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Rollover Data Special Study Final Report

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13. ABSTRACT (Maximum 200 words).

This report summarizes research results from the Rollover Data Special Study (RODSS) project. The research encompassed the design of a RODSS database for the National Highway Traffic Safety Administration, review of the RODSS data to evaluate the quality of the data collected and whether they can support crash safety evaluations, and analysis of detailed rollover crash data records to assess the effectiveness of recent safety features in light vehicles (e.g., passenger cars, sport utility vehicles, minivans, vans, and light pickup trucks) in minimizing the occurrence of rollover crashes and in mitigating occupant injuries that result from such crashes. These safety features include rollover protection that includes sensors to trigger inflatable side curtain air bags to mitigate occupant injuries, electronic stability control to reduce loss of yaw control, and roll stability control to minimize the number of rollover crashes.

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EXECUTIVE SUMMARY

This report presents a summary of the research conducted on the Rollover Data Special Study (RODSS) project. This effort was initiated in support of the National Highway Traffic Safety Administration's (NHTSA) research in rollover occupant protection. Rollover crashes still comprise a disproportionately large number of highway fatalities. Although they account for only three percent of vehicles in crashes, they lead to approximately one-third of all occupant deaths. Some vehicle safety features recently introduced in the motor vehicle fleet may be contributing to a reduction in rollover crashes and the harm they cause. These features include rollover protection which includes sensors to trigger inflatable side curtain air bags (SCABs) to mitigate occupant injury, Electronic Stability Control (ESC) to reduce loss of yaw control, and Roll Stability Control (RSC) to minimize the number of rollover crashes that occur.

The objectives of the RODSS project included the following:

- Investigate a new data collection process and document whether it can augment NHTSA's existing methodologies.
- Review the RODSS data to evaluate the quality of the data collected and whether it could support crash safety evaluations
- Review rollover cases involving vehicles equipped with SCABs (with or without rollover sensing) to examine their effectiveness in preventing ejection.
- Review rollover cases for a sample of vehicles with ESC to examine the kinds of rollover crashes that may occur after ESC becomes standard equipment

The objective of the RODSS program was to determine if it was feasible to obtain additional crash data, how to accomplish it, and have the data coded into a RODSS specific case database. NHTSA was in need of additional data on rollover crashes. It was known that there were additional crashes outside those being captured by the National Automotive Sampling System (NASS), Special Crash Investigations (SCI) and Crash Injury Research and Engineering Network (CIREN) programs. The RODDS project was to obtain local police investigation reports from jurisdictions outside the NASS sampling area. A Special Crash Investigator would then review the reports and enter a common set of data elements about the crash. Initially, recent crashes were selected from the Fatality Analysis Reporting System (FARS) and General Estimate System (GES) databases. It was later established that only the FARS database would be queried for potential cases, because severe cases would involve specialized police crash reconstruction teams that would take photos and conduct a higher level crash investigation. RODDS then was limited to only crash cases from the FARS database. Data from 328 cases were collected and coded in this project. The criteria for case selection included: model year 2000 and newer vehicles (with or without ESC and/or SCABS) and the availability of crash scenes photographs/images.

Calspan's Crash Data Research Center (CDRC) was contracted to collect the applicable crash investigation cases, review the materials, and code the entries into a database. NHTSA and Volpe staff identified a subset of vehicle and rollover crash data variables. The data elements were collected into Microsoft Access to facilitate case review.

The RODSS project collected 328 rollover cases, 68 percent of which were single vehicle crashes. More than half of these rollover occupants were belted. About 30 percent of the cases involved a driver under the influence of alcohol. In addition, approximately 40 percent of the rollover occupants involved in rollover crashes were ejected, with 87 percent of the ejected occupants unbelted. The majority (60 percent) of the ejected occupants exited through the side windows. The cases selected for this study were intended to include all ESC equipped vehicles, However, only sixty-two percent of the rollover involved vehicles were equipped with ESC. Approximately 10 percent of the vehicles were equipped with rollover sensing. About half of the side curtain airbags deployed during the crash events.

Fifty-one RODSS cases were analyzed to examine SCAB performance in rollover crashes and to look at rollover conditions for vehicles with ESC/RSC systems. The analysis showed that approximately 30 percent of the occupants in vehicles equipped with SCABs with rollover sensing were ejected. Four of these 12 ejections occurred through the side window/door areas. The SCABs did not deploy during two of the four ejection events. The case data did not provide sufficient information to determine a cause of the non-deployments. The other two ejections occurred from vehicles where the SCABs deployed. However the results also show that there were fewer (approximately 70 percent less) side window ejections in vehicles equipped with SCABs with rollover sensing compared to vehicles equipped with SCABs without rollover sensing.

Local crash investigation data can be useful as a supplement to the existing crash data systems. The limitations of these data sources must be considered in planning this type of study. The quality and availability of local crash investigation information varied widely and was generally focused on crash causation and documenting criminal liability. For the cases with photographs, there were insufficient interior photographs to evaluate occupant injury sources. Complete crash reconstructions tend to be available for more serious crashes and crashes where there is a potential requirement for criminal prosecution. However, given the appropriate topic, this methodology seems appropriate to support anecdotal studies on emerging safety concerns.

1.0 Background

In 2008 motor vehicle crashes resulted in 37,261 fatalities and 2,346,000 injuries in the United States. The Research and Innovative Technology Administration (RITA), Volpe National Transportation Systems Center (Volpe Center) provides technical support to NHTSA in crashworthiness and crash avoidance research. This research supports NHTSA's mission to save lives, prevent injuries, and reduce health care and other economic costs associated with motor vehicle crashes.

Rollover crashes still comprise a disproportionately large number of highway fatalities. Although they account for only three percent of vehicle crashes, they lead to approximately one-third of all occupant deaths. Some vehicle safety features recently introduced in the motor vehicle fleet may be contributing to a reduction in rollover crashes and the harm they cause. These features include rollover sensors to trigger inflatable SCABs (aka rollover protection) to mitigate occupant injury, Electronic Stability Control (ESC) to reduce loss of yaw control, and Roll Stability Control (RSC) to minimize the number of rollover crashes that occur. These safety features are typically installed in Light Trucks and Vans (LTVs).

2.0 Objectives

The Volpe Center conducted research on the Rollover Data Special Study (RODSS) project. This effort was initiated in support of NHTSA's research in rollover occupant protection. The following objectives were addressed:

- Prepare RODSS variable list for database input
- Review the RODSS data to examine the distribution of various rollover variables
- Review rollover cases involving vehicles equipped with SCABs (with or without rollover sensing) to examine their effectiveness in preventing ejections.
- Review rollover cases for a sample of vehicles with ESC to examine the kinds of rollover crashes that may occur after ESC becomes standard equipment.
- Provide a list of the items learned during the case analysis
- Prepare a final report summarizing the results

3.0 Background Information on RODSS

The RODSS project was initiated in 2006 as an effort to collect additional rollover crash data involving crashes outside the police jurisdictions sampled by NASS. The objective of the Rollover Data Special Study (RODSS) program was to utilize local police investigation data to provide additional rollover crash data. The scope of this project was to determine the availability and suitability of local police collected data for anecdotal crash safety evaluations. Initially, the Fatality Analysis Reporting System (FARS) and General Estimate System (GES) databases were to be queried for potential crashes that met the RODSS criteria. It was later decided that the fatal cases in the FARS database were more likely to have reconstruction data and photos. In all, data from 328 rollover cases were collected and coded into the RODSS database.
The RODSS case data was stored in a Microsoft Access database. This database contains a total of 139 variables which were derived from police reports and scene photos.

4.0 Preparation of RODSS Variable List and Database Development

Variables contained in the NASS Crashworthiness Data System (CDS), FARS, and CIREN coding manuals were examined by Volpe in collaboration with NHTSA to identify those variables that would be useful in the RODSS database. Additional consideration regarded which variables could be discerned or estimated from police records or photographs. An initial list of 70 preliminary variables was provided to NHTSA and is listed in Appendix 1. This list of variables was modified and expanded to include a total of 139 variables (Appendix 2).

The RODSS database was developed by NHTSA. The database contains seven tabs which include variables for the data fields listed below. The numbers in parentheses denote the number of variables in each data field.

Case Summary (11)
Vehicle Information (14)
Driver Information (24)
Occupant Information (27)
Pre-Crash Information (15)
Glazing Information (15)
Rollover Information (33)

5.0 Initial RODSS Case Selection Criteria

Initially, FARS cases were elected from calendar years 2005-2007. The criteria for case selection included the following:

a. Model year 2000 and newer passenger car and LTVs
b. Vehicle must be involved in a rollover crash
c. Vehicle must be equipped with ESC and/or SCABs as standard equipment

The Vehicle Identification Number (VIN) obtained from the applicable Police Accident Report (PAR) was used as input to a VIN decoding software to check the availability of ESC and SCABs as standard equipment. A total of 325 FARS cases were initially selected as potential cases to be investigated for the RODSS effort.

5.1 RODSS Data Collection Process

Calspan's Crash Data Research Center (CDRC) was awarded a contract in April 2007 to initiate the RODSS data collection, processing, and coding of the required variables in the database. The CDRC is the NASS Zone Center and Special Crash Investigation (SCI) Contractor for NHTSA. The CDRC reviewed the 325 cases to determine the availability of the standard equipment, reconstruction reports, photographs or images, and to confirm that each case was a non-CDS case. The PAR did not always indicate whether photographs were available and whether a reconstruction was initiated. The CDRC contacted the Investigating Police Agency to obtain the police photographs/images of the crash along with the PAR and reconstruction report. The Investigating Police Agency was determined from the PAR and an internet search was

conducted to obtain the appropriate telephone contact information. The CDRC contacted via telephone the appropriate division (e.g., Records or Photo Lab) to determine the availability of the documents. In addition, the CDRC prepared a letter request with supporting documentation and mailed it to the appropriate division. In some cases, there was a fee for the documents. In all cases, the CDRC staff adhered to confidentiality requirements for handling and disposal of the provided information. The CDRC agreed to adhere to customary NHTSA data collection procedures which require the reports, photographs, and diagrams to be destroyed before public release of the study data. For this study the photographs were mandatory for understanding the rollover crash conditions and without these photographs, there was insufficient information to document the rollover crash.

The reconstruction reports were provided in various levels of detail. Some were full reconstruction reports containing in-depth PARs which included detailed interviews, laboratory (including blood alcohol concentration (BAC)) and medical reports, officer's opinions and conclusions, speed estimates (not common), detailed scene schematics, and a detailed reconstruction of the crash dynamics. In addition, 13 of the reconstruction reports provided printouts obtained from the vehicle's Event Data Recorder (EDR) using the Bosch Crash Data Retrieval software. These outputs were restricted to Ford and GM vehicles. The reconstruction of the crash dynamics included a description of the pre-crash, crash, and post-crash phases of the crash (including trajectories, driver actions, and maneuvers). The vehicle travel speed was estimated using software applications or hand calculations. Some police reports were not very detailed. When provided, the reconstruction reports were separate reports from the standard State Forms. Some police agencies classified reconstruction reports as internal documents and were unable to provide them. In general, police reconstruction reports were typically written for the following reasons:

a. As a response to crashes involving serious injury and/or fatality
b. To determine fault and to criminally charge appropriate party
c. To protect/determine culpability of State/County roads, signage, and/or vehicle

As a result, the local police reconstructions tended to focus on crash causation and roadway construction or roadside hardware. There was significantly less information on vehicle structure, restraints, or occupant injury than is available in a typical NASS CDS case. A total of 185 cases contained photographs/images obtained from the crash scene and were coded in the RODSS database. Sixty-six out of these cases contained reconstruction reports in various levels of detail.

5.1.1. Exclusion of FARS Cases for RODSS Database Input

Due to the issues itemized below, the above case selection criteria was expanded to include all the model year 2000 and newer (up to mid 2007 – 2008 coverage years) vehicles (with or without ESC and/or SCABs). In addition, the availability of crash scene photographs/images was included as the most important criteria for selecting the cases for RODSS. An additional 143 potential cases were selected which contained photographs obtained from the crash scene. A total of 25 out of the 143 cases contained reconstruction reports in various levels of detail. In summary, there were a total of 328 (185 plus 143) cases selected for the RODSS study.

The number of cases was eliminated from inclusion due to the following:

a. VIN Decoding Software Issues

   Errors found in NHTSA's VIN decoding software resulted in some vehicles being incorrectly identified as having the ESC and/or SCABs as standard equipment. In addition, ten FARS cases were eliminated due to the VIN software identifying a Volvo heavy truck (non-CDS vehicle) with air bags as the case vehicle. If the VIN breakdown did not list the SCAB as being available as standard equipment, then an internet search was conducted to confirm this. It should also be noted here, that in certain cases, the availability of ESC as optional equipment was not able to be determined using internet sources.

b. There were no crash scene photographs/images available for the case.

c. Some of the photographs/images were incomplete and others were unusable (e.g., nighttime photographs/images, scene without case vehicle, views of undercarriage only, etc.).

d. The selected case was a NASS CDS case.

e. State/Police Issues

Certain police departments contacted by the CDRC did not wish to participate in this project. On the other hand, police agencies from states such as California, Colorado, Maryland, New York, Florida, and Missouri were very helpful in providing the information requested by the CDRC.

5.1.2 Issues with Police Reconstruction Teams

As stated previously, the reconstruction reports were provided to the CDRC in various levels of detail. The states which provided detailed PARS/Reconstruction reports included Missouri, Colorado, California, New York, and South Portland, Maine. The other states were hit or miss depending on the crash, location, and the agency. The majority of state police agencies and large county/city police departments have dedicated crash investigators and reconstruction divisions.

The inconsistent level of detail of the reconstruction reports can be attributed to the lack of manpower. Several jurisdictions have limited manpower to cover an entire state. Although a reconstructionist may be called to the scene of a fatal crash or to initiate a follow-on investigation, he/she may not complete a detailed report due to backlog and/or crash type. Other reasons associated with the inconsistencies in the level of detail of the reconstruction reports are listed below:

a. Funding issues to support training and equipment acquisitions
b. The reconstruction activity was not perceived to provide any direct benefit to the department

c. The reconstruction process usually takes full-time personnel out of service. On-duty officers generate revenue and provide direct services to "protect and serve"
d. Some agencies scale back on the number of responses and investigations. For example, in the case of a single vehicle crash with a driver fatality there is no one to criminally charge and therefore, no perceived need to conduct an investigation.

