
time since manufacture (‘global time’)
time from ignition on
brake pedal position
clutch pedal position
throttle position (‘driver requested torque’)
steering wheel angle
driving direction
vehicle speed
engine speed
status and reliability of engine speed sensors (‘engine speed quality factor’)
engine torque
status and reliability of engine torque sensors (‘engine torque quality factor’)
longitudinal acceleration
lateral acceleration
yaw rate
roll rate
voltage supply to brake control module (BCM)
anti-lock braking system (ABS) enabled/disabled
anti-lock braking system (ABS) active/inactive
electronic brake distribution (EBD) enabled/disabled

electronic brake distribution (EBD) active/inactive

stability control (SC) enabled/disabled

stability control (SC) active/inactive

traction control (TC) enabled/disabled

traction control (TC) active/inactive

active yaw control (AYC) enabled/disabled

active yaw control (AYC) active/inactive

roll stability control (RSC) enabled/disabled

roll stability control (RSC) active/inactive

(dynamic) stability and traction control (STC/DSTC) switch manually on/off

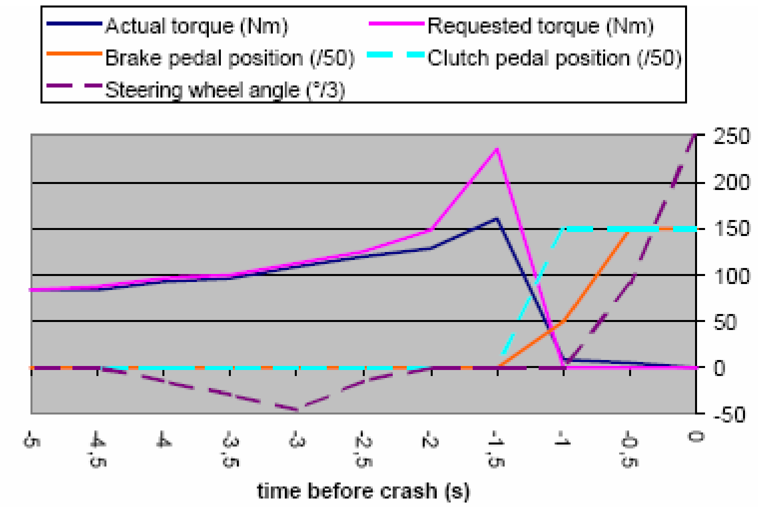


**Figure 7 Illustration of Volvo pre-crash recorder data**

Figure 7 illustrates the type of data available from the Volvo pre-crash recorder. Readings for five parameters are recorded at half-second intervals during the five seconds before impact. The chart shows throttle position ('requested torque') and engine torque ('actual torque') peaking at 1.5 seconds before impact; following this, the clutch and brake pedals are depressed and the steering wheel rotated.

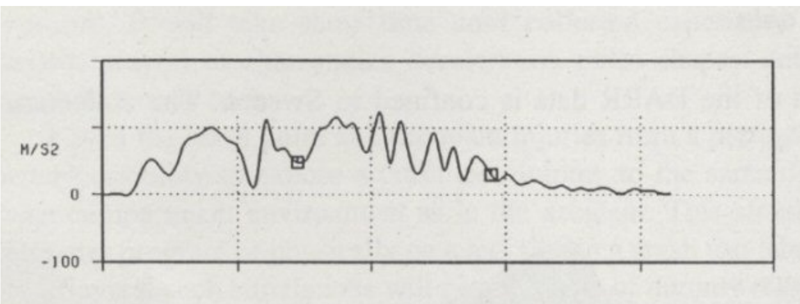

**Figure 8 Accelerometer output from Volvo digital accident research recorder**

Figure 8 shows an acceleration trace from the Volvo DARR EDR over a period of 107 milliseconds; acceleration peaks at over 10 g (100 m/s$^2$) several times in the 30-60 millisecond range. (The time intervals marked on the horizontal axis are 25 milliseconds.)

