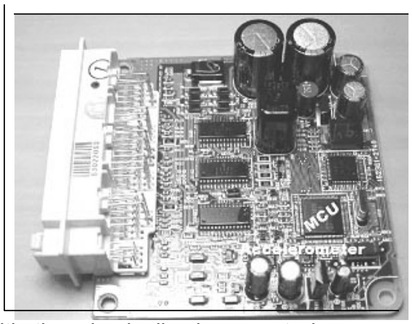
C10 A Method for Evaluating the Reliability of EDR Crash Data and Considerations of Consistency Between EDR Crash Data and Post-Accident Artifacts

William Rosenbluth, MS, Automotive Systems Analysis, Inc., 12015 Canter Lane, Reston, VA 20191*

By describing these efforts and methodology, the attendee will learn the methods of characterizing crash sensor sensitivity. These methods include an introduction to the identification and analysis of public accelerometer specifications and to public micro controller specifications as can be identified from a teardown analysis of the EDR series to be investigated. This analysis is illustrated with an algebraic derivation of EDR unit data sensitivity using binary and hexadecimal arithmetic. Lastly, the process to derive a cumulative velocity loss from a hexadecimal crash record will be shown for an example.

This presentation will impact the forensic community and/or humanity by teaching the attendee to de-mystify the subject of black box data and black box data analysis by seeing practical examples of technical analysis. This will allow the attendees to extend their existing forensic skills, abilities and professionalism by applying them to an area scientific investigation where pre-2000 skills are often inadequate.

SYNOPSIS: This analysis illustrates a method of evaluating the reliability crash record data in Event Data Recorder (EDR) and includes a discussion of the consistency of EDR data with the physically reconstructed evidence after a collision. The method described illustrates an engineering analysis to determine the calibration of an electronic crash sensor, and then requires using series of calibrated acceleration pulses impinged on an exemplar electronic crash sensor to document its response to known input pulses. These steps allow the investigator to derive a calibration transfer function for the raw EDR data versus a known calibrated acceleration input. Once the relationship between the saved EDR data and the external calibrated acceleration pulse is known, the subject electronic crash record could be evaluated for consistency with the physically documented reconstruction evidence.



LEARNING OBJECTIVES: By describing these efforts and methodology, the attendee will learn the methods of characterizing crash sensor sensitivity. These methods include an introduction to the identification and analysis of public accelerometer specifications and to public micro controller specifications as can be identified from a teardown analysis of the EDR series to be investigated. This analysis is illustrated with an algebraic derivation of EDR unit data sensitivity using binary and hexadecimal arithmetic. Lastly, the process to derive a cumulative velocity loss from a hexadecimal crash record will be shown for an example.

THEORY OF THE ANALYSIS: The steps required to accomplish this analysis had to focus on several problems:

Retrieving the Crash-Related Data The first problem to be solved was to develop the ability to read the crash-related data inside the appropriate event data recorder (EDR). This required a study of SAE and ISO guidelines and specifications for vehicle networks, and a verification of which particular sub-specification applied in the instant case. This was done using several vehicle network analysis tools as a network traffic monitor for manufacturer/aftermarket scanner equipment doing similar or partial interrogations. In general, the retrieval development process had to include:

A. Interrogation of the target EDR so as to obtain the desired electronic information [e.g., EEPROM/Flash-memory hexadecimal data]. This information is often enclosed within interrogation commands and responses, not part of the actual desired information.

B. Parsing is the next step. Parsing is the process of extracting the desired electronic information from within the undesired interrogation commands and responses.

C. Formatting, the next step is the process of assembling the parsed data into a structured format so that it can be easily read and interpreted. This often involves adding address identifiers and spaces between data elements.

D. Translation is the fourth step, is the process of performing an evaluation of the address-identified data elements into meaningful engineering units. Data element translation is usually accomplished in accordance with a standard specification such as SAE J2178-2, SLOT instructions [scaling, limits, offset and transfer function guidelines]. Meaningful engineering units allow the investigator to report such parameter facts as acceleration, timing, seatbelt usage, instantaneous velocity change, cumulative velocity change, etc.