6.0 Processing of RODSS Data for Database Input

Case numbers were assigned to each crash investigation received. The format of the case number was (RAABBB). The definitions of these characters are noted below:

R – denotes RODSS
AA – denotes the year of the crash
BBB – denotes the consecutive sequence number

The CDRC reviewed all of the reports and documentation from each rollover crash. The CDRC recorded consistent variables related to the vehicle (including glazing), driver, occupant, rollover event, and pre-crash conditions. Some of the variables collected included vehicle year, make, and model, safety equipment (e.g., air bags, ESC, etc.) availability, vehicle damage, roof crush, air bag curtain deployment and damage, tire/wheel condition, vehicle speed, occupant demographics, injury severity, and safety belt use.

The CDRC prepared a detailed summary of each rollover event including a description of the pre-crash conditions, rollover event, and post-crash conditions with available data. Several variables were coded based on the reviewer's interpretation of the available reconstruction information. Information on glazing damage was generally obtained from available photographs. Information on curb weight and air bag system availability was obtained from the VIN decoding software (PCVINA) used by CDRC

6.1 Overview of RODSS Cases

A summary of RODSS cases are shown in Tables 1 through 11. Table 1 shows the distribution of RODSS cases by the number of vehicles involved in the rollover crash. As shown in Table 1, the majority (68 percent) of the rollover cases were single vehicle crashes whereas 26 percent involved two vehicles. The RODSS cases were drawn from fatal rollover accidents with available crash reconstructions and are not nationally representative. Table 2 shows the distribution of RODSS cases by the number of occupants in the case vehicle. As shown in Table 2, half of the rollover crashes involved the driver only and approximately 30 percent involved vehicles containing two occupants. Table 3 shows the distribution of occupants in rollover crashes by restraint use. As shown in this table, over half of the occupants in rollover crashes wore their safety belts. Table 4 shows the distribution of drivers in rollover crashes by age and gender. As shown in Table 4, the majority (approximately 70 percent) of the drivers were male and approximately half of them (52 percent) were between the ages of 20 and 40. Table 5 shows the distribution of RODSS cases by driver alcohol involvement. The distribution shows that in approximately 38 percent of the known RODSS cases, the driver was reported as being under the influence of alcohol. Table 6 shows the distribution of occupants in rollover crashes by ejection

(including partial ejections) status. The distribution here shows that approximately 40 percent of all the occupants were ejected.

Table 7 shows the distribution of occupant ejections in rollover crashes by seat position and ejection medium. As shown in the table, approximately 60 percent of the ejections occurred through the side windows. In addition, approximately 15% of the ejections occurred through the sunroof. Table 8 shows the distribution of RODSS cases by vehicles equipped with ESC. As shown in this table, the majority (62 percent) of the vehicles were equipped with ESC. Approximately 40 percent of these vehicles were also equipped with SCABs. In addition, there was only one RODSS case where the vehicle was known to be equipped with RSC. The vehicle was a 2005 Ford Explorer and the tailgate was labeled with RSC. It should be noted here that the availability of RSC was difficult to determine. Table 9 shows the distribution of RODSS cases by vehicles equipped with SCABs and the deployment status of these safety devices. As shown in this table, approximately 40 percent of the vehicles were equipped with SCABs. In addition, approximately 10 percent of the vehicles were equipped with rollover sensing. As also shown in Table 9, approximately half of all the SCABs deployed during the crash event. It should also be noted that 90 percent of all the SCABs with rollover sensing deployed during the crash event. Table 10 shows the distribution of RODSS cases by vehicle roof crush in the vertical and lateral direction. More than 60 percent of the cases had 10 inches or less of roof crush in the vertical and lateral directions. Over half of the vehicles were equipped with roof racks. There were three RODSS cases where this equipment contributed to the roof crush.

Table 1. Distribution of RODSS Cases by Number of Vehicles in the Rollover Crash

Number of RODSS Cases	Number of Vehicles Involved in the Rollover Crash	Percent of Total
224	1	68%
85	2	26%
14	3	4%
5	>3	2%
Total 328		100%

Table 2. Distribution of RODSS Cases by Number of Occupants in Case Vehicle

Number of RODSS Cases	Number of Occupants in Case Vehicle	Percent of Total
164	1	50%
86	2	26%
39	3	12%
39	>3	12%
Total 328		100%

Table 3. Distribution of Occupants in Case Vehicles Involved in Rollover Crashes by Restraint Use

Total Number of Occupants	Belted				Unbelted			
	Driver		Passenger		Driver		Passenger	
	Count	Percent[1]	Count	Percent[2]	Count	Percent[1]	Count	Percent[2]
656	187[3]	57%	182[4]	56%	134	41%	136	41%

Notes:
1 – Denotes percent of all drivers
2 – Denotes percent of all passengers
3 – There were 7 cases (2% of all drivers) where the restraint use of the driver was unknown.
4 – There were 10 cases (3% of all passengers) where the restraint use of the passenger was unknown.

Table 4. Distribution of Drivers in Rollover Crashes by Age and Gender

Age	Male		Female		Total	
	Count	Percent	Count	Percent	Count[1]	Percent
≤ 20	22	10%	7	7%	29	9%
21-30	70	31%	21	21%	91	28%
31-40	47	21%	19	19%	66	20%
41-50	28	12%	24	24%	52	16%
51-60	24	11%	11	11%	35	11%
61-70	16	7%	14	14%	30	9%
> 70	15	7%	4	4%	19	6%
Unknown	3	1%	2	2%	5	2%
Totals	225	100%	102	100%	327	100%

Notes:
1 – There was one case where the driver gender was coded as unknown

Table 5. Distribution of RODSS Cases by Driver Alcohol Involvement

Number of RODSS Cases	Driver Alcohol Involvement	Percent of Total
102	Yes	31%
170	No	52%
16	Not Reported	5%
40	Unknown	12%
Total 328		100%

Table 6. Distribution of Occupants in Rollover Crashes by Ejection Status

Occupant And Ejection Status	Yes		No		Unknown	
	Count	Percent	Count	Percent	Count	Percent
Driver	137	42%[1]	188	57%[1]	3	0%[1]
Other Passengers	121	37%[2]	199	61%[2]	8	2%[2]
Totals	258	39%[3]	387	59%[3]	11	2%[3]

Notes:
1 – Denotes percent of all drivers
2 – Denotes percent of all passengers
3 – Denotes percent of all occupants

Table 7. Distribution of Occupant Ejections in Rollover Crashes by Seat Position and Ejection Medium

Occupant Seat Position	Ejection Medium						
	SW[1]	Doors	FWS[2]	RBL[3]	Roof	Sunroof	Unk[4]
Driver	75	14	3	1	14	23	7
Right Front	33	2	4	0	5	13	2
Left Rear	18	0	0	0	0	3	0
Middle Rear	8	0	0	0	0	0	2
Right Rear	15	2	0	0	2	0	0
3rd Row Left	4	0	0	0	0	0	0
3rd Row Middle	2	0	0	0	0	0	0
3rd Row Right	2	0	0	0	0	0	0
Unknown Rear	1	0	0	3	0	0	0
Totals	158	18	7	4	21	39	11

Notes:
1 - SW denotes Side Windows
2 - FWS denotes Front Windshield
3 - RBL denotes Rear Back Light
4 - Unk denotes Unknown

Table 8. Distribution of RODSS Cases by Vehicles Equipped with ESC

Equipped with ESC	Count	Percent
Yes	204[1]	62%
No	93	28%
Unknown	31	9%
Total	328	100%

Notes:
1 – 90 of 204 vehicles (44%) were equipped with SCABs

Table 9. Distribution of RODSS Cases by Vehicles Equipped with SCABs and Deployment Status

Total Number of RODSS Cases	Vehicles Equipped with SCABs (Percent of Total RODSS Cases)	Vehicles Equipped with Rollover Sensing (Percent of Total RODSS Cases)	SCABs Deployed (Percent of Total Vehicles Equipped with SCABs)	SCABs Deployed with Rollover Sensing (Percent of Total SCABs with Rollover Sensing)
328	122 (37%)[1]	27 (8%)[2,3]	60 (49%)[4]	18 (86%)[5]

Notes:
1 – 4 of 328 cases were unknown
2 – 17 of 328 cases were unknown
3 – 5 of 27 vehicles were convertibles with automatic roll bars
1 of 27 vehicles was equipped with RSC but no SCABs
4 – 11 of 122 cases were unknown
5 – 3 of 27 cases had no deployment

Table 10. Distribution of RODSS Cases by Estimated Vehicle Roof Crush*

Roof Crush (Inches)	Vertical		Lateral	
0 – 5	129	39%	185	56%
6 – 10	80	24%	58	18%
11 – 20	58	18%	10	3%
> 20	6	2%	2	1%
Unknown	55	17%	73	22%
Totals	328	100%	328	100%

* Notes:
1 - 177 of 328 (54%) vehicles equipped with roof racks
2 - There were 3 RODSS cases where this equipment contributed to the roof crush.
3 - 30 cases were unknown

6.1.1 Analyses of RODSS Cases Involving SCABS

The following 51 RODSS cases were analyzed to determine the effects of vehicle safety features such as inflatable rollover protection and ESC/RSC in preventing or mitigating injuries and the occurrence of rollover crashes.

2005 FARS

R05004, R05006, R05010, R05011, R05012, R05014, R05019, R05021, R05022, R05023, R05030, R05032, R05041, R05044, R05046, R05048, R05070, R05071, R05073, R05076, R05077, R05154 (total = 22)

2006 FARS

R06080, R06081, R06089, R06092, R06098, R06109, R06110, R06116, R06118, R06119, R06121, R06122, R06129, R06130, R06145, R06147 (total = 16)

2007 FARS

R07195, R07198, R07199, R07219, R07220, R07238, R07242, R07254, R07269 (total = 9)

2008 FARS

R08283, R08284, R08289, R08302 (total = 4)

The analysis involved reviewing each case including available photographs/images, crash summaries, and relevant variables to document information such as critical pre-crash event, ESC effectiveness, ejections (full and partial), ejection medium, occupant injuries and injury sources, air bag contact, air bag deployment/non-deployment, and safety belt usage, etc. A summary for 33 of the 51 RODSS cases is contained below. It should also be noted that these 51 cases contained limited information on injuries and injury sources and did not contain sufficient interior photographs denoting interior contact points including contact with the SCAB. The assessment of the effects of the SCAB was based on a reasonable inference of the occupant kinematics in the vehicle during the rollover event including the possible contact with the SCAB.

Table 11 shows the distribution of the above listed 51 RODSS cases by the critical pre-crash event. As shown in Table 11, in 32 of the 51 cases (63 percent), the critical pre-crash event involved a single vehicle departing the roadway to a paved or non-paved surface. In 14 cases the pre-crash event involved two vehicles colliding prior to the case vehicle departing the roadway. The other five cases involved an unknown cause of vehicle control loss (4 cases) and a disabling vehicle failure (1 case). Table 12 shows the distribution of ESC performance for the above 51 cases. It should be noted here that the ESC was assumed to be in the "On" position for all the RODSS cases examined. It should also be noted that the maximum speed at which ESC remains effective is a situation dependent parameter [1]. The three factors which affect the performance of the ESC at a given speed include: available friction, severity of maneuver, and ESC tuning. As shown in Table 12, in one-third of the cases, the high speed and operating conditions appeared to limit the effectiveness of the ESC. As also shown in Table 12, 12 cases involved vehicle-to-vehicle impacts which precluded the ESC from being a benefit. In addition, one third of the cases involved a vehicle not equipped with ESC and another 5 cases involved operating conditions that did not require ESC engagement.
Table 13 shows the distribution of occupant ejections (full and partial) by restraint status. As shown in the table, approximately 90 percent of the ejected occupants were completely ejected from the vehicle. Over half of the partially ejected occupants were belted. Table 14 shows the distribution of non-ejected occupants by restraint status. As shown in the table, 80 percent of the non-ejected occupants were belted.

Table 15 shows the distribution of occupant ejections (full and partial) in vehicles equipped with SCABs (without rollover sensing). As shown in the table, 44 percent of the occupants were ejected. As noted on the bottom of Table 15, a total of 13 of the 24 ejections (54 percent) occurred through the side window/door areas. The SCABS did not deploy during 8 of the above 13 ejection events. Based on examination of available photographs and crash summaries, it was not clear whether the SCABs without rollover sensing would have been expected to be deployed. The five ejections which occurred in the vehicles in which the SCABs were deployed can be attributed to the SCABs without rollover sensing having a different triggering algorithm (trigger during side impact events only) and shorter inflation times compared to SCABs with rollover sensing.

Table 16 shows the distribution of occupant ejections (full and partial) in vehicles equipped with SCABs (with rollover sensing) during rollover crashes. Approximately 30 percent of the occupants were ejected. As noted on the bottom of Table 16, 4 of the 12 ejections (33 percent) occurred through the side window/door areas. The SCABs did not deploy during two of the four

ejection events. The RODSS case numbers for these two non-deployment events were R05032 and R06121. It was not clear what the cause of the non-deployment was. The other two ejection cases (R07238 and R08289) occurred in vehicles where the SCABs had deployed. In case number R07238, the driver's side front tether was ruptured. In case number R08289, the belted driver was partially ejected. The partial ejection was evidenced by the blood stains on the outboard portion of the SCAB and the roof side rail. It was also noted in Table 16 that the SCABs did not deploy during one rollover event (case number R07242) in which none of the occupants were ejected. It should be noted here that all of the occupants were belted and survived. It is not clear what may have caused the non-deployment. The data from Tables 15 and 16 also show that there were fewer (approximately 70 percent less) side window ejections in vehicles equipped with SCABs with rollover sensing compared to vehicles equipped with SCABs without rollover sensing.