## 2.4 UDS

The Unfalldatenspeicher (UDS)—literally 'accident data recorder'—is an autonomous, aftermarket EDR manufactured by Siemens VDO Automotive AG (see Figure 1). In 2003 approximately 40,000 devices had been installed in vehicles throughout the world, perhaps around half of these in Europe. European fleets with the device include various police forces (Berlin, Sachsen, German border control, Vienna, Rotterdam-Rijnmond, London Met and other UK counties) and other blue-light vehicles, UK Ministry of Defence, Swiss government, EC SAMOVER research project (Safety Assessment Monitoring on Vehicles with Automatic Recording), Suedbaden Bus, WKD Security, Koetter Security and Hatscher Funkmietwagen. These fleets were first fitted with the device during the years 1995-2001. The equipment and software required to download the data stored in the UDS may be purchased with the device and the information is therefore accessible to the general public. An add-on module can also be purchased for radio transmission of the data. The price of the UDS depends on the options and level of service requested by the customer; €500-600 can be taken as indicative.

The information available from the UDS includes:

- date and time
- ignition on/off
- headlights on/off
- indicators on/off (left and right)
- siren on/off (if applicable)
- blue-lights on/off (if applicable)
- door contact
- seat belt use
- direction of travel (compass)
- brake application

wheel speed

longitudinal acceleration

lateral acceleration

The UDS is capable of storing multiple events. Recording is initiated automatically when the device detects an impact or the vehicle stops, or manually when the operator button or hazard light switch is activated. The duration of recording extends approximately 30 seconds before impact, 15 seconds after impact and 100 milliseconds during the impact phase. Additional post-crash recording is made if the vehicle continues to move, up to about 100 metres. Readings are stored at least 16 times per second (≥16 Hz) during the pre- and post-crash periods and 256 times per second (256 Hz) during impact.

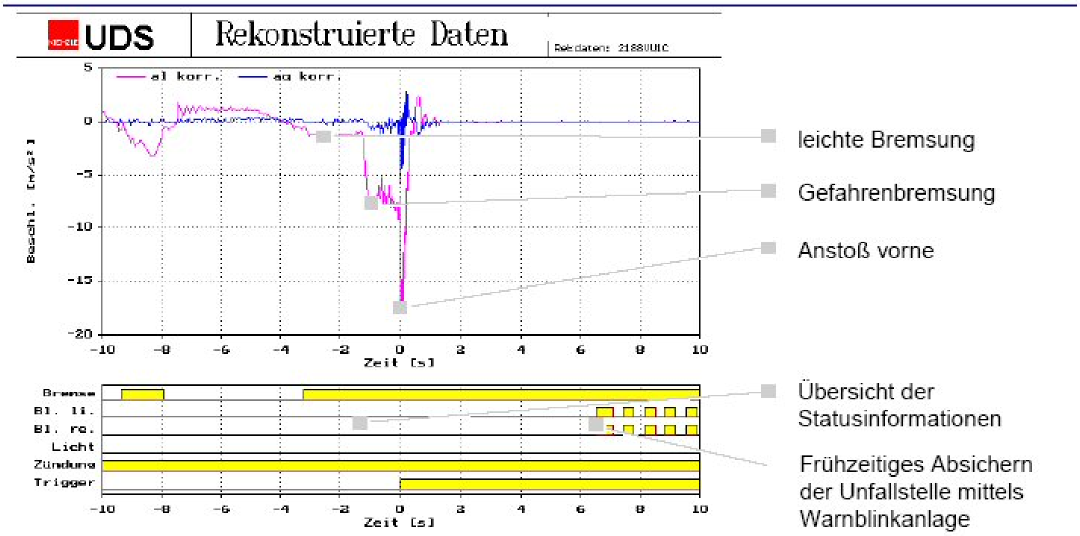


**Figure 9 VDO Unfalldatenspeicher EDR acceleration and input status data elements**

Figure 9 illustrates some of the data elements available from the UDS. In this example a time span of 10 seconds before and after impact is covered. Longitudinal acceleration peaks at about 1.7 g (17 $m/s^2$) during impact (Anstoß vorne); light braking (leichte Bremsung) and emergency braking (Gefahrenbremsung) are shown in the preceding seconds. The lower section of the chart shows from top to bottom the status of brakes, left and right indicators, headlight, ignition and event trigger. The brakes were applied briefly 8-9 seconds before impact and again continuously from 3 seconds before impact; the emergency warning lights were turned on within 7 seconds after the accident.

