GM Technical Training

Frontal Air Bag Sensing

March 29, 2007
Agenda

- Sensing Overview
- History of Sensing Technology
- Sensing System Development
- Challenges with Discrimination
- Sensing Algorithms (Proprietary information - Slides removed)
- Sensor data vs. EDR
- Q&A
Sensing Overview
Overview

RERAINT SYSTEM COMPONENTS

- Structure
  - Bumper system
  - Front End Sheet Metal
  - Upper Rails and Mid Rails

- Restraints
  - Seat Belts and Pretensioners
  - Air Bags
  - Knee Bolsters

- Sensing System
  - SDM
  - Satellite Sensors
  - Wiring

The sensing system is part of a complex system designed to provide occupant restraint in vehicle collisions.
Sensing Performance Objectives

- Balance sensing performance to achieve occupant performance goals for moderate to severe impacts while reducing the potential for deployments in events where they are not needed.

- Determine deployment level vs. non-deployment level for pretensioner, Stage 1 and Stage 2.

- Determine when air bag should deploy for deployment level events.
Air Bag System Design Considerations

- Regulated Conditions (i.e. FMVSS208)
- Consumer Metric Tests (i.e. NCAP, IIHS)
- Other Field Relevant Impact Conditions (i.e. Bumper Underride and Pole Impact)
- Conditions Where Air Bags should not Deploy (Immunity Conditions)
- Evaluate Various Occupant Sizes
Evaluate Expected Usage

- Where Will Vehicle Be Driven?
  - Less Developed Road Systems
  - Off-Road Conditions
- How Will Vehicle Be Used?
  - Snow Plow Impacts
Considerations May Change

- Changes to Safety Regulations
- Additional Consumer Metric Tests
- Vehicle Usage Influences What Conditions May be Considered
Frontal Air Bag Sensing

- Air Bag Sensors Measure Physical Parameters
- Identify Crashes Likely to Produce Injuries Above a Desired Level
- Air Bag Sensors Measure Vehicle Reaction to the Crashes
- Sensing System Deployment Decision is Based on Information From Vehicle Development Testing
Concept of “Ridedown”

Velted Occupant

V UNBelted Occupant

Ideal Occupant Ridedown Slope

V vehicle

Time

Velocity
Ridedown and Deploy Targets

22.2 kph (13.8 mph) Frontal Barrier Impact

- T_{fill}
- T_{125}
- T_{125-30}
- T_{sense}

Ave. Rear Rocker Long. Velocity
Driver Head Long. Velocity
Driver Chest Long. Velocity

Longitudinal Velocity (kph)

Time (msec)
Crash Sensing Terms

- **Accelerometer**
  - Device used to quantify acceleration, velocity change or distance
  - A sensor which converts an acceleration from motion or gravity into an electrical signal
  - Acceleration integrated over time yields the change in velocity
  - Velocity integrated over time yields displacement or distance traveled
Crash Sensor Locations

**EFS**  Electronic Front Sensor

**SIS**  Side Impact Sensor

**SDM**  Sensing and Diagnostics Module
Crash Sensing Terms

- **Crash Pulse**
  - Period when a vehicle is acting on an object or another vehicle and the resultant characteristics.

- **Acceleration**
  - The rate at which an object’s velocity changes with respect to time.

- **Delta-V**
  - Change of Velocity
  - Velocity is a vector quantity with both magnitude and direction
  - Delta-V in a crash is the difference between the vehicle’s impact velocity and the post impact velocity
  - Delta-V is the area under the curve in a plot of acceleration and time.
Crash Sensing Terms

- **Safing/Arming**
  - A redundant method to confirm that an event is occurring

- **Deployment Time**
  - The time at which the vehicle’s restraint countermeasures are deployed. Deploy time estimates of “T125-30” (the time it takes an unrestrained occupant to move 5 inches minus time it takes to inflate the bag) or targets based on occupant simulation are used prior to having barrier test data.