It should also be noted here that the five RODSS cases noted above have been made into Special Crash Investigations (SCI) to facilitate the publication of additional documentation related to the crashes. These cases are noted below along with their respective SCI case numbers. As stated above, the first two cases were non-deployments that resulted in ejections, the third was a non-deployment without an ejection, and the fourth and fifth were cases where the curtain deployed, but there were ejections.

1. RODSS 5032 – SCI CA09061
2. RODSS 6121 – SCI CA09062
3. RODSS 7242 – SCI CA09063
4. RODSS 7238 – SCI CA09069
5. RODSS 8289 – SCI CA10006

Tables 17 and 18 show the restraint status of the ejected and non-ejected occupants respectively in rollover crashes for 36 of 51 cases examined. These two tables provide information on the restraint status of each occupant, ejection medium, the deployment status of the SCABs and whether or not the case vehicle was equipped with rollover sensing.

Table 11. Distribution of RODSS Cases by Critical Pre-Crash Event

	Critical Pre-Crash Event			
Total Number of RODSS Cases	**Single Vehicle Departing the Roadway (Percent of Total)**	**Case Vehicle Impacted Another Vehicle (Percent of Total)**	**Unknown Cause of Control Loss (Percent of Total)**	**Disabling Vehicle Failure (Percent of Total)**
51	32 (63%)	14 (27%)	4 (8%)	1 (2%)

Table 12. Distribution of RODSS Cases by ESC Performance

Total Number of RODSS Cases	High Speed and Operating Conditions Appeared to Limit the Effectiveness of ESC (Percent of Total)	Vehicle-to-Vehicle/Object Impact Precluded ESC From Being a Benefit (Percent of Total)	Vehicle not Equipped with ESC (Percent of Total)	Operating Conditions did not Require ESC Engagement (Percent of Total)
51	17 (33%)[1]	12 (24%)[2]	17 (33%)[3,4]	5 (10%)[5]

Notes:
1 - 13 of 17 cases involved a driver under the influence of alcohol
2 - 1 of 12 cases involved a driver under the influence of alcohol
3 - 3 of 17 cases involved a driver under the influence of alcohol
4 - In 5 of 17 cases, it was not known if the case vehicle was equipped with ESC.
5 - 3 of 5 cases involved a driver under the influence of alcohol

Table 13. Distribution of Occupant Ejections (Full and Partial) by Restraint Status

Number of Ejected Occupants	Number of Full Ejections	Number of Partial Ejections	Restraint Status of Partially Ejected Occupants	
			Belted	Unbelted
42	37 (88%)[1]	5 (12%)[1]	3 (7%)[1]	2 (5%)[1]

Notes:
1 – Denotes percent of all occupant ejections (full and partial)

Table 14. Distribution of Non-Ejected Occupants by Restraint Status

Number of Non-ejected Occupants	Restraint Status		
	Belted	Unbelted	Unknown
60	48 (80%)	9 (15%)	3 (5%)

Table 15. Distribution of Occupant Ejections (Full and Partial) in Vehicles Equipped with SCABs (without Rollover Sensing) During Rollover Crashes

Total Number of RODSS Cases	Total Number of Occupants	Ejected	Not Ejected
29	55	24 (44%)[1,2,3]	31 (56%)[3,4]

Notes:
1 - There were 13 ejections (54% of all ejections) which occurred through the side window/door areas. There was one case where the ejection medium was unknown.
2 - The SCABs did not deploy during 8 of the above 13 ejection events
3 - Denotes percent of all occupants
4 - 18 of 31 (58%) non-ejected occupants were belted

Table 16. Distribution of Occupant Ejections (Full and Partial) in Vehicles Equipped with SCABs (with Rollover Sensing) During Rollover Crashes

Total Number of RODSS Cases	Total Number of Occupants	Ejected [1, 2, 3]	Not Ejected [4,5]
21	47	12 (26%)[6]	35 (74%)[6]

Notes:
1 - There were 4 ejections (33 percent) through the side window/door areas.
2 - SCABs did not deploy during 2 of the above 4 ejection events
3 - The remaining two ejection events involved the driver's side tether rupturing during one of the remaining two rollover events and the possible late deployment of the SCABs during the other rollover event.
4 - 31 of 35 (89%) non-ejected occupants were belted
5 - SCABs did not deploy in one RODSS case. All occupants were belted and survived the crash.
6 - Denotes percent of all occupants

Table 17. Restraint Status of Ejected (Full and Partial) Occupants in Rollover Crashes

RODSS Case Number	Restraint Status of Ejected Occupants
R05010	Unbelted rear seated occupant was ejected through left side window. The occupant sustained fatal injuries. Driver side SCAB[1] may have not deployed in time to prevent the ejection.
R05014[2]	Two belted occupants (driver and left rear seated passenger) were partially ejected due to the roof being torn off. Unbelted right front passenger was ejected through right front window. All occupants sustained fatal injuries. The SCABs did not appear to be deployed.
R05022	Unbelted rear seated occupant was ejected through the rear back light and sustained fatal injuries. The SCABs deployed during the crash event.
R05023	Unbelted right front passenger was ejected through the sunroof. The ejected occupant sustained fatal injuries. The SCABs deployed during the crash event.
R05032	The unbelted driver was ejected through the right rear window. The SCABs with rollover sensing did not deploy during the crash event.
R05041	Unbelted driver was ejected through the sunroof. Left rear passenger was ejected through the left rear window. Both sustained fatal injuries. The driver's side impact air bag and SCAB did not deploy during the crash event.
R05044	The unbelted right front passenger was ejected through the sunroof and sustained fatal injuries. None of the air bags deployed.
R05046	The unbelted right front passenger was ejected through the right front window and expired. The vehicle was not equipped with SCABs.
R05070[2]	The unbelted driver was ejected through the left front window and expired. The unbelted right front passenger was partially ejected

	under the deployed SCAB through the left front door.
R05073[2]	The unbelted driver was partially ejected through the right front window. None of the side air bags deployed. The driver sustained a fatal heart attack at the on-set of the crash and had expired.
R05076	The unbelted driver was ejected through the sunroof and expired. The SCABs deployed during the crash event.
R05077	Unbelted right front and right rear occupants were ejected through the right front and right rear windows respectively. The front passenger survived and the rear passenger sustained fatal injuries. None of the side air bags deployed during the crash event.
R05154	Unbelted occupant seated in the left rear seat was ejected through the sunroof and expired. SCABs with rollover sensing deployed during the crash event.
R06080[2]	Right front passenger was partially ejected through the right front window and sustained fatal injuries. None of the air bags deployed.
R06089	Unbelted passenger was ejected through the windshield and expired. The SCABs deployed during the rollover event.
R06092	The unbelted driver was ejected through the left front window and expired. The SCABs were deployed during the rollover event.
R06109[2]	The belted driver was partially ejected through the left front window and sustained fatal injuries. The SCABs deployed during the rollover event.
R06110	Unbelted right front passenger was ejected through the sunroof and expired. The SCABs deployed during the rollover event.
R06116	The unbelted driver was ejected through the right front window. The right side SCAB did not deploy during the crash.
R06121	Unbelted driver was ejected through the right front door and expired. Based on the VIN description, the vehicle was equipped with SCABs with rollover sensing. However, the SCABs did not deploy.

R06129	The unbelted driver was ejected through the sunroof and expired. The right side SCAB deployed during the crash event.
R06130	The unbelted right front passenger was ejected through the sunroof. The SCABs with rollover sensing deployed during the crash event.
R06145	The unbelted driver was ejected through the sunroof and expired. The SCABs with rollover sensing deployed during the crash event.
R06147	The unbelted right front passenger was ejected through the sunroof and expired. The SCABs with rollover sensing deployed during the crash event.
R07238	The unbelted driver was ejected through the left front window. The SCABs with rollover sensing did deploy during the crash event.
R08289	The belted driver was partially ejected through the left front window. The SCABs with rollover sensing did deploy during the crash event.

Notes:

1. Unless noted that the vehicle is equipped with rollover sensing, the SCABs were designed for side impact crashes only
2. Denotes case where one or more occupants were partially ejected

Table 18. Restraint Status of Non-Ejected Occupants in Rollover Crashes

RODSS Case Number	Restraint Status of Non-Ejected Occupants
R05004	Unbelted driver sustained fatal head injuries due to contact with roof structure. Seat back mounted side air bags and SCABs were deployed during the crash event.
R05006	Unbelted driver sustained fatal head injuries due to contact with roof structure. The driver's SCAB deployed during the crash event.
R05010	The driver and right front passenger were belted and survived. The SCABs deployed during the crash event and may have prevented these occupants from being partially ejected.
R05011	The driver was belted and survived. No SCABs deployed during the rollover crash.
R05019	The driver was belted and survived. The SCABs were deployed during the crash event and may have prevented the driver from being partially ejected.
R05021	The driver was belted and sustained fatal head injuries due to contact with roof structure. The driver side SCAB deployed during the crash event.
R05022	The driver was belted and survived the crash. The SCABs deployed during the crash event and may have prevented the partial ejection of the driver.
R05023	The unbelted driver remained in the vehicle and survived the crash. The SCABs deployed during the crash event and may have prevented the partial ejection of the driver.
R05041	The right front passenger was belted and the right rear seat passenger was unbelted. Both occupants survived. The passenger side SCAB deployed during the crash event and may have prevented the front passenger from being partially ejected and the rear passenger from being fully or partially ejected.
R05044	The unbelted driver and belted right rear passenger were not ejected and survived.

	None of the air bags deployed.
R05046	The vehicle was not equipped with SCABs. Four of six occupants survived the crash. Two of the six occupants were belted.
R05048	The driver was belted and sustained fatal injuries. The driver side SCAB deployed during the crash event.
R05071	The driver sustained fatal injuries due to impact with another vehicle in a frontal offset mode at high speed. The driver side SCAB deployed during the crash event.
R05077	The unbelted driver survived the crash. The SCABs did not deploy.
R05154	The belted driver and right front passenger were not ejected or partially ejected. The SCABs with rollover sensing deployed during the crash event and may have prevented the partial ejection of these two occupants.
R06080	The driver survived the crash. None of the air bags deployed during the crash event.
R06089	The belted driver survived the crash. The SCABs deployed during the crash event and may have prevented the partial ejection of the driver.
R06092	The belted right front passenger and right rear passenger survived the crash. The SCABs deployed during the crash event and may have prevented the partial ejections of these occupants.
R06098	The belted driver sustained fatal injuries due to extensive roof crush from impact with a tree. The SCABs with rollover sensing deployed during the crash event. .
R06110	The belted driver and right rear occupant remained in the vehicle. The SCABs with rollover sensing deployed during the crash event and may have prevented the partial ejections of these two occupants.
R06118	The belted driver remained in the vehicle which was submerged on its roof in a canal. The left side SCAB did not deploy.

R06119	The belted driver and belted right front passenger remained in the vehicle. The right front passenger sustained fatal injuries to the head. The driver side SCAB deployed during the crash event and may have prevented the partial ejection of the driver.
R06130	The belted driver remained in the vehicle and survived. The SCABs with rollover sensing deployed during the crash event and may have prevented the partial ejection of the driver.
R06145	The unbelted right front passenger and belted right rear passenger were not ejected or partially ejected. The SCABs with rollover sensing deployed during the crash event and may have prevented the full and/or partial ejection of the right front passenger and may have prevented the partial ejection of the right rear passenger.
R06147	The unbelted driver was not ejected or partially ejected. The SCABs with rollover sensing deployed during the crash event and may have prevented the ejection or partial ejection of the driver.

Evaluation of RODSS Case No. R05004

This was a single vehicle rollover crash involving a 2004 Porsche Cayenne sport utility vehicle (SUV). The vehicle was equipped with ESC, Antilock Brakes (ABS), Traction control, dual front air bags, front seatback mounted side air bags, front and rear SCABs, belt pretensioners, and active head restraints. The vehicle was not equipped with rollover sensing.

The vehicle was driven by an unbelted 39-year old male, under the influence of alcohol, during the evening hours of a weekday. The vehicle was being driven on a two-lane suburban roadway approaching a 90-degree left turn. The roadway was a dry asphalt surface and the weather conditions were clear. Both sides of the roadway were bound by paved shoulders that were covered by snow and ice. The travel speed, calculated from a police reconstruction, was between 77 and 79 mph in a 25 mph speed limit zone. Due to the high speed, the driver was not able to negotiate the curve successfully and as a result, caused the vehicle to spin in a counterclockwise (CCW) direction about the yaw axis and to depart the roadway. The high speed and operating conditions appeared to limit the effectiveness of the ESC. The vehicle then began to furrow through the packed snow on the roadside while rotating and eventually was tripped into a rollover event. The vehicle rolled one-quarter turn to the right and then became airborne

impacting a pole and the corner of a brick building. The impacts occurred on the roof region of the vehicle. The vehicle eventually landed on its wheels.

The vehicle sustained significant roof damage as a result of the impact with the building. The maximum roof crush was estimated to be between 18 - 22 inches. Most of the crush occurred near the left front A-pillar and along the midpoint of the left rear door frame. The driver's side air bags (SCAB and seat mounted air bag) deployed as a result of the impact with the side of the building. According to the summary, it appeared that the forward tether of the curtain air bag was damaged due to the roof intrusion. A review of the photographs confirmed this. The driver was not ejected or partially (e.g., head, arms, etc.) ejected. The severe roof intrusion may have prevented the driver from being ejected. Due to the lack of interior photographs, no determination can be made of any occupant-to-vehicle interior contact points (including the SCAB). However, based on the description of the vehicle response during the crash event, and the region of the vehicle impacted, it is likely that the driver contacted the left SCAB. According to the case summary, the driver sustained fatal head injuries. These were mostly likely due to the contact with the roof structure. Although it was noted that the driver was under the influence of alcohol, the BAC was not provided.

Evaluation of RODSS Case No. R05006

This was a single vehicle rollover crash involving a 2004 BMW X3 SUV. The vehicle was equipped with ESC, ABS, Traction Control, dual stage front air bags, door mounted side air bags, front and rear tubular head protection system (HPS) air bags, and belt pretensioners. This vehicle was not equipped with rollover sensing.