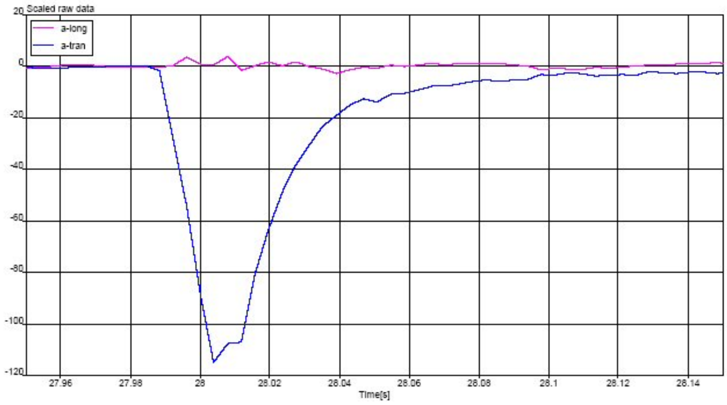


**Figure 10 VDO Unfalldatenspeicher longitudinal and lateral acceleration during impact**

Figure 10 illustrates the detailed measurement of acceleration during impact. In this example longitudinal acceleration peaks at almost 12 g (120 m/s$^2$) while lateral acceleration remains less than 1 g. The time intervals marked on the horizontal axis are 20 milliseconds.

## 2.5 Folksam

The Folksam crash pulse recorder is an autonomous device that records an acceleration pulse by the movement of a mass over a photographic film as indicated schematically in Figure 11.

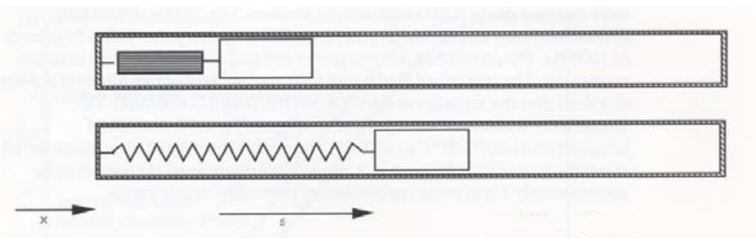

**Figure 11 Principle of operation of Folksam crash pulse recorder**

The mass is retarded by a spring and carries a light-emitting diode that pulses 1000 times per second (1000 Hz), exposing the film as shown in Figure 12. While not a smart technology as characterised above, the system is described here because of the valuable contribution made to research in Europe for over a decade.

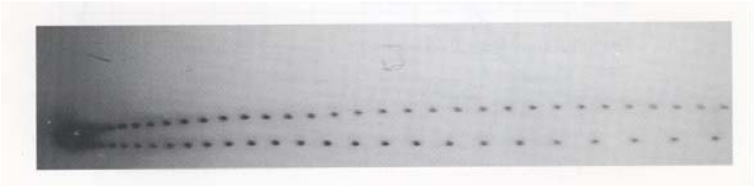

**Figure 12 Record of displacement on photographic film**

In 2003 crash pulse recorders had been installed in approximately 220,000 vehicles since 1992. This includes at least four car makes and twenty-two models. It is understood that this research is based and conducted primarily in Sweden.

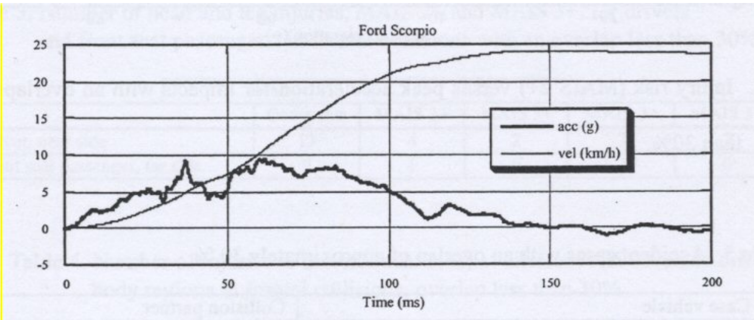


**Figure 13 Acceleration-time history from Folksam crash pulse recorder**

Acceleration and change of velocity can be derived from the Folksam crash pulse recorder. The duration of recording depends on the shape of the crash pulse; around 120 milliseconds can be taken as indicative. Figure 13 shows acceleration peaking at almost 10 g about 60 milliseconds after impact.