- **Algorithm Enable**
  - The algorithm is the procedure (program) used to reach the decision of whether and when to deploy restraints
  - When acceleration exceeds a predetermined value, the SDM begins the sensing algorithm calculations to determine whether to deploy the air bags. Typically the enable has been based on acceleration at the SDM, but in some systems the signal at the EFS may enable the algorithm.
History of Sensing Technology
Air Bag Sensing History

- Electro-mechanical sensors with a Diagnostics and Energy Reserve Module (DERM)
- First Generation SDM’s
  - Single-Point Accelerometer based
- Second Generation SDM’s
  - Newer technology hardware
  - Increased Software Capability
  - More Sophisticated Sensing Algorithms
- Electronic Front Sensors
  - Contain accelerometer and microprocessor
  - Process acceleration, make decision and transmit to SDM
- Raw Data Sensors
  - All computations and decisions made at SDM
Today’s Sensing and Diagnostics Module (SDM)

- Located in Passenger Compartment
- Contains:
  - Accelerometer
  - Microprocessor
    - Diagnostics
    - Deployment Control Algorithm
  - Method for Safing
  - Devices that Turn on Current for Deployment Loops
- Communicates on Vehicle Data Network
  - Diagnostic messages
  - OnStar Notification
  - Event Data Recording
SDM Technology
Sensing System Development
Predictive Sensing

- Crash Sensing Must Be Predictive
  - The sensing system must anticipate collision severity that warrants deployment of the occupant restraints.
  - Sensors respond to the input at their location, regardless of the actual point or angle of impact.
  - When the algorithm is enabled, the SDM calculates if the crash parameters are of sufficient severity to deploy the occupant restraints.
  - Deploy decisions are not based on total Delta-V, but on terms that evaluate the early portion of crash pulse ... usually in the first 10 to 60 msec of the crash.
Sensing Development Process

- Develop Air Bag System Test Plan
- Acquire test data for sensing development
- Evaluate occupant data to determine deployment thresholds and target deploy times
- Work with sensing system supplier to determine sensor locations and develop specific sensing performance
- Conduct additional testing as needed
- Review final sensing performance
  - Balance between timely deployments and immunity levels
  - Decisions may be based on vehicle data, simulation results or engineering judgment
Location in Vehicle vs. Pulse

40 mph ODB

Example of Front EFS Signal VS SDM Signal
Red is EFS, Blue is SDM
Number of Sensors

- Factors in Determining Front Sensor Quantities Include:
  - Safety Regulations and Consumer Metric Tests
  - Sensing Algorithm
  - Vehicle Usage
  - Immunity Conditions and Goals
  - Crash Pulse for Deployment Events
  - Test Data For Immunity Events
  - Target Time for Air Bag Deployments
  - Available Sensing Technology
Contributions to Sensing Variability

SDM

Accelerometer Sensitivity  Accelerometer Orientation
Accelerometer Clipping    Integer Based Calculations
Accelerometer Resolution  Structure Resonance
Communication Timing     Filtering

Vehicle

Sensor Orientation  Rails  Mass
Bumper  Chassis  Engine  Welds

Worst Case Variation
Assessing Sensing Variability

Front Sensor (EFS)

Center Tunnel (SDM)
Challenges with Discrimination
How to Make Timely Decisions

- Create measures that allow separation of events without respect to the event type. (e.g. non-deploy barrier from a 25 mph ODB)

- Create measures that allow separation of events of increasing severity with a particular crash type, and develop measures that can classify the crash as a pole, full frontal, angle, ODB, etc.
  - Once event is classified, the signals are processed by the algorithm with calibration values or thresholds related to that event type.

- Use information from additional vehicle locations.
Discrimination Challenges

16 mph Frontal (NDH) vs. 40 mph ODB (ADH) - Velocity

Example of Stage 2 No Deploy vs Stage 2 All Deploy Event
No Deploy Red Vs Deploy Event Green

NDH

ADH
Discrimination Challenges

16 mph Frontal (NDH) vs. 40 mph ODB (ADH) – Acceleration

Example of Stage 2 No Deploy vs Stage 2 All Deploy Event
No Deploy Red Vs Deploy Event Green