The vehicle was driven by an unbelted 39-year old male, under the influence of alcohol, during the evening hours of a weekend night. The vehicle was being driven on a two lane rural roadway approaching a right side curve. The asphalt surface was wet due to heavy rainfall which was occurring at the time of the crash. According to the case summary, the vehicle was being driven at an unknown high speed in a 45 mph speed limit zone. Due to the high speed, the driver was not able to negotiate the curve. The vehicle left the right side of the roadway. The high speed and operating conditions appeared to limit the effectiveness of the ESC. Upon leaving the roadway, the right front of the vehicle impacted an embankment that caused the vehicle to vault toward the left and back on the roadway. The vehicle landed on its wheels and proceeded toward the left half of the roadway exiting the roadway on the left side. During this part of the crash sequence, the vehicle impacted and overrode a guardrail and made contact with a parked vehicle. The vehicle then proceeded toward the edge of a steep downhill embankment and became airborne. While airborne; the vehicle began to pitch forward and to rollover on its left about the longitudinal axis. While airborne, the vehicle impacted a tree. This impact resulted in severe damage to the vehicle hood, windshield, and forward roof region. The vehicle rotated off the tree and its undercarriage came in contact with a garage. The vehicle ultimately landed on its left side on top of an aluminum shed, which was demolished.

Based on examination of available photographs the vehicle sustained significant roof intrusion in the front passenger compartment area. The amount of roof crush was not provided. The driver side frontal air bag and the HPS deployed during the crash event. Due to the lack of interior

photographs, no determination can be made of any vehicle interior contact points. The driver was not ejected or partially ejected. The driver most likely contacted the HPS during one or both of the final two crash events. However, the HPS did not have an effect in preventing the ejection or partial ejection. The driver sustained fatal head injuries as a result of contact with the roof structure. Although it was noted that the driver was under the influence of alcohol, the BAC was not provided.

Evaluation of RODSS Case No. R05010

This was a single vehicle rollover crash involving a 2001 Mercedes-Benz E320 four-door sedan. The vehicle was equipped with ESC, ABS, Traction Control, dual stage front air bags, door mounted front and rear side air bags, front and rear SCABs, and active head restraints. The vehicle was not equipped with rollover sensing.

The vehicle was driven on a four-lane divided rural interstate roadway by a belted 73-year old male during the morning hours of a weekday. The road surface was concrete and was wet due to light rain that was falling at the time. In addition to the male driver, the vehicle was occupied by a belted 32-year old male right front passenger, and an unbelted 70-year old female lying down in the rear seat. The vehicle was being driven at an estimated travel speed of 80 mph in a 70 mph speed limit zone. According to the case summary, the driver fell asleep and this caused the vehicle to veer off to the right edge of the roadway. After realizing that the vehicle had veered off course, the driver began to steer the vehicle in the CCW direction back on the roadway. In the process of turning the vehicle, the driver contacted the side of a ramp which tripped the vehicle into rollover event on its right side. The high speed and operating conditions appeared to limit the effectiveness of the ESC. The vehicle underwent four-quarter turns before landing on its wheels.

Based on examination of available photographs, most of the damage to the vehicle occurred on the roof. The maximum roof crush was estimated to be between six to eight inches. Both sets of side air bags (door mounted and inflatable curtain) on the driver and passenger side deployed during the rollover crash. There were not enough interior photographs available to determine occupant-to-vehicle interior contact points. The belts prevented the driver and front seat passenger from being ejected and the SCABs may have contributed to the front seated occupants from being partially ejected. Both front seat occupants survived the crash. The driver and right front passenger sustained moderate and minor injuries respectively. The unbelted rear occupant was ejected through the left rear window. This is evident based on the left rear door window bar being displaced. The ejection may have occurred due to the left SCAB not being deployed at the time of the ejection. The rear occupant was most likely ejected during the vehicles second quarter-turn. The driver side SCAB most likely deployed at the completion of the third quarter-turn. The ejected occupant sustained fatal injuries to her head.

Evaluation of RODSS Case No. R05011

This was a rollover crash involving two vehicles. The case vehicle involved in the rollover event was a 2005 Honda Odyssey minivan and the other vehicle was a 1999 Mercury Grand Marquis 4-door sedan. The Odyssey was equipped with ABS, ESC, Traction Control, dual-stage frontal

air bags, seat back mounted side air bags, and front and rear SCABs. This vehicle was not equipped with rollover sensing.

The case vehicle was driven by a belted 76-year old female during the morning hours of a weekday. The vehicle was being driven westbound on four-lane divided rural interstate roadway. The estimated travel speed of the minivan was 30 mph. The asphalt surface was dry and the weather conditions were clear. The PAR did not contain any information on the local speed limit. Near the scene of the crash, on the eastbound side of the road, the road curved to the left and then entered a straight section. The 1999 Mercury Grand Marquis was traveling on the eastbound side of the roadway and began drifting toward the right as it approached the left handed curve. The driver attempted to overcorrect the vehicle to the left resulting in a CCW rotation. This maneuver resulted in the Mercury crossing into the westbound lane of the roadway and impacting the Odyssey minivan in a frontal offset configuration. The left front end of the Odyssey impacted the right front end of the Mercury and the two vehicles rotated into a side slap orientation. Following a second impact between the two vehicles which involved the right rear quarter panel and C-pillar of the Mercury and the left front quarter panel of the Odyssey, the minivan was deflected and rotated in a CCW direction. The minivan skidded off the road down a negatively sloped area and tripped into a rollover event. The minivan rolled to its right one-quarter turn.

Based on examination of available photographs, most of the damage to the Odyssey occurred on the sides and front end. The crash summary stated that all the air bags deployed during the crash sequence. However, based on close examination of the photographs, it appears only the front air bags deployed. The driver of the minivan was not ejected or partially ejected. The seat belts prevented the ejection. The driver most likely contacted the front air bag after the initial impact with the Marquis. Due to the lack of sufficient interior photographs, occupant-to-vehicle interior contact points cannot be determined. The driver survived and sustained moderately severe injuries. The driver of the Mercury sustained fatal injuries.

Evaluation of RODSS Case No. R05014

This was a single vehicle rollover crash involving a 2004 Infiniti G35 two-door coupe. The vehicle was equipped with ESC, ABS, dual stage front air bags, front seat back mounted side air bags, front and rear SCABs, front safety belt pretensioners, and active head restraints. This vehicle was not equipped with rollover sensing.

The vehicle was driven by a belted 22-year old male, under the influence of alcohol, during the late night hours of a weekend night in April 2005. The roadway was a five-lane divided interstate highway. The asphalt surface was dry and the weather conditions were clear. In addition to the driver, the vehicle was occupied by an unbelted 20-year old female passenger seated in the right front seat, and a belted 16-year old male passenger seated in the left rear seat. The vehicle was traveling in the southbound lane at an estimated (based on eye witness who was traveling in one of the other lanes) speed of 100 mph in a 70 mph speed limit zone. Based on an eye witness account, the Infiniti appeared to be involved in a race with another vehicle. Due to the high speed, the driver lost control and the vehicle began rotating clockwise (CW). The high speed and operating conditions appeared to limit the effectiveness of the ESC. As the vehicle

rotated CW, the left front tire contacted a concrete curb, which tripped the vehicle into a rollover event toward its left. The vehicle became airborne and landed on the asphalt roadway and continued to overturn while rotating CW in the yaw direction. During the rollover sequence, the rear end of the Infiniti impacted a steel guardrail and concrete wall. Based on the distance traveled from the initial trip point to the final rest position, it was estimated that the vehicle rolled a total of ten-quarter turns before coming to rest on its roof .

Based on examination of available photographs, most of the damage to the vehicle occurred on the roof and rear half of the vehicle. The PAR stated that all the air bags deployed during the crash event. However, based on the available photographs, the deployment of the air bags is not evident. The extensive roof intrusion precluded interior photos from being taken. The belted driver and left rear passenger were partially ejected due to the roof being deformed in the rearward direction. Both of these belted occupants were partially ejected with their heads impacting the roadway. They sustained fatal injuries. The unbelted right front passenger was ejected through the right front window. The passenger sustained severe injuries to the head, brain, chest, pelvis, and spine. She also expired at the scene. If the SCABs did deploy during the crash sequence, then they did not have an effect in preventing the right front passenger from being ejected. The ejection may have been attributed to the SCAB not deploying or perhaps the air bag tether(s) was torn as a result of the extensive roof crush.

Evaluation of RODSS Case No. R05019

This was a two-vehicle crash involving the case vehicle, a 2005 BMW 525i four-door sedan and a 1988 Cadillac Eldorado two-door coupe. The case vehicle was equipped with ESC, ABS, Traction Control, dual stage front air bags, front row seat back mounted side air bags, front and rear SCABs, and safety belt pretensioners. However, this vehicle was not equipped with rollover sensing.

The BMW was being driven southbound by a belted 46-year old female on a four-lane divided highway during the late afternoon hours of a weekday. The road surface was dry and the weather conditions were clear. The police calculated the speed of the BMW to be approximately 46 mph in a 50 mph speed limit zone. The Cadillac was travelling westbound on a two-lane roadway at a high speed (eye-witness estimate of 80 mph). The Cadillac approached an intersection and proceeded through a stop sign. The driver of the BMW tried to stop as she approached the intersection to avoid hitting the Cadillac but was not successful. The front end of the BMW impacted the right side of the Cadillac which resulted in severe damage to both vehicles. The impact caused the driver's side air bags (front and side) to deploy in the BMW. Following the impact, both vehicles rotated CW. The BMW exited the roadway and entered a grassy area with a slight negative slope. The left side tires of the BMW furrowed into the grass resulting in the center of gravity of the vehicle to shift to the left. This resulted in the BMW being tripped two-quarter turns on its left. The BMW ended up on its roof. There was minimal damage to the roof. The maximum vertical roof crush was one inch. Most of the damage to the BMW occurred in the front end and left side of the vehicle. The impact with the Cadillac precluded the ESC from being a benefit.

Based on the examination of available photographs, it was noted that the passenger SCAB also deployed. It is not known if the passenger side seat back mounted side air bag or frontal air bag deployed. Since the BMW initiated the roll event on its left side, the belted driver came in contact with the side air bags. The safety belt prevented the driver from being ejected and the SCAB may have contributed to the driver not being partially ejected. The driver sustained serious injuries. The injury sources are unknown due to lack of interior photos. The driver of the Cadillac sustained fatal injuries.

Evaluation of RODSS Case No. R05021

This was a single vehicle rollover crash involving a 2005 BMW 530i four-door sedan. The vehicle was equipped with ESC, ABS, Traction Control, dual stage front air bags, front row seat back mounted side air bags, front and rear SCABs, and front safety belt pretensioners. This vehicle was not equipped with rollover sensing.

The vehicle was driven by a belted 45-year old male, under the influence of alcohol, during the late afternoon hours of a weekday. The vehicle was being driven on northbound side of a six-lane divided interstate highway. The road surface was dry and the weather conditions were clear at the time of the crash. Several witnesses noted that the vehicle was moving erratically from one lane to another and at times swerved onto the shoulder of the highway. According to the witnesses, the vehicle was traveling at a speed between 90 - 100 mph. The posted speed limit was 65 mph. As the vehicle approached a left curve, the high speed prevented the driver from negotiating the curve and caused the vehicle to rotate CCW. The high speed and operating conditions appeared to limit the effectiveness of the ESC. The BMW proceeded to depart the right side of the roadway. The vehicle headed up and over an embankment, struck a mile marker post and became airborne. While airborne, the vehicle rotated CCW and impacted the base of a hillside and the floor of a drainage canal. The vehicle experienced a climb-over type of rollover event and rotated two-quarter turns on its left side. The vehicle landed on its roof.

Based on examination of available photographs, the vehicle sustained extensive roof damage with the maximum crush in the vertical direction estimated to be 20 inches at the A-pillar/windshield header junction and eight inches in the lateral direction. Both front air bags and driver side SCAB deployed during the crash event. The safety belts prevented the driver from being ejected. As was the case with the previous RODSS cases, there was not enough interior photographs available to determine occupant-to-vehicle interior contact points. The driver most likely sustained the fatal injuries from contact with the roof structure.

Evaluation of RODSS Case No. R05022

This was a single vehicle rollover crash involving a 2004 Acura TSX four-door sedan.
The vehicle was equipped with ESC, ABS, Traction Control, dual stage front air bags, and front seat back mounted side air bags, front and rear SCABs. This vehicle was not equipped with rollover sensing.

The vehicle was driven by a belted 22-year old male during early morning hours. The roadway was a four-lane divided roadway with an approaching left hand curve. The edges of the road

were bordered by concrete barrier curbs with grassy road sides. At the time of the crash, the road surface was dry; the weather conditions were cloudy under dark lighting conditions. The posted speed limit was 35 mph with an advisory speed limit of 25 mph for the left hand curve. In addition to the driver, the vehicle was occupied by a belted 22-year old male passenger seated in the right front seat, and an unbelted 24-year old male passenger seated in the right rear seat. The vehicle was traveling southbound in the inboard lane at an unknown high speed. As the driver entered the left curve, he applied the brakes and initiated a CCW yaw. The vehicle entered the outboard lane and came in contact with the barrier curb. The right rear wheel and brake assembly were separated from the vehicle along with the right front wheel. The high speed and operating conditions (including wheel and brake separation) appeared to limit the effectiveness of the ESC. Both right side tires impacted the curb. As the Acura continued to move in a southeast direction, the left side wheel contacted the curb. The vehicle proceeded over the curb onto the grassy roadside. The vehicle continued to yaw in the CCW direction until the right front wheel dug into the ground which tripped the Acura into a right side leading rollover event. The Acura was involved in an eight-quarter turn event. The vehicle came to rest approximately 170 feet south of the trip point.