## 2.6 National Highway Traffic Safety Administration (NHTSA)

Following recommendations in 1997 from the National Transportation Safety Board (NTSB) to 'pursue crash information gathering using EDRs' and from the National Aeronautics and Space Administration (NASA) and Jet Propulsion Laboratory (JPL) to 'study the feasibility of installing and obtaining crash data for safety analysis from crash recorders on vehicles', NHTSA launched a number of activities in the USA. In 1998 a working group containing industry, academic and governments representatives was formed 'to facilitate the collection and utilisation of collision avoidance and crashworthiness data from on-board EDRs'. This was followed in 2000 by a second working group was formed looking specifically trucks, school buses and motor coaches.

NHTSA has created and maintained a website devoted to EDRs as a technical resource and focal point for collection of information. NHTSA sponsored international symposiums on electronic data recording in 1999, 2000 and 2004 and has supported inclusion of the topic at other more general conferences. In 2002 NHTSA equipped its crash investigation research teams with Vetronix units for downloading EDR data. These research programs include the National Automotive Sampling System (NASS), Special Crash Investigations (SCI) and Crash Injury Research & Engineering Network (CIREN). NHTSA is supporting the compilation of an EDR database at Rowan University, New Jersey for which approximately 2000 cases are available. Even before 2002 NHTSA had worked collaboratively with several manufacturers on the collection of electronic data from their vehicles.

Very recently, in June 2004, NHTSA issued a notice of proposed rulemaking. The proposed rule does not require the installation of EDRs; however if an EDR is voluntarily installed by the manufacturer in a light vehicle, the rule will require from 2008 that the device record a minimum set of data elements, specify requirements for data format, set survivability requirements, and require that the data be accessible.

### 2.7 SAE Vehicle Event Data Interface standards committee

The Society of Automotive Engineers (SAE) formed the Vehicle Event Data Interface (VEDI) standards committee in 2002. Vehicle manufacturers and component suppliers are strongly represented in the group, including Autoliv, DaimlerChrysler, Delphi, Ford, GM, Honda, Mitsubishi, Nissan, Bosch, Siemens VDO, Toyota, Tyco, Vetronics, Visteon and Volkswagen. Among the objectives of the committee to compile the data elements that various manufacturers are currently recording, or may record in the foreseeable future, and to establish a common format for the presentation of this data after being downloaded. The scope is initially restricted to frontal impacts and single events. The committee also considered it outside their remit to recommend whether on-board data recording devices should be mandated and, if so, what type, quantity or manner of data collection should be implemented.

The recommended practice J1698 should be released in the relatively near future after the process of final balloting is completed. It will contain parts covering (1) vehicle output data definitions and (2) data extraction and interface. The first part is expected to include definitions and technical specifications of the data items, including the range and accuracy with which it is feasible to record the information.

### 2.8 IEEE Motor Vehicle Event Data Recorder working groups

The Institute of Electrical and Electronics Engineers Standards Association has very recently finalised (June 2004) the P1616 ‘Standard for Motor Vehicle Event Data Recorders’. The standard defines a protocol for output data compatibility and export protocols for EDR data elements. It does not prescribe which data elements should be recorded or how the data should be collected, recorded or stored internally. The standard is expected to contain terms and definitions, a description of which parameters are appropriate for various purposes, and technical specifications, including the sampling rate, accuracy, range and time with which the data elements should be recorded.

## 3. Discussion

*Impetus and obstacles to further implementation.* In the absence of a legal requirement to install EDRs, the main impetus to wider implementation is likely to be the technical interests of the motor manufacturers themselves. In order to monitor and develop the performance of the smart technologies that are increasingly being incorporated into modern motor vehicles, it is necessary to record the inputs and outputs of the systems. For an advanced supplemental restraint system this is likely to include restraint use and at least the early part of the crash pulse as inputs, for example, and the timing of deployment as an output. Some of this information may be very useful for other purposes such as accident reconstruction, research for improved road safety, and the determination of legal liability, and the groups involved with these activities, including governments, may advocate wider implementation and greater public access to data recorded by on-board systems. Manufacturers however are faced with the expense of developing and installing capabilities that go beyond their own needs—costs that are ultimately passed on to their customers—and must deal with the attitude of their customers toward EDR capabilities in the vehicles. Media coverage of vehicle EDR capability in the USA has at times played up the ‘Big Brother’ theme, and manufacturers are naturally concerned about the possibility of a consumer reaction against their products. This will remain an issue while not all manufacturers have EDRs as it provides a basis for differentiating between models on the market. Consumer reaction on a general scale merges into public acceptance, which in the case of EDRs could become a political problem, like the public acceptance (or otherwise) of police speed cameras. The questions of data ownership, data protection and invasion of privacy are bound to be raised and the resolution of these questions is likely to depend on the particular legal, social and political circumstances in each country. It seems to be widely assumed across the USA and Europe that ownership of EDR data resides with the vehicle owner and that consent or legal authority is needed to access the information.