Filtered Acceleration High Frequency

NDH

ADH

0 10 20 30 40 50 60
time ms
Discrimination Challenges

Frontal (NDL) vs. 20 mph Angle (ADH) - Velocity

Example of Stage 1 No Deploy vs Stage 1 All Deploy Event
No Deploy Red Vs Deploy Event Green
Discrimination Challenges

Frontal (NDL) vs. 20 mph Angle (ADH) – Acceleration

Example of Stage 1 No Deploy vs Stage 1 All Deploy Event
No Deploy Red Vs Deploy Event Green

NDH

ADH
Parameters Used in Sensing

- Delta-V (at SDM or EFS location)
- Average Acceleration (at SDM or EFS location)
- Slope of Acceleration (at SDM or EFS location)
- Oscillation of Acceleration (at SDM or EFS location)
- Ratio of longitudinal to lateral delta-v
- Ratio of longitudinal to lateral slope of acceleration
- Difference between signals at EFS and SDM
- Difference in signals between EFS (two EFS system)
- Crash classification as a function of time
- The parameters used vary between different sensing algorithms and different sensing suppliers.
Sensor data vs. EDR
When Should An Airbag Deploy?

- Sensing system is developed using data collected during vehicle development
- During an event sensors react to the inputs experienced at their location
- The sensors make a decision by comparing the inputs from the event being analyzed with thresholds that were determined by the data from the tests used to develop the air bag system
- The sensors deploy the air bags if they predict that the event will be severe enough for an air bag
Sensing Decision is Not Determined By:

- **Vehicle Speed Prior to the Collision**
  - Speed can influence crash severity

- **Delta-V of the Crash**
  - Crash severity is also influenced by the time to reach the Delta-v

- **Barrier Equivalent Velocity of the Crash**
A Comment on Event Data Recorder (EDR)

- The top priority of the SDM is to make deployment decisions and perform diagnostics on the restraint system
- The data stored in EDR is a subset of the information that is available to the SDM to make deployment decisions
- EDR records every ten msec, whereas sensors sample at 1 to 4 samples per msec.
Accelerometer Signal vs. EDR at SDM
When: Thursday, March 29, 2007 1:00 PM-4:30 PM (GMT-05:00) Eastern Time (US & Canada).
Where: ODI Conference Room

*~*~*~*~*~*~*~*~*

GM Quarterly Meeting in the afternoon.

GM technical training session in RM 2301 in the morning. (I will send out an invite on this portion soon.)
To: Demeter, Kathleen <NHTSA>; Boyd, Richard <NHTSA>; Person, George <NHTSA>; Quandt, Jeff <NHTSA>; Magno, Gregory <NHTSA>; Morgan, Tina <NHTSA>; Smith, Daniel <NHTSA>

Cc: Cooper, Thomas <NHTSA>

Sent on behalf of: Cooper, Thomas <NHTSA>

Sent: Thur 3/1/2007 4:15:11 PM

Importance: Low

Sensitivity: None

Subject: GM Quarterly Meeting

Categories: 0x00000000

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# NHTSA/GM Quarterly Review

March 29, 2007  
Washington, DC  
AGENDA

<table>
<thead>
<tr>
<th>Time</th>
<th>Subject</th>
<th>Presenters</th>
</tr>
</thead>
</table>
| 9:00  | Principles of Vehicle Operation  
Air Bag Sensing ........................................  
Break ..................................................... 10 mins  
Air Bag Field Assessment Techniques ........  | Matt Jerinksy (WebEx)  
Brian Everest (WebEx)                           |
| 11:30 | Lunch                                                                   | All                             |
| 1:00  | Review of Open Investigations ........................................ 90 mins  | Keith Schultz (WebEx)           |
| 2:30  | GM Investigation Metrics  
- Internal Investigation Metrics .................. 5 mins  
- TREAD Metrics .......................................... 5 mins  | Doug Wachtel (WebEx)            
Gay Kent (WebEx)                                |
| 2:40  | External Investigation Metrics  
& Recall Completion Rates ................................ 15 mins  | Keith Schultz (WebEx)           |
| 2:55  | Roundtable ........................................................................... 20 mins  | All (WebEx)                     |
| 3:15  | Seat Belts Workshop .................................................. 45 mins  | Brian Stouffer (WebEx)          |
| 4:00  | Adjourn                                                                |                                 |
Field Events and Event Data