The Acura sustained severe damage on the left side. The roof crush at the left A-pillar was estimated at four inches vertically and six inches laterally. All of the air bags, including the SCABs deployed during the crash. Based on examination of available photographs, dirt and blood were present on the driver side SCAB. There was no apparent damage to the SCABs that resulted from the crash. The belted driver and right front passenger remained in the vehicle during the rollover event. Both sustained moderate level injuries. However, the rear passenger was most likely ejected through the rear back light which was disintegrated. The SCAB prevented the driver from being partially ejected. In addition, the passenger side SCAB, may have prevented the rear seated passenger from being ejected through the side windows. The right front glazing did not disintegrate and therefore, may have been beneficial in preventing a partial ejection of the right front passenger. Outside of the photograph denoting the driver contact with the SCAB, there were no additional photographs available to determine additional occupant-to-vehicle interior contact points.

Evaluation of RODSS Case No. R05023

This was a two-vehicle crash involving the case vehicle, a 2002 Mercedes-Benz C240, four-door sedan and a 1998 Ford Escort two-door coupe. The case vehicle was equipped with ESC, dual stage front air bags, front door mounted side air bags, front and rear SCABs, and may have been equipped with rollover sensing.

The vehicle was driven by an unbelted 20-year old male during late afternoon hours. The PAR stated that the driver had been drinking, however the level of alcohol impairment was not reported. In addition to the driver, the vehicle was occupied by an unbelted 21-year old male seated in the right front seat. The crash occurred on the eastbound section of the roadway at an intersection controlled by traffic lights. The roadway consisted of two through lanes and two designated left turn lanes. A curbed median separated the eastbound and westbound lanes. In addition, a commercial driveway was located immediately past the intersection on the right hand side. The outboard edge of the east bound lane was curbed with grass extending beyond the curb

line. The eastbound lanes were straight and level with a posted speed limit of 40 mph. At the time of the crash, the road surface was dry and the weather conditions were cloudy under light conditions. The Mercedes was traveling eastbound in the inboard lane and was in a race with the 1998 Ford Escort. In an attempt to pass the Escort, the Mercedes entered the first left turn lane and realized there was not much travel distance available due to other vehicles waiting in the lane to turn left. The driver of the case vehicle then initiated a lane change toward the right and sideswiped the left side of the Escort. Following the impact with the Escort, the case vehicle rebounded toward the left and impacted the curbed median barrier with its left front and rear wheels. Upon separation from the curbed median barrier, the case vehicle initiated a CW yaw as it moved across the eastbound travel lanes. The vehicle crossed the commercial driveway and continued to rotate CW until the right side wheels made contact with the curb at the other end of the driveway. At this point, the Mercedes had rotated 270 degrees from its original heading. The right rear tire was dislocated from the rear axle and the right front tire was de-beaded from the alloy wheel. The impact of the right side wheels with the curb caused the vehicle to be tripped into a right side rollover event. The case vehicle underwent a four-quarter turn rollover event. The vehicle-to-vehicle impact precluded the ESC from being a benefit.

The left rear corner of the vehicle sustained the most damage. An engine fire was started after the rollover event. There was minimal exterior damage from the fire. The interior did not exhibit any fire damage. All frontal and side air bags deployed during the rollover event including the SCABs. The SCABs were tethered at the A and C-pillars. This vehicle may have been equipped with rollover sensing. The SCABs did not sustain any damage. The roof crush was estimated at 1 inch vertical and 1 inch laterally at the right C-pillar. The unbelted driver remained in the vehicle. He sustained non-incapacitating injuries. The unbelted right front passenger was ejected through the sunroof. The SCAB may have prevented the driver from being ejected. In addition, the SCABs, which were tethered across the pillars, may have prevented the front seated passenger from being ejected through the side windows. There were not enough interior photographs available to determine occupant-to-vehicle interior contact points.

Evaluation of RODSS Case No. R05041

This was a single vehicle rollover crash involving a 2003 Infiniti FX35 SUV. The vehicle was equipped with ABS, Traction Control, all wheel drive, front air bags, front seat back mounted side air bags, and front and rear SCABs. This vehicle was not equipped with ESC and rollover sensing.

The vehicle was being driven by an unbelted male, under the influence of alcohol, in a westerly direction on a two-lane rural roadway during nighttime hours of a weekend night. The asphalt surface was dry and the weather conditions were cloudy. The vehicle contained four occupants and only the right front seated passenger was belted. The vehicle was traveling at a police computed speed of 63 mph in a 35 mph speed limit zone. The vehicle approached a left hand curve at this speed and the driver lost control trying to negotiate this turn. The vehicle began to rotate CCW and began to depart the roadway down a grassy down slope. At this point the right front tires furrowed into the dirt and caused the vehicle to trip into a right side roll. The Infiniti rolled over a minimum of seven-quarter turns before coming to rest on its left side.

There were no crush estimates provided in the crash summary report. Both frontal air bags and passenger side seat back mounted side air bag and SCAB deployed. The driver's seat back mounted side air bag and SCAB did not deploy. The driver was ejected through the sunroof and sustained fatal injuries. The belted right front seat passenger and unbelted right rear seat passenger remained in the vehicle and survived with serious injuries. The safety belt prevented the right front seated passenger from being ejected. The SCAB may have also prevented the front seated passenger from being partially ejected. The SCAB most likely prevented the right rear seated passenger from being ejected or partially ejected. The left rear passenger was ejected through the left rear window and sustained fatal injuries. There were not enough interior photographs available to determine occupant-to-vehicle interior contact points.

Evaluation of RODSS Case No. R05044

This was a single vehicle rollover crash involving a 2004 Lexus RX330 SUV. The vehicle was equipped with ESC, ABS, Traction Control, dual stage front air bags, front seat back mounted side air bags, and front and rear SCABs. This vehicle was not equipped with rollover sensing.

The vehicle was driven by an unbelted 26-year old male, under the influence of alcohol, during the morning hours of a weekday on a two-lane divided rural roadway. The asphalt road surface was dry under clear weather conditions. In addition to the male driver, the vehicle was occupied by an unbelted 28-year old male seated in the right front seat, and a belted 20-year old male seated in the right rear seat. The vehicle was being driven at an estimated travel speed of 85 mph. The posted speed limit was 55 mph. According to the RODSS summary, the vehicle veered right off the road onto a flat dirt surface before the driver rotated the steering wheel CCW to get the vehicle back on the road. The Lexus then proceeded to cross the roadway while rotating in a CCW direction and then headed toward the left side off-road area. The high speed and operating conditions appeared to limit the effectiveness of the ESC. The side of the road contained a canal surrounded by a flat dirt surface. The vehicle became airborne and crossed the canal impacting the side of the canal with its front and right sides. The vehicle came to rest on its wheels.

Based on examination of available photographs, most of the damage to the Lexus occurred on the front and right passenger side. Based on the summary of the crash event, the damage sustained by the Lexus did not support a rollover event. None of the air bags deployed during this event. The unbelted driver and belted right rear passenger were not ejected and survived the crash with moderate injuries. Due to lack of interior photographs, there was no information of occupant-to-vehicle interior contact points. The right front passenger was ejected through the sunroof and landed in the canal. He sustained fatal injuries.

Evaluation of RODSS Case No. R05046

This was a two-vehicle crash involving the case vehicle, a 2005 Ford Explorer XLT SUV and heavy duty truck with attached trailer. The case vehicle was a rental vehicle equipped with frontal air bags, ESC, Traction Control, and ABS. The Explorer was not equipped with side air bags and SCABs.

The case vehicle was driven at an unknown speed by a belted 33-year old female during early dawn hours. In addition to the driver, the vehicle was occupied by an unbelted 45-year old female seated in the right front seat. In addition, there were five other passengers seated in the rear seat. One of the five passengers was belted. The crash occurred on the northbound section of a three lane roadway. The weather was clear and the road surface was dry. The posted speed limit was 70 mph. A W-beam guardrail divided the north and south bound travel lanes. An off-ramp was located immediately past the crash site. In addition, a wide asphalt shoulder was located on the right of the northbound lanes and it was bound with a concrete curb. A W-beam guardrail was located to the right of the curb. There was heavy brush located outboard of the guardrail.

The case vehicle was headed to the airport along with two other vehicles. The Explorer was travelling in between the other two vehicles. The driver of the case vehicle failed to detect the lead vehicle as it exited the interstate on the off-ramp. The driver quickly began to slow down and pull the vehicle off onto the shoulder. The driver of the heavy truck was in the outboard lane behind the Explorer. The driver of the truck failed to realize that the Explorer was slowing down and proceeded to impact the rear of the Explorer. The impact caused the Explorer to accelerate forward while initiating a CW yaw. The case vehicle rotated a total of 90 degrees along the shoulder. The left rear wheel of the Explorer gouged into the asphalt shoulder and tripped the vehicle into a left side leading rollover. During the rollover event, the left front fender of the case vehicle contacted the guardrail for a distance of 28 feet before vaulting over the rail. The vehicle continued to roll through four-quarter turns. The vehicle ended up on its wheels in the brush. There was significant roof damage in the vicinity of the right B-pillar region. The estimated crush was 15 inches in the vertical direction. In addition, a fire originated in the engine compartment and burned the front end of the vehicle including the interior driver's area. The vehicle-to-vehicle impact precluded the ESC from being a benefit.

The belted driver sustained serious injuries. The right front passenger was ejected through the right front window. She sustained fatal injuries. The PAR contained conflicting police notes in regards to the ejection status of two of the rear seated occupants. Two of the rear seated occupants who remained in the vehicle were killed. Two of the remaining three occupants sustained serious injuries and the other sustained moderate injuries. There was not enough interior photographs available to determine occupant-to-vehicle interior contact points.

Evaluation of RODSS Case No. R05048

This was a rollover crash involving two vehicles. The case vehicle involved in the rollover event was a 2004 BMW X3 SUV. The other vehicle was a 2003 Hummer H1 pickup (open bed with utility box attached). The case vehicle was equipped with ESC, ABS, Traction Control, dual stage front air bags, door mounted side air bags, front and rear SCABs, and belt pretensioners. However, this vehicle was not equipped with rollover sensing.

The case vehicle was driven by a belted 57-year old male during the morning hours of a weekend day. The vehicle was being driven northbound on a two-lane divided roadway. One witness estimated the speed of the BMW to be between 85-90 mph. The asphalt surface was dry and the weather conditions were clear. As both vehicles approached a bridge, the BMW veered into the

southbound lane and impacted the Hummer in a frontal offset collinear mode. The bridge was lined on both sides by a three foot high concrete wall. The impact involved the left front area of both vehicles. Both vehicles separated after impact and continued along their respective direction of travel. The BMW traveled approximately 60 feet before impacting the wall with its right front and side areas. The impact with the wall caused the vehicle to rotate 90 degrees CW and to flip two-quarter turns toward its left side, coming to rest on its roof and with its front end in contact with the concrete wall. The impact with the Hummer and subsequent impacts with the concrete wall precluded the ESC from being a benefit.

Based on examination of available photographs, most of the damage to the BMW occurred on the front and left side areas of the vehicle. The left side damage extended rearward to the C-pillar. The BMW sustained minimal roof damage. The crush was estimated as minor and most of it occurred at the left A-pillar/windshield header region of the vehicle. The driver side front air bag and the left SCAB deployed during the crash event. The driver most likely contacted the left SCAB during this event. Due to the severe deformation of the vehicle front end and resulting intrusion, both the front and side air bags did not provide any benefit to the driver. The driver sustained fatal injuries. However, due to lack of interior photographs, there was no information of occupant-to-vehicle interior contact points.

Evaluation of RODSS Case No. R05070

This was a two-vehicle crash involving the case vehicle, a 2005 Hyundai Tucson GLS SUV and a 2005 Honda Civic LX two-door coupe. The crash occurred at a four-way intersection consisting of two multi-lane roadways with posted speed limits of 45 mph. The road was surfaced and bordered by curbs. The northbound and southbound lanes were separated by a curbed median. There were no traffic signals at the intersection. The eastbound/westbound traffic flow through the intersection was controlled by stop signs. The case vehicle was equipped with ESC, dual stage frontal air bags, front seat back mounted side air bags, and SCABs. This vehicle was not equipped with rollover sensing.

The case vehicle was driven at an unknown speed by an unbelted 42-year old female shortly after midnight. In addition to the driver, the vehicle was occupied by an unbelted 49-year old female seated in the right front passenger seat. The Civic was being driven at an unknown speed by a 20-year old female who according to the PAR was under the influence of alcohol. The Hyundai was traveling southbound on the inboard travel lane approaching the intersection. The Civic was traveling westbound toward the intersection. The driver of the Civic failed to stop at the stop sign and proceeded to impact the left front side of the Hyundai. The impact caused the Honda to rotate in a CCW direction. The Hyundai was deflected toward the southwest quadrant of the intersection and began to rotate CW. The case vehicle proceeded to mount a barrier curb as it continued to rotate CW. The impact with the curb fractured the left front wheel and caused both the tire and wheel to separate from the vehicle. This event caused the Hyundai to trip into a left side leading rollover event. The case vehicle rolled down an embankment into a water filled drainage ditch. According to the PAR, the ditch was located approximately 16 feet below the grade of the intersection. The case vehicle completed four-quarter turns before coming to rest on its wheels.

The Hyundai sustained significant damage in the front and left front regions including the driver's side door. The left side roof rail displaced approximately four inches laterally to the right. The roof sustained minimal crush in the vertical direction. The impact caused the driver's side air bag and SCAB to deploy. The vehicle-to-vehicle impact precluded the ESC from being a benefit. The driver was fully ejected through the left front window and sustained fatal injuries. She may have been ejected prior to the SCAB being deployed. The right front passenger was partially ejected through the left front door under the deployed SCAB. She sustained serious injuries to her upper body. As stated earlier, this was a side impact curtain bag and therefore the time that it stays inflated is less than the inflation time of a rollover SCAB. One of the photographs showed blood stains on the instrument panel to the right of the radio. This may have been one of the injury sources for the right front passenger.

Evaluation of RODSS Case No. R05071

This was a two-vehicle crash involving the case vehicle, a 2000 BMW 323i four-door and a 2000 Chevrolet Corvette two-door coupe. The case vehicle was equipped with dual stage frontal air bags, door mounted side impact air bags, and the HPS in the front and rear outboard seating positions. The other standard equipment included ESC, Traction Control, and ABS. The BMW was not equipped with rollover sensing.