E. **Interpretation** of the translated data is the fifth step. Data interpretation involves evaluation of the reported and translated data with respect to their consistency with complementary investigator findings and conclusions [e.g., reconstruction, bio-mechanics, human factors, etc.].

Deriving a Scaling and Transfer Relationship From the Data. A standard for interpreting ECU data hexadecimal values is given as an SAE SLOT definition for the parameter saved at that address, so that the ECU data can be readily interpreted and used for engineering analysis. In general, information for specific ECU SLOT definitions is not publicly available, so it was required to open the appropriate ECU and photographically document its componentry, specifically, its accelerometer and its micro controller. An example of such a photographic documentation is shown in Figure 2.1. Once the key components are identified, as in this case, industry specifications will reveal the SLOT factors specific to those components. As a tutorial example,

A. We assume that the micro controller used an 8-bit A/D converter with a 5,000-volt reference.

B. We assume that the accelerometer used has an output sensitivity of 40G/volt, or 1G/0.0250 volt or 0.0250 volt/1G.

C. We assume that acceleration A/D counts are represented in EDR memory where each byte (8 bits) is a separate value.

For an 8-bit A/D converter as assumed above, it is known that its hexadecimal count range is $00 to $FF (0 dec to 255dec). It can be determined (from manufacturer public specifications) that its full count (255 dec) represents 5.000 volts and that it is a linear radiometric device. Thus, each linear count represents 5.000/255 volts or 0.0196078 volts.

For the accelerometer assumed above it can be determined (from manufacturer public specifications) that its nominal sensitivity of that device is 0.0250 volts/G or 1G/0.0250V.

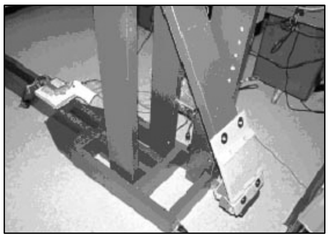
$$\frac{0.019698V}{1count} \times \frac{1G}{0.02500V} \equiv \frac{0.78792G}{1count}$$

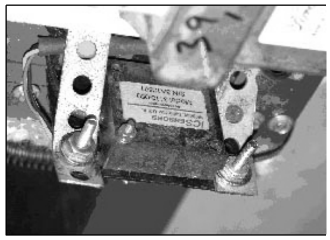
Using those two data specifications, the subject EDR data byte acceleration data sensitivity can be calculated as:

for each byte of an acceleration record.

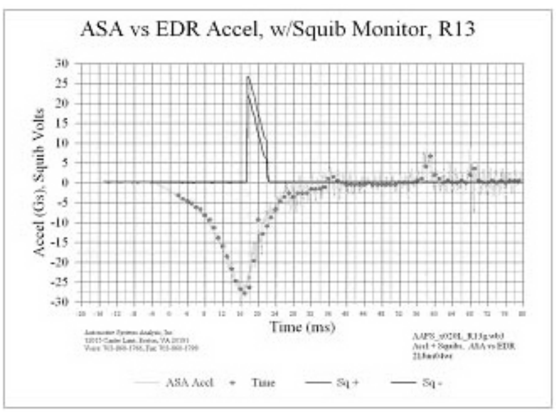
Some EDRs report their crash-related data in units of direct acceleration per time period ($a_{(t)}$), some report units of averaged acceleration per time period $<a_{(t)}>$ and others report their data in units of cumulative velocity change per time period time (_ $v_{(t)}$) . Of course, for any unit time period (t_p), the period velocity change, $v_{(t)}$ is no more than the product *of* $a_{(t)}$ t_p, thus, any subsequent validation of EDR Delta V analysis is really validating the analysis of acceleration recording capability. The above discussion assumes that a reasonably complete crash pulse function is being analyzed. However many EDRs may report their data as a different function that incorporates only a portion of, or derivative of, $a_{(t)}$ or $v_{(t)}$. One such value that may be reported is the cumulative velocity at the time of a deploy command, _ $v_{(t)}$|at fire command. Next the methods and tests to determine and/or confirm such relationships are explored.