- Event Data Recorder (EDR): Historical Perspective
- Analysis Overview
- Examples from the Field
  - Example One: Concatenated crash
    - Proper air bag deployment?
    - Commanded roof rail air bags?
  - Example Two: New rollover technology
    - Proper system operation?
Event Data Recording (EDR)

- Sensing and Diagnostic Module (SDM) Function
- The SDM is not a “Black Box” recorder
- The SDM’s top priorities
  - Detect Crashes
  - Deploy the airbags if necessary
  - Perform system diagnostics
- EDR data has evolved over time
EDR Evolution

More objective data with which to evaluate systems and vehicle

Air Bag System Capability and Complexity
Simplified History of EDR Capacity
Air Bag Controllers 1990-2012

SDM EDR Capacity

Parameters

0 5 10 15 20 25 30 35

90 DERM 94-99 SDM 99-03 SDM 04-05 SDM SDM C 06-? Next Gen SDM

General SDM Family

Buckle
Vehicle
System

DERM – Diagnostic Energy Reserve Module
SDM – Sensing and Diagnostic Module
EDR – Event Data Recorder
First & Second Generation SDM
(1994 MY Introduction)

- Records Deployment and Non-Deployment Events
  - DERM – Deployment Only

- Includes information at time of event:
  - State of Air Bag System Warning Lamp
  - Warning Lamp “On Time”
  - Air Bag System Fault Codes
  - Ignition Cycles
  - Longitudinal Delta-V vs. Time (max velocity approximately 28 mph)
  - Time from algorithm enable to deployment command
  - Thresholds Exceeded
  - Max Delta-V for Non-Deployment Event
  - Driver’s Seat Belt Switch Status

- Next Generation SDM (1996 MY introduction)
  - Max delta velocity of approximately 56 mph
  - PSIR switch suppression status
  - Diagnostics for side impact air bags
Third Generation SDM
(1999 MY INTRODUCTION)

- Records Deployment and Non-Deployment Events

- Included additional information at time of event:
  - Time between non-deployment events

- Pre Crash Data
  - Engine Speed (5 samples @ 1 second intervals)
  - Vehicle Speed (5 samples @ 1 second intervals)
  - Throttle Position (5 samples @ 1 second intervals)
  - Brake Switch Status (5 samples @ 1 second intervals)
Fourth Generation SDM (2004 MY INTRODUCTION)

- Records Deployment and Non-Deployment Events
  - Some with minimum recording threshold

- Included additional information at time of event:
  - Lateral delta-v vs. time
  - Accelerator pedal position (2 samples @ 1 second intervals)
  - Cruise control status (2 samples @ 1 second intervals)
  - Transmission actual gear selected at impact
  - Steering wheel angle (5 samples @ 1 second intervals)
  - Antilock brake system status (5 samples @ 1 second intervals)
  - Door Status (closed, ajar, open) at impact
  - Tire pressure low lamp status at impact
  - Headlamp status at impact

- SDM-C – Number of vehicle data parameters reduced
EDR Definitions

- Volatile Memory
  - A type of memory that does not retain its contents after power is lost

- Non-Volatile Memory
  - Memory that will retain its contents after power is lost
EDR Definitions

- **Deployment Event**
  - An event that resulted in a commanded deployment by the air bag sensing system

- **Non Deployment Event**
  - An event severe enough to cause the SDM’s crash sensing algorithm to “enable” or “wake up” but not severe enough to deploy the air bags

- **Deployment Level Event**
  - An event that resulted in a decision to deploy the air bags by the air bag sensing system, but a deployment had been previously commanded
Deployment Event

- A deployment event cannot be overwritten or cleared from the SDM

- Typically the SDM can store up to two different deployment events
Non-Deployment Event

- A non-deployment event can be overwritten by an event that has a greater recorded velocity change
  - In some SDM types, a non-deployment event may be overwritten by the next ND event regardless of severity

- A non-deployment event can be cleared by the SDM after sufficient ignition cycles

- The non-deployment event file may be locked if a deployment event happens within 5 seconds of the non-deployment event

- The non-deployment area may be used to store a second “deployment level” event
Application of EDR Data to Field Events

- Questions to answer can be broad or specific
  - Examples
    - Why didn’t the air bag deploy?
    - Did the system function as intended?
    - Why did only one bag deploy?