The crash occurred on a two lane road during early morning hours under a clear sky and dark conditions. The asphalt road surface was dry and the speed limit was posted at 50 mph. At the scene of the crash, the road surface was curved to the right.

The case vehicle was driven by a 16 year-old male. His restraint status was unknown. According to the PAR, the case vehicle was being driven eastbound at an estimated speed of 75 mph. The driver of the case vehicle initiated a passing maneuver, crossed the double yellow centerline and entered the westbound lane. The Corvette was travelling westbound at PAR reported speed of 55 mph. The Corvette was being driven by a 43 year-old female. In addition to the driver, the vehicle was occupied by a 61 year-old male seated in the right front passenger seat. Both occupants were belted. Both vehicles collided in a 60% frontal-offset crash mode. According to the PAR, the BMW travelled a total of 82 feet from the initial impact point and ended up facing east on a steep embankment. Following the impact with the embankment, a fire was initiated and consumed the entire vehicle. The vehicle-to-vehicle impact precluded the ESC from being a benefit.

It is not clear from the PAR whether or not the BMW was involved in a rollover event. According to the case summary, there was one scenario which may have resulted in the BMW being involved in a rollover event. This would have involved the BMW rotating in a CCW direction after impact and riding up the steep embankment and into a flip-over type of an event.

In addition to the damage caused by the fire, the BMW sustained severe frontal damage from the impact. The intrusion into the BMW compartment extended to the left B-pillar.
The driver remained in the vehicle and sustained fatal injuries. The driver of the Corvette was killed and the right front passenger sustained incapacitating injuries. The fire destroyed all

evidence of safety belt use and deployment of the air bags. There was not enough interior photographs available to determine occupant-to-vehicle interior contact points.

Evaluation of RODSS Case No. R05073

This was a single vehicle crash involving the case vehicle, a 2000 Mercedes Benz E320 four-door sedan. The case vehicle was equipped with dual stage frontal air bags, side impact air bags, Traction Control, and ESC. The Mercedes was not equipped with SCABs. The crash occurred on a two lane road during the afternoon hours under clear and dry conditions. The road was straight and level with paved shoulders and the speed limit was 60 mph. The travel lanes and shoulders were paved with asphalt. Outboard of the shoulder was a grassy area which extended from the edge of the shoulder and sloped downward to a shallow dry drainage ditch. In addition, several driveways intersected the road with shallow culverts for the ditch.

The case vehicle was driven by an unbelted 64 year-old male. The driver was 76 inches in height and weighed approximately 400 pounds. According to the PAR, the driver had a history of Hypertrophic Cardiomyopathy and depression and was on a medication known as Zoloft. The driver was traveling southbound at a witness reported speed of 60 mph. Other witnesses noted that the driver slowed down to an estimated speed of 45-50 mph and began to swerve within his travel lane. The vehicle then proceeded to drift off the road edge, cross the shoulder and head toward the grassy area. The vehicle proceeded down the sloped region before initiating a CCW yaw of 8-10 degrees. The Mercedes entered the ditch causing the front undercarriage to impact one of the culverts. The Mercedes vaulted the driveway and initiated an end-over-end rollover event. The front end of the vehicle dived into the ditch on the south side of the driveway. The case vehicle eventually rolled onto its right side where it came to rest. This case did not contain any photographs of the crash site.

The case vehicle sustained significant frontal damage. The roof crushed approximately eight inches vertically at the right A-pillar locations and six inches laterally. The driver's frontal air bag deployed. However, the passenger side frontal air bag and all side air bags did not deploy. The driver's head was partially ejected through the right front window. An autopsy determined that the driver had sustained a fatal heart attack at the on-set of the crash. There was not enough good quality interior photographs available to determine occupant-to-vehicle interior contact points.

Evaluation of RODSS Case No. R05076

This was a single vehicle crash involving the case vehicle, a 2001 BMW 325i four-door sedan. The case vehicle was equipped with dual stage front air bags, front door mounted side impact air bags, and the HPS, which as stated previously provides head protection for occupants seated in the front and rear outboard seating positions. The other standard equipment included ESC, Traction Control, and ABS. The BMW was not equipped with rollover sensing.

The crash occurred on a two lane road during early morning hours under a clear sky and dark conditions. The asphalt road surface was dry and the speed limit was posted at 50 mph. At the scene of the crash, the road surface was curved to the right for the case vehicle's westbound

direction of travel. In addition, a drainage ditch bordered the left side of the road. Beyond the ditch, there was a flat vacant field topped with grass.

The case vehicle was driven by an unbelted 57 year-old male. According to the PAR, a blood test was administered and yield negative results for alcohol and/or drugs. The case vehicle was proceeding in the outboard lane at an unknown speed as it approached the right curve. The driver had difficulty negotiating the curve and as a result forced the vehicle to drift wide into the inboard lane and depart the left road edge. This may have been due to the driver temporarily falling asleep. The ESC probably did not engage as the vehicle was tracking at the point of departure. After departing the road, the case vehicle impacted the drainage ditch which tripped the vehicle into a left side leading rollover event. The vehicle completed eight-quarter turns and ended up on its wheels.

The right A-pillar/roof area crushed eight inches in the vertical direction and four inches in the lateral direction. In addition, the midpoint of the roof was deflected upward and the left C-pillar area sustained significant damage. There was no crush estimate provided for this region of the vehicle. In regards to glazing damage, the side glazing on both front doors, left rear door and rear back light were disintegrated. The right rear door and both rear quarter windows remained intact. The sunroof was also disintegrated and the cover door was displaced. The driver's frontal air bag, both front door mounted side air bags, and both HPS air bags deployed during the rollover event. Both HPS bags did not exhibit any evidence of damage. According the case summary, all the tether attachment points at the A- and C-pillars appeared to be intact. The bags were deployed across both windows and with a designed long inflation period, the driver was likely ejected through the sunroof. His body came to rest next to the left side of the vehicle. He sustained fatal injuries.

Evaluation of RODSS Case No. R05077

This was a single vehicle crash involving the case vehicle, a 2005 Audi A4 four-door sedan. The case vehicle was equipped with dual stage frontal air bags, front seat back mounted side impact air bags, SCABs, ESC, Traction Control, and ABS. The Audi was not equipped with rollover sensing.

The crash occurred on an interstate roadway during early morning hours under a clear sky and dark conditions. The asphalt road surface was dry. At the location where the crash occurred, the road transitioned from three lanes to two at the inboard side of the road. A dirt median strip separated the northbound and southbound travel lanes. Within the median, north of the lane merge area, there was a dry drainage ditch with a culvert pipe. It should be noted here that there was no schematic provided with the PAR. In addition, the black and white photographs were of poor quality and were provided in a 16 image per page format.

The case vehicle was driven by an unbelted 31-year old male. In addition to the driver, the vehicle was occupied by an unbelted male passenger of unknown age in the right front seat and an unbelted 23-year old seated in the right rear seat. According to the PAR, a blood test performed on the driver was negative for alcohol and positive for Methamphetamine and Cocaine. The case vehicle was proceeding northbound on the far left travel lane at an unknown

high speed. As the left travel lane ended, the driver proceeded straight onto the dirt surface of the median which induced a CCW yaw. The high speed and operating conditions (vehicle speed and low friction coefficient of dirt surface) appeared to limit the effectiveness of the ESC. The driver proceeded to counter steer to the right which caused the vehicle to enter the ditch and impact the culvert with its right front wheel and tire. This impact tripped the Audi into a right side leading rollover event on the median surface. The vehicle completed eight-quarter turns and landed on its wheels.

The Audi sustained damage to all sides. The impact with the culvert caused the separation of the right front tire and wheel assembly from the front suspension. The drive axle also separated with the wheel/brake assembly. There was approximately six inches of vertical and lateral roof crush at the left C-pillar area. All side, rear, and roof glazing was disintegrated. The frontal air bags deployed. However, none of the side air bags deployed. The driver remained in the vehicle during the rollover event and sustained PAR listed A-injuries. Both passengers were fully ejected. The right front passenger was probably ejected through the right front window. He sustained incapacitating injuries. The rear seated passenger was probably ejected through the right rear window opening. He sustained fatal injuries.

Evaluation of RODSS Case No. R05154

This was a single vehicle crash involving the case vehicle, a 2005 Volvo XC90 SUV. The case vehicle was equipped with a front wheel drive system, four-wheel ABS, Traction Control, ESC, frontal air bags, side impact air bags, and inflatable rollover protection.

The crash occurred on a two lane roadway during early afternoon hours. At the time of the crash, the weather conditions were clear and the asphalt road surface was dry. The roadway was oriented in a north/south direction. The travel lanes were delineated by a dashed white centerline and both edges of the travel lanes were delineated with solid white fog lines. Paved shoulders were located outside of the fog lines. Outboard of the paved shoulders, the grassy area sloped negatively into shallow drainage ditches. The posted speed limit was 70mph. A secondary roadway intersected the northbound lane in a 90-degree configuration. There were no photographs available for this case.

The case vehicle was driven by a belted 62-year old male. In addition to the driver, the vehicle was occupied by a belted 54-year old female passenger seated in the right front seat and an unbelted 77-year old female seated in the left rear seating position. According to the PAR, there was no alcohol involvement. Prior to the crash, the Volvo was traveling northbound at or near the posted speed limit. As the driver reached to his right to retrieve something in the glove box, the vehicle drifted to the right and exited the east edge of the roadway. Due to the off-road tracking, the ESC did not engage and was not a factor in the crash. As the vehicle proceeded down the grassy surface, the right front end of the Volvo stuck an embankment located adjacent to the intersecting roadway. The impact caused the Volvo to vault and to begin yawing in the CW direction. While airborne the vehicle struck a sign post. The vehicle touched down north of the intersecting roadway and continued to yaw to a 30-35 degree angle with respect to its path of travel. This caused the vehicle to trip into a rollover event on its left side. It is estimated that the Volvo rolled a total of eight quarter turns.

The Volvo sustained minimal damage to the roof. According to the PAR, the maximum roof crush occurred at the left upper A-pillar region and was estimated to be in the 2" – 3" range. The driver sustained B (non-incapacitating) level injuries and was not ejected or partially ejected. The right front passenger sustained A (incapacitating) level injuries and was also not ejected or partially ejected. The left rear passenger was ejected through the sunroof. According to a witness report, when the passenger was ejected, she was thrown forward of the vehicle and as the vehicle continued to roll, it rolled on top of her. She sustained fatal injuries. Both curtain air bags deployed during the rollover event due to the rollover sensing. Both of the curtain bags may have been beneficial in preventing both front seated occupants from being partially ejected. As stated above, there were no photographs available for this case and therefore, there was no information on occupant injury sources and contact points. According to the PAR, both front curtain tethers appeared to be cut. The front air bags and the side impact air bags did not deploy during the crash event.

Evaluation of RODSS Case No. R06080

This was a single vehicle crash involving the case vehicle, a 2004 Cadillac CTS four-door sedan. The case vehicle was equipped with dual stage frontal air bags, front seat back mounted side impact air bags, and SCABs without rollover sensing. ESC was an option for this vehicle. According to the case summary report, the pre-crash maneuvers of the case vehicle would lead one to conclude that the vehicle was not equipped with ESC.

The crash occurred on a three lane road during the late morning hours under a clear sky and light conditions. The speed limit was 65 mph. The southbound lanes were bordered with paved shoulders. All surfaces were asphalt and were dry at the time of the crash. A W-beam median barrier separated the north and southbound travel lanes. The inboard shoulder consisted of rumble strips. It should also be noted here that the southbound lanes were resurfaced which resulted in a 1-2 inch pavement drop to the shoulder.

The case vehicle was driven southbound by a 75 year-old female. In addition to the female driver, the vehicle was occupied by a 75 year-old male occupant seated in the right front seat. According to the PAR, the restraint use for these occupants was unknown. The driver was traveling in the center lane at an estimated speed of 65 mph. According to the PAR, the driver applied a rapid CCW steering input that induced the vehicle into a CCW yaw. The vehicle yawed across the left travel lane and moved onto the shoulder. The vehicle rotated approximately 30 degrees in the CCW direction. The frontal area of the case vehicle impacted the W-beam barrier. As the case vehicle separated from the barrier, it continued to rotate CCW and proceeded to move toward the travel lanes. The pre-crash yaw of the vehicle would be indicative of a vehicle not equipped with ESC. The availability of ESC would have applied selective braking to allow the driver to control the vehicle. The right rear tire de-beaded from the alloy wheel and gouged the asphalt shoulder. The left side tires subsequently engaged the pavement edge of the inboard travel lane. This caused the vehicle to trip into a left side leading rollover event across the travel lanes. On the third-quarter turn, the right side of vehicle impacted the ground with great force resulting in severe crush to the right side of the vehicle. The Cadillac completed four-quarter turns before coming to rest on its wheels.

The impact with the ground caused the right side rail region to crush inward which caused the roof to buckle in the upward direction. The maximum roof crush was estimated at four inches in the vertical direction and eight inches in the lateral direction at the right C-pillar area. In regards to glazing damage, all side and rear back light glazing was disintegrated. Both occupants remained in the vehicle. The driver survived with serious injuries. However, the passenger sustained fatal injuries. Although the PAR listed both occupants as not being partially ejected, autopsy images of the right front passenger showed a large laceration on the right elbow area, which would suggest the passenger was partially ejected through the right front window and contacted the ground with his elbow. There were limited photographs available of the vehicle interior. One photograph showed the driver's side knee panel deformed which would indicate a possible injury source for the driver right knee. No other information was available on other injury sources. None of the air bags deployed during the crash. Due to the severe right side deformation of the vehicle, the SCABs most likely would not have been a benefit in preventing the fatality.