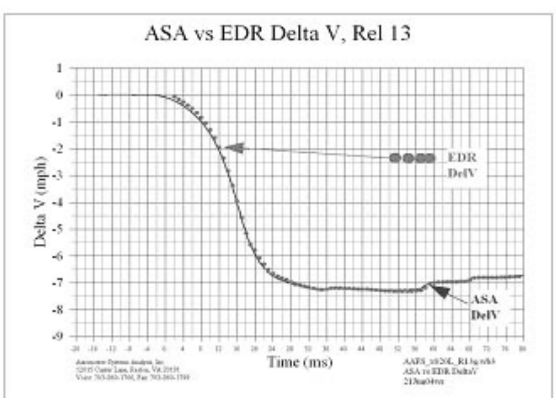
Conducting Tests to Verify the Above Analysis The ultimate validation of any theoretical analysis is a physical trial of the analysis theory. In this case such a trial consists of impinging a known calibrated acceleration pulse on an EDR and then comparing the EDR record with the known input pulse. For confidence this must be done over several calibration levels around the pulse magnitude of interest. Additionally, if the data acquisition system used to record the impinged acceleration pulse also records an air bag/pre-tensioner squib fire pulse, the time relationship from EDR acceleration record start to squib firing decision can be documented (for the test input acceleration pulse). An example of one of the calibration trial (from a process of several such trials) is illustrated the sequence of Figures 3.1, 3.2, 3.3, 3.4, 3.5. This figure sequence shows the accelerationimpingement fixture, the external recording accelerometer, the external acceleration record, the EDR acceleration record, the superposition of the EDR record on the external acceleration record and the squib fire pulse resulting from that external acceleration input. Lastly, Figure 3.6 shows a superposition of the (calculated) cumulative velocity changes for both the EDR and the external acceleration pulse. That superposition shows that the cumulative velocity changes are essentially congruent (thus proving that the EDR is recording a true representation of the input pulse that it was impinged upon it. Additionally, the time value data for the start of squibfire time shown on Figure 3.5 is also called the time of deploy command. This time can be applied to Figure 3.6 to determine the cumulative velocity change at the time of the deploy command, _ $v_{(t)}$at fire command·

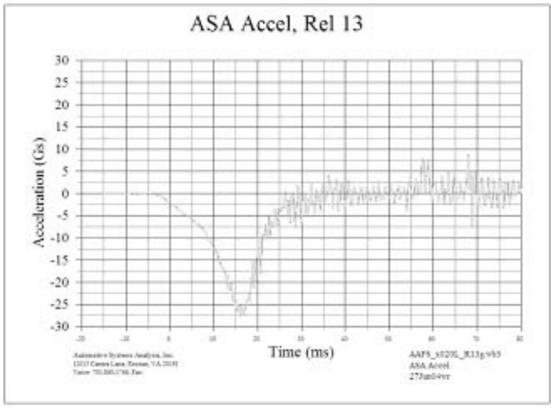


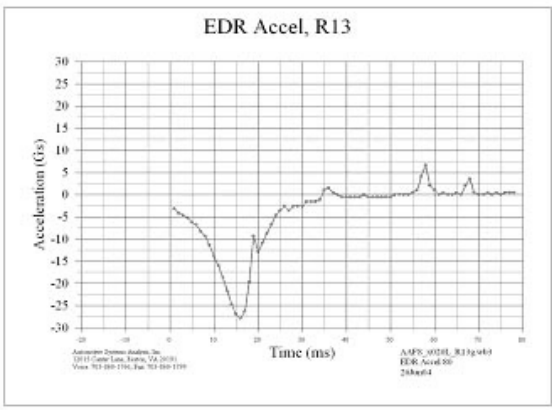


The above example illustrates a reasonably complete example for a substantially complete whole crash-event. However, a similar analysis could actually illuminate a sub-event. Postulating the sub-event as a whole event would be incorrect. Thus the investigator must consider the consistency and plausibility of the physical reconstruction assessment of the ensemble event with every EDR record analysis. Examples of plausible and implausible EDR analyses are shown to assist the investigator in future such determinations.









Electronic Data Recorders, EDR Analysis, Crash Data Analysis