- EDR Process – how and when is data written
  - In response to a roadway hazard
  - Data is objective
Data Recording Process

- **Deployment?**
  - YES: Store Data Volatile to Non-volatile Cannot Overwrite
  - NO: Store Data Volatile to Non-volatile Can Overwrite

- **Algo Enable**
  - Gathers Data Makes Calculations Analyzes Compares

- **End of Event**

**Power loss can result in partial or no event record**
Applying EDR Data to a Crash

- **Step One**
  - Is the EDR data recorded for “my crash” or the particular event being analyzed?

- **Step Two**
  - Which crash does the data apply to?
    - Single crash – not an issue
    - Multiple events – an issue
      - Knowing the process for writing data is essential
      - Making use of multiple event counters

- **Step Three**
  - Is the EDR data in harmony with the other available information
  - EDR is an important tool in the analyst’s tool box
  - It is but one tool
Sources of Information
Analyzing a Field Event

- Police Report
- Witness Statements and interviews
  - Driver
  - Occupants of the subject vehicle
  - Bystanders
  - Occupants of other vehicles
- Vehicle Photographs
  - Subject vehicle
  - Adverse vehicle
- Scene Photographs
- Crash Reconstruction
- Tech2 scan tool interrogation
- EDR Data
- Medical Records
When Should an Air Bag Deploy?

- Sensing system is developed using data during vehicle development

- During an event the sensors react to the inputs experienced at their locations

- The sensors make a decision by comparing the inputs from the event being analyzed with thresholds that were determined by the data from the tests used to develop the air bag system

- The sensors deploy the air bags if they predict that the event will be severe enough for an air bag deployment
Sensing Decision Is Not Determined By:

- Vehicle Speed Prior to the Collision
  - Can Influence Crash Severity

- Delta-V of the Crash
  - Crash Severity is Also Influenced by the Time to Reach the Delta-V

- Barrier Equivalent Velocity of the Crash
  - Good tool for estimating magnitude
  - Limited if only one of two or more vehicles is available
  - Understand the ramifications of subject vehicle crush profile
EDR Summary

- The EDR is a tool to help understand what happened during an event
- Additional factors to help understand an event may include such items as:
  - crash report
  - physical damage to the vehicle
  - occupant injuries
  - physical damage to the adverse vehicle/objects involved in the collision
  - information from the scene of the collision
- The EDR data can be used for more than understanding the air bag system performance
Example of EDR Application

- 2005 MY Saab 9-7 Sport Utility
  - Dual Stage Frontal Air Bags
    - Automatic passenger supplemental inflatable restraint (PSIR) suppression
  - Side Curtain Air Bags
  - Crash sensing
    - SDM-DS
    - Two electronic front sensors
    - Rollover Sensing Ros-A

- Single Vehicle Single Occupant Crash
  - Driver lap and shoulder belted, coded “possible injury, none visible”
  - Off roadway, multiple tree impacts
  - An unsubstantiated adverse vehicle crossed the centerline and forced the SAAB 9-7 off the road to the right
  - Speed limit on roadway = 55 mph
  - Daylight, cloudy but dry

- Questions
  - Why didn’t the passenger air bag deploy?
  - What commanded the roof rail air bags to deploy?
**Multiple Event Data**

<table>
<thead>
<tr>
<th>Event Description</th>
<th>Status</th>
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<tbody>
<tr>
<td>An Event(s) Preceded the Recorded Event(s)</td>
<td>No</td>
</tr>
<tr>
<td>An Event(s) was in Between the Recorded Event(s)</td>
<td>Yes</td>
</tr>
<tr>
<td>An Event(s) Followed the Recorded Event(s)</td>
<td>Yes</td>
</tr>
<tr>
<td>The Event(s) Not Recorded was a Deployment Event(s)</td>
<td>No</td>
</tr>
<tr>
<td>The Event(s) Not Recorded was a Non-Deployment Event(s)</td>
<td>Yes</td>
</tr>
<tr>
<td>Associated Events Not Recorded</td>
<td>3</td>
</tr>
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</table>