Evaluation of RODSS Case No. R06089

This was a two vehicle crash involving the case vehicle, a red 2004 Toyota Sienna LE minivan and another silver colored Toyota Sienna LE minivan. The case vehicle was equipped with frontal air bags and ABS. Front seat back mounted side impact air bags and SCABs were optional equipment on this model. However, based on the few images available of the vehicle, it appeared that the case vehicle was equipped with the SCABs. It was not clear from the photographs whether or not the Sienna was equipped with the seat back mounted side air bags. The case vehicle was not equipped with rollover sensing. Traction Control and ESC were also listed as optional equipment on this model. However, there was not enough information available to determine if this equipment was installed on the case vehicle.

The crash occurred on a six lane divided interstate roadway during early morning hours under an overcast sky and dry conditions. The crash occurred on the southbound travel lanes. These lanes were surfaced with asphalt and were straight and level. The speed limit was 55 mph. The roadway was bounded by paved shoulders. The northbound and southbound lanes were separated by a median strip lined with grass and a W-beam barrier. It should be noted here that the PAR did not contain any crash schematic. Therefore, the description of the vehicle kinematics below, was obtained from CDRC's review of available photographic evidence.

The case vehicle was driven by a belted 54 year-old male. In addition to the driver, the vehicle was occupied by an unbelted 47 year-old female seated in the right front seat. Both of the vehicles were traveling in the third southbound lane. However, the other Sienna was traveling in the wrong direction (northbound). According to the PAR, the driver was intoxicated. The two vehicles collided in the third southbound lane in a frontal offset collision mode. There was no speed estimate available. However, based on the damage sustained by the case vehicle, it would appear that it had the greater velocity at the point of impact. Following the impact, the silver colored Sienna was deflected backward and initiated a rapid CCW rotation. The vehicle rotated approximately 270 degrees and came to rest on the left side shoulder of the southbound roadway. A fire ignited in the vehicle after it came to rest. The driver was rescued from the vehicle from a passerby. The case vehicle continued forward and was deflected toward its right in a CCW

rotation. The case vehicle skidded across the center and first lanes before rolling over on its right side on the right side shoulder. Prior to coming to rest, the vehicle rotated approximately 180 degrees in the CCW direction. Availability of ESC would not have made a difference in the response of the case vehicle due to the impact with the other vehicle.

Based on available photographs, it appeared that most of the vertical and lateral roof crush occurred on the right side at the A-pillar region. However, there was not enough information to estimate the amount of crush since the vehicle was only photographed on its right side at its final rest position. The frontal air bags and SCABs deployed during the crash event. The unbelted right front passenger was ejected. The most likely ejection area was the right windshield area. The occupant sustained fatal injuries to the head and chest. The driver of the case vehicle sustained serious injuries. The SCAB may have been beneficial in preventing the driver from being partially ejected. The driver of the other vehicle also sustained serious injuries. Due to the lack of sufficient interior photographs, the contact points and injury sources were not able to be determined.

Evaluation of RODSS Case No. R06092

This was a single vehicle crash involving the case vehicle, a 2002 Mercedes Benz C240 four-door sedan. The case vehicle was equipped with frontal air bags, front door mounted side impact air bags, SCABs, ESC, Traction Control, and ABS. According to the crash summary, the case vehicle may have been equipped with rollover sensing. However, this was not able to be confirmed.

The crash occurred in the northbound direction on a two lane suburban road during nighttime hours. The lane was surfaced with asphalt and was straight and level. The speed limit was posted at 30 mph. The northbound side of the road ended at a T-intersection. Vehicles arriving at this point were required to complete a 90 degree right turn onto an eastbound/westbound roadway. A temporary construction driveway extended north from this intersection. The road surface was dry and the weather was clear.

The case vehicle was driven northbound by an unbelted 21 year-old male. According to the PAR, he was intoxicated and tested positive for marijuana. In addition to the driver, the vehicle was occupied by a belted 21 year-old male seated in the right front seat and a belted 19 year-old male seated in the right rear seat. The Mercedes was proceeding northbound at a witness estimated speed of 50+ mph. Upon approaching the T-intersection, the driver did not attempt to turn the vehicle to the right, but continued in a straight northerly direction. According to the witness, the driver entered the construction driveway and did not apply his breaks. As the vehicle proceeded forward, the left front area of the vehicle struck and overrode a mound of dirt. This caused the Mercedes to begin yawing in the CCW direction. As the vehicle continued to yaw, its right front wheel contacted a large chunk of concrete. The impact deflated the right front tire and caused the vehicle to trip into a side over side rollover to the right. The case vehicle rolled over a total of six-quarter turns and landed on its roof.

Most of the roof crush occurred along the right A-pillar region. The roof crush estimate was three – four inches in both the vertical and lateral directions. The glazing on both front doors

and rear back light was disintegrated. All the air bags deployed during the crash event. According to the summary, the SCABs covered approximately three-quarters of the window opening and were tethered at the A- and C-pillars. The A-pillar was not protected by a sail panel. The driver was ejected through the left front window. He sustained fatal injuries. If the vehicle was equipped with rollover sensing, there would have been a greater likelihood of the driver remaining in the vehicle. Therefore, it is unlikely that the vehicle was equipped with rollover sensing. Both of the belted passengers survived the crash with minor injuries. The right side SCAB may have prevented both the right front and right rear passenger from being partially ejected.

Evaluation of RODSS Case No. R06098

This was a single vehicle crash involving the case vehicle, a 2004 Lincoln Aviator four-door SUV. The case vehicle was equipped with four wheel ABS, frontal air bags, and inflatable rollover protection. ESC and side impact air bags were not available. According to the PAR, the Lincoln was equipped with laminated side glass and a laminated sunroof. All glazing was closed at the time of the crash.

The rollover crash occurred off-road of a rural two lane roadway during late morning hours. The roadway was oriented in an east/west direction. The travel lanes were delineated with a dashed white centerline and both road edges were delineated with solid white fog lines. There were narrow paved shoulders located outboard of the fog lines. Outboard of the shoulders, there were shallow embankments. Near the crash site, the road curved toward the left and was level. The posted speed limit was 50 mph and the reported weather conditions were clear and travel surface was dry. A private driveway intersected the roadway on the right.

The case vehicle was driven by a belted 68 year-old female. The PAR did not list any alcohol involvement. The Lincoln was moving in a westerly direction. For some unknown reason, the driver allowed the vehicle to drift off to the right (north) edge of the roadway. The driver made a sharp correction to the left and then back to the right. The vehicle exited the roadway a second time and proceeded in a west/northwest direction. After moving past the edge of a shallow ditch, the driver tried to turn sharply to the left to regain the roadway. This caused the vehicle to begin yawing in a CCW direction and the right side tires began furrowing into the grass/dirt surface. This tripped the vehicle into a right side leading rollover. The Lincoln rolled one quarter turn to the right. While on its right side, the Lincoln slid for approximately 10 – 15 feet and then struck a tree with the forward portion of its roof structure. If the vehicle was equipped with ESC, it may not have made a difference since the vehicle was traveling on a grassy surface.

The Lincoln sustained significant roof crush. The maximum roof crush at the left roof side rail region between the A and B-pillars was estimated to be 22 – 24 inches. There was minimal lateral displacement of the roof. The sunroof was fractured but remained intact. The laminated front door glazing was cracked and fell from the window frames. The belted driver was not ejected or partially ejected. She sustained fatal head injuries from roof contact. The forward tether of the air bag was completely torn through due to the intruding tree. Due to the lack of interior photographs, other contact points and injury sources were not able to be determined.

Evaluation of RODSS Case No. R06109

This was a single vehicle crash involving the case vehicle, a 1998 BMW 740 il, four-door sedan. The case vehicle was equipped with advanced frontal air bags, front door mounted side impact air bags, and the HPS air bags. This vehicle was not equipped with ESC and rollover sensing.

The crash occurred off-road of a divided roadway. The road consisted of two lanes in each direction. The crash occurred during daytime hours under a cloudy sky and dry conditions. The road was straight and level and the speed limit was posted at 65 mph. The travel lanes were bordered by shoulders. The outboard lane was bordered by a 7 foot wide shoulder. Both lanes and the shoulders were surfaced with asphalt. A shallow asphalt mountable curb bordered the edge of the outboard shoulder. Adjacent to outboard shoulder was a grassy area that was level with a documented width of twelve feet. This transitioned to a 45 degree negative slope that contained trees and brush. This negatively sloped region terminated at a railroad bed which contained a single set of tracks.

The case vehicle was driven by a belted 62 year-old male. While heading to work, the driver lost control and caused the vehicle to depart the right shoulder. The vehicle proceeded toward the grassy roadside. After impacting two trees, the vehicle proceeded down the steep embankment and overturned in a fall-over type of rollover event. The vehicle landed on its roof along the edge of the railroad track. If the case vehicle was equipped with ESC, it probably would not have engaged since the vehicle tracked toward the steep embankment.

The vehicle sustained severe damage along the left roof rail area. The maximum vertical roof crush was estimated at 16 inches at the left A-pillar area. The maximum lateral crush was estimated at four – six inches at the same location. Glazing on all four doors, sunroof, and rear back light was disintegrated. All of the available air bags deployed during the crash event. The driver was partially ejected through the left front window. The driver's head and upper torso were located outboard of the vehicle under the HPS air bag. The driver sustained fatal injuries to the head and chest. His head came to rest on the track rail.

Evaluation of RODSS Case No. R06110

This was a single vehicle crash involving the case vehicle, a 2004 BMW 545i four-door sedan. The case vehicle was equipped with dual stage frontal air bags, front door mounted side impact air bags, and SCABs. The SCABs consisted of a tubular air bag encased in a sleeve to form a curtain. The sleeve was split aft of the B-pillar with the tubular bag exposed at this location. Based on available photographs, the SCAB covered approximately 50 percent of the window opening. This vehicle was also equipped with ESC and was probably equipped with rollover sensing. However, this was not able to be confirmed.

The crash occurred at a Y-intersection of a four lane roadway during nighttime hours. The road, which was lined with street lights, forked into two lanes in each direction. The median between the two roads was curbed and landscaped. The conditions at the time of the crash were clear and dry. The eastbound lanes were curbed with asphalt with an approaching sharp right curve. The speed limit at this location was 35 mph.

The case vehicle was driven by a belted 29 year-old female who was intoxicated. In addition to the driver, the vehicle was occupied by an unbelted 31 year-old male seated in the right front seat, and a belted 38 year-old female seated in the right rear seat. The driver was traveling east in the inboard lane as she approached the split in the road. According to the PAR, the driver estimated her speed at 35-40mph. However, based on the severity of the crash and the distance traveled, the speed was probably higher. As she attempted to negotiate the right side curve, she allowed the vehicle to drift toward the left and crossover the inboard lane. The vehicle overrode the pavement and impacted the curb with the left side tires and wheels. This impact caused the left side tires to deflate. The vehicle was initially redirected by the curb but then the driver applied a CCW turn which caused the vehicle to override the curb. The vehicle proceeded through the landscaped area and rotated CCW as it exited the area. The vehicle proceeded onto a parking area with an asphalt surface. At this point, the front wheels and suspension had separated from the vehicle. As the case vehicle continued to rotate CCW, the undercarriage gouged the pavement that tripped the vehicle into a left side leading rollover event. The vehicle completed four-quarter turns and ended up on its wheels. Following this event, the right rear door and wheel of the vehicle impacted a fire hydrant. At the same time, the right B-pillar impacted and fractured a 4x4 inch sign post. The ESC did not engage since the driver relinquished control at the curve and the vehicle tracked onto the curb following a driver steering maneuver.

The roof crush was minor with an estimated vertical crush of one inch at the right B-pillar. The vehicle sustained significant damage to the right rear door area, hood and front bumper. The SCABs and the right door mounted side impact air bag deployed during the rollover event. In regards to glazing damage, the right rear door, windshield, and sunroof glazing disintegrated during the crash. The right front passenger was ejected through the sunroof. He sustained fatal injuries. The final rest position of the ejected passenger was on the ground next to the right side of the vehicle. The other two occupants remained in the vehicle and exited through the left side doors. Both of them sustained minor injuries. The SCABs may have provided a benefit in preventing the belted right rear occupant from being partially ejected. There were not enough interior photographs to determine contact points and injury sources.

Evaluation of RODSS Case No. R06116

This was a single vehicle crash involving the case vehicle, a 2001 BMW 330i four-door sedan. The case vehicle was equipped with dual stage frontal air bags, front door mounted side impact air bags, and the HPS air bags. In addition, the vehicle was equipped with ESC. However, the BMW was not equipped with rollover sensing.

The crash occurred in the northbound lanes of a four lane divided roadway during nighttime hours. At the time of the crash, the asphalt road surface was dry under clear conditions. The northbound lanes were bordered by inboard and outboard shoulders. In addition, the northbound lanes curved to the right with a slight downgrade. The median and outboard roadside consisted of crushed stone. The outboard roadside was flat for a distance of approximately 20 feet with a slope extending upward at an angle of approximately 15-20 degrees. The speed limit was posted at 55 mph.

The case vehicle was driven by an unbelted female of unknown age. She was coming from a party and was advised by others not to drive. As she was driving in the inboard travel lane in a northbound direction, several witnesses reported that she was driving erratically and passing vehicles at a high speed. As she attempted to negotiate the right hand curve, she allowed the vehicle to depart the inboard road edge and shoulder. The vehicle entered the stoned median before the driver initiated a CW steering maneuver. This forced the vehicle into a CW yaw on the stone surface. The BMW re-entered the northbound travel lanes while still rotating in the yaw direction. The operating conditions appeared to limit the effectiveness of the ESC. During this rotation process, the left front tire rolled under the alloy wheel. This event forced the alloy wheel to gouge the asphalt surface that tripped the vehicle into a left side leading rollover event. The BMW continued to roll about its longitudinal axis as it departed the outboard road edge and shoulder. The BMW continued to roll across the stone roadside. It had completed eight-quarter turns prior to coming to rest.

The maximum roof crush was estimated at four inches vertically at the header/right A-pillar region. The lateral crush amount was two inches. The glazing on both front doors and rear back light disintegrated during the rollover. The front suspension including the tires, wheels, and brake assemblies were separated from the vehicle. The driver side door mounted air bag and the HPS deployed during the rollover event. The driver was ejected through the right front window. She sustained fatal injuries. Due to lack of sufficient interior photographs, there was no information on contact points and/or injury sources.