Further incentives to recording on-board data arise from the other applications of EDRs and data loggers, some of which are mentioned in the Introduction. Insurance companies may offer a discount on insurance premiums if the customer agrees to fit a black box on the expectation that the improvement in driving behaviour, faster resolution of claims and legal proceedings, and detailed data on where, when and how the vehicle is used will justify the cost. Automatic crash notification systems promise faster, more efficient and more appropriate delivery of medical and other emergency services. Large fleet operators, especially self-insured companies, may be attracted by the potential for improved driving behaviour and reduction in accidents (health & safety), operational efficiency, reduction in fraud, and the objective assessment of accident and injury circumstances.

To the extent that it has been publicly discussed, the cost of the production EDRs installed in vehicles to date is understood to be low, as the systems have exploited the surplus memory capacity of supplemental restraint systems, anti-lock braking systems or other advanced technologies. It is reasonable to assume that the cost of providing access to the data through equipment provided commercially, such as the Vetronix CDR, is recouped from the sale of the hardware and software. Governments may need to assess whether the overall benefit to society of encouraging or mandating electronic data recording outweighs the cost. There are some indications that fitting black box recorders to vehicles results in safer driving behaviour; however there is not yet a clear consensus in the literature that an overall net benefit to society from encouraging or mandating EDRs has been demonstrated.

*Accident research.* As mentioned in the Introduction, EDRs are capable of providing information about road accidents based on accurate measurements that is difficult or impossible to infer from the residual post-crash evidence using traditional reconstruction methods. The crash phase is the main focus of secondary safety, where the some of the most important EDR data elements would be:

crash pulse (acceleration), longitudinal
crash pulse (acceleration), lateral
change of velocity, longitudinal
change of velocity, lateral
airbag deployment (by stage, where applicable)
pretensioner deployment (by stage, where applicable)
seatbelt status

Acceleration and change of velocity are directly related to each other. The short duration of the crash phase requires high-frequency recording for parameters that vary rapidly during impact such as acceleration.

Active safety research focuses more on the pre-crash phase, where events develop more slowly and relatively low-frequency recording would generally suffice. In addition to crash phase parameters, some of the more important EDR data elements of immediate interest would include:

vehicle speed
steering wheel angle
brake application
throttle opening
indicator status
headlight status

For accident researchers the first challenge is accessing electronic data. The hardware and software kit marketed by Vetronix Corporation—the only system for extracting data that has been made publicly available—is applicable to very few if any European vehicles, and the authors are unaware of any intention to extend its scope beyond North

America. Secondly, no technical standard for a basic set of data elements has yet been adopted by the industry, although this will change in the USA through NHTSA's proposed rulemaking. Attention will be directed toward ensuring adequate coverage of the crash phase using high-frequency recording and of the pre-crash phase using low-frequency recording. Even in the USA where recorded data can already be collected, it will be of great assistance to accident researchers to have a standard set of parameters that can be directly compared across a wide range of makes and models.

## 4. Recommendations

North America is moving faster than Europe in the installation of production EDRs, the collection of data through research bodies for improved road safety, and the consideration of rule-making. The benefits of these activities in the USA and Canada will however not automatically flow to Europe as the road environment, vehicle fleets, and traffic accident patterns here are significantly different than in North America. It is recommended:

(1) that a political commitment be made in Europe to facilitate the collection and utilisation of collision avoidance and crashworthiness data from on-board EDRs on the model on the National Highway Traffic Safety Administration;

(2) that the European Union consults with the USA to ensure that benefits from the proposed rule on event data recorders will become available in Europe as well as North America;

(3) that research be initiated to form and consult with a group of experts from industry to ascertain what data is available from production EDRs in Europe;

(4) that a pilot study be initiated in Europe to collect data from production and aftermarket EDRs;

(5) that research be initiated on the potential for combining different data recording applications (e.g. data loggers, crash recorders, emergency call-out, road toll collection) into a single black box.

(6) that a review be conducted across European countries on the social acceptability of electronic data recording and legal issues relating to data ownership, privacy and right of access.

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