**System Status At 1 second**

<table>
<thead>
<tr>
<th>Door Status</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Front Door Ajar</td>
<td>No</td>
</tr>
<tr>
<td>Right Front Door Ajar</td>
<td>No</td>
</tr>
<tr>
<td>Left Rear Door Ajar</td>
<td>No</td>
</tr>
<tr>
<td>Right Rear Door Ajar</td>
<td>No</td>
</tr>
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</table>

**Pre-crash data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>-5 sec</th>
<th>-4 sec</th>
<th>-3 sec</th>
<th>-2 sec</th>
<th>-1 sec</th>
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</thead>
<tbody>
<tr>
<td>Vehicle Speed (MPH)</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>53</td>
</tr>
<tr>
<td>Engine Speed (RPM)</td>
<td>1792</td>
<td>1684</td>
<td>1684</td>
<td>1684</td>
<td>1684</td>
</tr>
<tr>
<td>Percent Throttle</td>
<td>16</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Brake Switch Circuit Status</td>
<td>not applied</td>
<td>not applied</td>
<td>not applied</td>
<td>not applied</td>
<td>not applied</td>
</tr>
</tbody>
</table>
## Deployment Event EDR Summary

<table>
<thead>
<tr>
<th></th>
<th>First Deploy</th>
<th>Second Deploy</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIR Lamp</td>
<td>Off</td>
<td>Off</td>
</tr>
<tr>
<td>Cycles, Investigation</td>
<td>1260</td>
<td>1260</td>
</tr>
<tr>
<td>Cycles, Event</td>
<td>1259</td>
<td>1259</td>
</tr>
<tr>
<td>Driver Belt Switch Status</td>
<td>Buckled</td>
<td>Buckled</td>
</tr>
<tr>
<td>Passenger Belt Switch Status</td>
<td>Unbuckled</td>
<td>Unbuckled</td>
</tr>
<tr>
<td>Dr. Seat Pos.</td>
<td>Rearward</td>
<td>Rearward</td>
</tr>
<tr>
<td>Pass. Seat Pos.</td>
<td>Rearward</td>
<td>Rearward</td>
</tr>
<tr>
<td>Automatic PSIR Suppression</td>
<td>Suppressed</td>
<td>Suppressed</td>
</tr>
<tr>
<td>AE to Dr. 1&lt;sup&gt;st&lt;/sup&gt; stage</td>
<td>21.25 ms</td>
<td>0</td>
</tr>
<tr>
<td>AE to 2&lt;sup&gt;nd&lt;/sup&gt; stage</td>
<td>Disposal</td>
<td>0</td>
</tr>
<tr>
<td>Dr. 1&lt;sup&gt;st&lt;/sup&gt; stage commanded</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Dr. 2&lt;sup&gt;nd&lt;/sup&gt; stage commanded</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Dr. SIAB commanded</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Dr./Pass Pretens commanded</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Rollover Sensor Status</td>
<td>Invalid</td>
<td>0-1/4 turn</td>
</tr>
<tr>
<td>AE to RRAB Command</td>
<td>N/A</td>
<td>318.75</td>
</tr>
<tr>
<td>Dr./Pass RRAB commanded</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Longitudinal Delta-V

Longitudinal Axis Deployment Data

Time (milliseconds)

SDM Recorded Velocity Change (MPH)
Second Deployment Event
Longitudinal Delta-V

5S3ET13MXXXXXXXXX  Longitudinal Axis Deployment Level Data

SDM Recorded Velocity Change (MPH)

Time (milliseconds)
Second Deployment Event
Lateral Delta-V

5S3ET13MXXXXXXXXX Lateral Axis Deployment Level Data

SDM Recorded Velocity Change (MPH)

Time (milliseconds)

0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
2005 MY Saab 9-7
2005 MY Saab 9-7
2005 MY Saab 9-7
Example Two: SRX Rollover
D/A 04/26/06

- Date of Crash: April 26, 2006
- Time of Crash: approx. 9:30 AM
- Vehicle: 2006* Cadillac SRX  *with modified 2007 components
- Crash location: Milford Proving Ground Road Course
- Occupants: Driver and right front passenger
- Reported Injuries: Driver (Minor) , Passenger (None)
- Test purpose: Transmission Calibration Verification

Question
- Did this new technology function as intended?
SRX Rollover

Road and weather conditions

- Dry asphalt surface
- “One-way” travel direction (width of road approx. 35 ft.)
- Typical off-road soil shoulder composite soil
- Curves and hills in this section of course
- Concrete “rumble” strips present at selected curves
- Daylight and clear
SRX Rollover

Observations

- ESC (Electronic Stability Control) manually disabled (Off)
- Off road “soil” trip
- Trip speed was approx. 10 -14 mph
- ¼ roll: driver side leading
- Loss of control due to driver input, aggressive driving schedule, and road course terrain
- Rollover trip occurred on an incline (uphill)
SRX Rollover

EDR Summary

- **ROS Data**
  - Rollover Event
  - SDM sync counter = 1350
  - Vehicle speed prior to ROS AE = 54 mph
  - AE to rollover bag command = 4.180 sec.
  - Deploy off battery power
  - ROS in development mode
  - REC mode deployment

- **SDM Data**
  - Pre-crash data about -.5 second
    - speed = 53 mph
    - engine RPM = 4736
    - % throttle = 27
    - brake = off
  - SDM sync counter = 1350
  - Dr. & Pass. = buckled
  - Side bags commanded due to rollover event
  - SDM indicated ROS AE to RRAB command = 4.200 sec.
  - Dr. & Pass. pretensioners and RRAB commanded = YES
ROS Angular Rate Data

EDR A Angular Rate Crash Data

Rate (deg/sec)

Angular Rate

Time (ms)
ROS Lateral Input Data

EDR A Y Accel Crash Data

Acceleration (g)

Time (ms)

Y Accel
ROS Vertical Input Data

EDR A Z Accel Crash Data

Acceleration (g)

Time (ms)

Z Accel
SRX Rollover
Crash scene photos

Final Rest Position
SRX Rollover

Crash scene photos

Both side curtains deployed
SRX Rollover

Crash scene photos

Vehicle up-righted at scene

Note that this damage was caused by tow truck cable during up-righting.
SRX Rollover
Photos of damaged SRX
Driver side

Relatively minor damage:
- Left front wheel
- Left rear wheel
- Driver window
- Side view mirror
- Fender and doors
SRX Rollover

Photos of damaged SRX

Driver side

- Broken mirror and driver window
- Embedded grass and soil

Left Front

- Rim abraded and tire de-beaded

Left Rear

- Embedded stone and soil
SRX Rollover

Tire mark and tire rut identification
SRX Rollover
Tire mark identification

Right rear tire sidewall scuffing
Right rear tire mark on rumble strips

Right Front and Left Rear

GM VEHICLE STRUCTURE & SAFETY INTEGRATION
Field Performance Assessment

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SRX Rollover
Asphalt gouge and tire mark identification

Asphalt gouging from Left Front rim
SRX Rollover

ROS Algorithm Enable area (near rumble strip)
approximately 140 feet

Contact with rumble strip to Final Rest Position
approx. 140 ft.

Final Rest Position

Concrete "Rumble" Strip

SRX accident (Road Course)
Driver side leading 1/4 Roll

Fog Line

Concrete "Rumble" Strip

Fog Line

Concrete "Rumble" Strip

Fog Line

Glass

Left front
Right front
Left rear
Right rear
SRX Rollover

Scene diagram overlaid onto enlarged aerial section
SRX Rollover
Preliminary speed calculations

Speed at 1st rumble strip:
Approx. 52 - 56 mph

Speed at 2nd rumble strip:
Approx. 45 - 52 mph

Trip speed:
Approx. 10 - 14 mph
THE END