Evaluation of RODSS Case No. R06118

This was a single vehicle crash involving the case vehicle, a 2004 Lexus ES330 four-door sedan. The case vehicle was equipped with ABS, advanced frontal air bags, front seat back mounted side impact air bags, and SCABs. ESC was optional on this model. It is therefore, unknown if this vehicle was equipped with ESC. This vehicle was not equipped with rollover sensing. It should be noted here that this case contained a sanitized PAR and poor quality nighttime images. The PAR contained a rough sketch of the scene along with conflicting evidence in regards to the driver.

The crash occurred on a four lane road around midnight in a zone where the speed limit was 50 mph. The road was divided by a median. The type of median was not specified in the PAR. The conditions at the time of the crash were clear and dry. The road surface was asphalt and the travel lanes were straight in the eastbound direction of travel. The travel lanes were bordered by shoulders. Adjacent to the left shoulder was a grassy roadside with an embankment. In addition, a T-intersection was located on the left side of the roadway. The intersecting road consisted of two lanes. On the left side of this two-lane roadway was an embankment which sloped downward into a canal that ran parallel to the intersecting roadway. The canal was bounded by a six foot high retaining wall above the level of the water. Several trees were also planted along the surface of the canal.

The case vehicle was driven by a belted elderly male of unknown age. The vehicle was traveling in an easterly direction. According to the PAR, the driver relinquished control of the vehicle. The vehicle proceeded to cross the median and the westbound travel lanes departing the roadway

toward the left hand side. The case vehicle impacted a small diameter tree with its front end. The impact with the tree did not alter the course of the vehicle as it proceeded along an easterly direction. The case vehicle crossed the intersecting roadway, overrode the embankment and entered the canal. The case vehicle overturned as it entered the water. According to the PAR, it is not clear what caused the vehicle to overturn. Since vehicle yaw was not an issue, the availability of ESC would not have had any mitigating effects. The case vehicle came to rest on its roof. The right front door skin was also separated from the vehicle. All side glazing and rear back light were disintegrated.

The estimated roof crush was three-four inches. According to the PAR, this damage probably occurred during the removal of the vehicle. All exterior sheet metal surfaces were deformed. The front and rear bumpers were separated from the vehicle. The hood, front grill, and headlight assemblies were also separated from the vehicle. The driver's frontal air bag and passenger side SCAB deployed during the crash. The driver remained in the vehicle and sustained fatal injuries. Some of the injuries noted in the PAR included multiple lacerations of the left forearm. According to the PAR, the cause (drowning and/or crash related) of death was unknown. Rescue personnel removed the driver from the vehicle.

Evaluation of RODSS Case No. R06119

This was a single vehicle crash involving the case vehicle, a 2004 Infiniti G35 four-door sedan. The case vehicle was equipped with dual stage frontal air bags, front seat back mounted side impact air bags, and SCABs. The vehicle was also equipped with ESC. The Infiniti was not equipped with rollover sensing. According to the PAR, the vehicle was equipped with worn tires (tread depth equal to 1/32 inches) on its rear axle.

The crash occurred on a two lane road around midnight under dry conditions. The northbound and southbound direction of traffic was divided by a solid double yellow line. The road sloped upward toward a hillcrest. Following the hillcrest, the road transitioned to a long downgrade. It was also bordered by narrow shoulders. Both roadway and shoulders were surfaced with asphalt. Approximately eight feet from the right shoulder a stand of oak trees lined the off-road region. The posted speed limit was 50 mph.

The case vehicle was driven by a belted 20 year-old male. According to the PAR, the driver was operating the vehicle on a suspended license for a previous Driving Under the Influence (DUI) conviction and was intoxicated at the time of the crash. In addition to the driver, the vehicle was occupied by a belted 20 year-old male seated in the right front seat. It should also be noted here that the available data obtained in the PAR was not sufficient to clearly identify all events in this crash. According to witnesses, the case vehicle was traveling southbound at a high speed. The estimated travel speed by witnesses and police was 90-100 mph. As the vehicle passed the top of the hill, it became airborne and traveled a police reported 81 feet. As the vehicle contacted the center of the northbound lane, the left front tire became flat. This caused the alloy wheel to gouge the asphalt surface and force the vehicle to initiate a CW yaw. The case vehicle continued to yaw in the CW direction across the centerline and southbound lane eventually departing the right shoulder area. The frontal part of the vehicle impacted one of the oak trees with sufficient force to deploy the frontal air bags. Following the impact with the tree,

the case vehicle continued to rotate CW which separated it from the tree. The G35 continued to travel south a total of 37 feet prior to impacting a second oak tree. The left front door and A-pillar impacted the tree. This impact caused both of the driver side air bags (i.e., seat back mounted side impact air bags and SCABs) to deploy. Following the impact with the second tree, the case vehicle probably rotated off this tree in a CW direction and traveled 22 feet south prior to impacting a third oak tree. Following the impact with this tree, the case vehicle initiated a right side leading tripped rollover. It proceeded in a southerly direction for about 15 feet before impacting another two closely spaced trees and coming to rest on its right side. It should be noted here that the two trees interrupted the rollover event. The passenger side air bags (including the SCAB) also deployed during the rollover event. The operating conditions appeared to limit the effectiveness of the ESC.

The Infiniti sustained significant damage on its left side. According to the PAR, the maximum roof crush occurred at the left A-pillar area. The maximum vertical crush at the A-pillar region was estimated at 12 inches while the lateral crush at the same area was estimated at 10 inches. All the glazing on the vehicle was disintegrated. Both occupants needed to be extricated from the vehicle. This required the roof to be cut. The right front passenger sustained fatal injuries to the head. The driver survived with neck and head injuries. The left side SCAB may have been a benefit in preventing the driver from being partially ejected. The source of injuries is unknown and there are limited interior photographs denoting contact points.

Evaluation of RODSS Case No. R06121

This was a single vehicle crash involving the case vehicle, a 2006 Ford Explorer SUV. The case vehicle was equipped with four-wheel ABS, Traction Control, ESC, frontal air bags and side impact air bags. This vehicle was also equipped with inflatable rollover protection. There were few photographs of the vehicle provided for this case.

The crash occurred on a four lane, divided asphalt roadway during nighttime hours. The roadway was oriented in a north/south direction. The east edge of the northbound lane was bounded by a low barrier curb with a sidewalk located immediately outboard of the curb-line. The posted speed limit was 40 mph and the weather conditions were cloudy and the road surface was dry. According to the PAR, the road surface was straight and level.

The case vehicle was driven by an unbelted 23 year-old male. It was unknown if there was alcohol or drug involvement. The case vehicle was traveling northbound at a police estimate speed of 70 mph. According to the PAR, the driver lost control of the vehicle. This caused the vehicle to proceed over the curb and impact a tree with its right front corner. This initial impact caused the right front door to open. According to the PAR, there was no evidence of braking or steering inputs over this travel distance. The impact with the tree separated the right front wheel from the vehicle and induced a CW yaw as the vehicle proceeded in a northerly direction. After traveling a short distance, the Explorer impacted another tree with its right frontal region. This impact caused the vehicle to yaw in the CW direction and induced a left side leading rollover event back toward the roadway. The Explorer rolled four quarter turns to the left before coming to rest on its wheels in the first northbound travel lane.

The maximum vertical roof crush was estimated at 4" – 5" at the right upper A-pillar region. The front air bag on the driver's side deployed during the crash sequence. All other air bags did not deploy. There appeared to be a malfunction with the rollover sensors. The unbelted driver was ejected through the right front door. He sustained fatal injuries to the head and neck. If the rollover sensors had operated properly, there would have been a greater likelihood of the driver not being ejected and surviving the crash. Due to the lack of interior photographs, no determination can be made of any occupant-to-vehicle interior contact points.

Evaluation of RODSS Case No. R06129

This was a two vehicle crash involving the case vehicle, a 2005 Cadillac four-door SUV and a 1999 Ford Taurus sedan. The case vehicle was equipped with frontal air bags, front seat back mounted side impact air bags, and SCABs. The Cadillac did not have rollover sensing. The other standard equipment included ESC.

The crash occurred on a four-way intersection during the late morning hours. The conditions were clear and dry. Traffic flow along the eastbound/westbound lanes through the intersection was uncontrolled while traffic flow along the northbound/southbound travel lanes was regulated by stop signs. The asphalt road surface was straight and level with a posted speed limit of 55 mph. Images were not available for this case.

The case vehicle was driven by an unbelted 35 year-old male. According to the PAR, the driver was traveling westbound in the center lane at a police estimated speed of 55 mph. As the case vehicle approached the intersection, the Taurus, which was initially traveling southbound initiated a left turn into the Cadillac's path of travel. The two vehicles collided in a frontal offset/oblique impact mode. The right front end of the Taurus impacted the right side area of the Cadillac. The Taurus rotated CW and proceeded to sideswipe the case vehicle. The sideswipe impact engaged the right rear tire and wheel of the Cadillac. This impact fractured the alloy wheel at the hub assembly which resulted in it being separated from the vehicle. This induced the Cadillac into a CW yaw across the westbound lane. The case vehicle yawed 50-60 degrees CW prior to initiating a left side leading turn-over rollover event. According to the PAR, there was no evidence to support wheel engagement with the asphalt road surface. Both left side tires remained inflated post-crash and the alloy wheels were damage free. The Cadillac rolled over four to eight-quarter turns. The Cadillac came to rest on its wheels. The vehicle-to-vehicle impact precluded the ESC from being a benefit.

The Cadillac sustained significant roof crush at the right A-pillar area. The crush was estimated at 12 inches vertically and 8 inches laterally. Half of the windshield glazing disintegrated. In addition, the glazing on all side doors, rear back light, and sunroof disintegrated. The frontal air bags did not deploy. The passenger side SCAB deployed upon impact with the Taurus. However, the seat mounted side air bags did not deploy. The driver was ejected through the sunroof. He sustained fatal injuries.

Evaluation of RODSS Case No. R06130

This was a single vehicle crash involving the case vehicle, a 2004 Lincoln Aviator SUV. The case vehicle was equipped with frontal air bags and SCABs with rollover sensing. This vehicle was not equipped with seat back mounted side air bags or ESC.

The crash occurred on a rural two lane road during early afternoon hours under a clear sky and dry conditions. The asphalt road surface was dry and the speed limit was posted at 45 mph. At the scene of the crash, the two travel lanes were divided by broken yellow lines. The road surface was bordered by gravel shoulders that where five feet in width on the left side and 10 feet in width on the right side. A drainage ditch was located outboard of the right hand shoulder. In addition, a barbed wire fence and tall grass extended beyond the ditch.

The case vehicle was driven by a belted 19 year-old female. The case vehicle was proceeding in the eastbound direction. In addition to the driver, the vehicle was also occupied by an unbelted 59 year old female seated in the right front seat. The driver was traveling at a witness estimated speed of 45 mph. According to the PAR, the driver was engaged in an argument with the passenger. For some unknown reason, the driver increased her speed to a police reconstructed speed of 77-80 mph. During the argument, the driver was distracted and allowed the vehicle to drift right onto the right side gravel shoulder. Realizing what was happening; the driver quickly applied a CCW steering input in an attempt to get back on the travel lane. The maneuver forced the vehicle across the eastbound lane and onto the westbound lane. The driver then applied a rapid CW steering maneuver which induced the vehicle into a CW yaw. The vehicle headed toward the eastbound lane and eventually into the right side shoulder. As the driver approached the right shoulder, she initiated a CCW yaw. The case vehicle continued to travel in an easterly direction along the shoulder and into the drainage ditch. If this vehicle was equipped with ESC, the driver may have been able to keep the vehicle under control. The vehicle's right side tires furrowed into the dirt which tripped the vehicle into a right side leading rollover event. The vehicle impacted several T-posts and a barbed wire fence. The vehicle rolled seven-quarter turns before coming to rest on its left side.

Most of the roof damage occurred at the left A-pillar area. The vertical roof crush was estimated at eight inches at the A-pillar area. The maximum lateral roof crush was estimated at three inches in the lateral direction at the A-B pillar area. The right front tire de-beaded from the alloy wheel during the rollover event. In regards to glazing damage, the rear quarter windows, rear back light, and sunroof were disintegrated. The rollover sensors deployed the SCABs. These SCABs were tethered to the A- and C-pillars. The SCABs were rectangular in shape and covered the entire rear window and half of the front window. The void between the A-pillar and the edge of the SCAB could be a portal for a partial ejection (e.g., head and arms). The belted driver remained in the vehicle and survived. She exited the vehicle on her own with unknown injuries. The SCAB may have been beneficial in preventing the driver from being partially ejected. Both frontal air bags did not deploy. The unbelted passenger was ejected through the sunroof. She sustained fatal injuries.

Evaluation of RODSS Case No. R06145

This was a single vehicle crash involving the case vehicle, a 2003 Mercedes C320 four door sedan. This vehicle was equipped with four-wheel ABS, Traction Control, ESC, frontal air bags and door mounted side impact air bags. This vehicle may have also been equipped with inflatable rollover protection. However, this was not able to be confirmed.

The crash occurred on a two lane roadway during nighttime hours. The roadway was oriented in a north/south direction. The east edge of the roadway was bounded by a concrete rain gutter. The posted speed limit was 25 mph and the weather conditions were clear and the road surface was dry. According to the PAR, the road surface was straight and level.

The case vehicle was driven by an unbelted 21 year-old male. According to the PAR, the driver was under the influence of alcohol. In addition to the driver, the vehicle was occupied by an unbelted 19 year-old male seated in the right front seat and a belted 15 year-old seated in the right rear seat. According to the PAR, the Mercedes was a stolen vehicle and was being driven away from the scene of a robbery. Prior to the crash, the case vehicle was involved in an earlier hit and run incident. During the earlier incident, the Mercedes struck and overrode a median curb and sideswiped three trees which resulted in damage to the left side of the vehicle. In addition, the left front and rear wheel rims and suspensions were damaged. The left front tire was also deflated and the wheel rim was periodically gouging the pavement.
According to witnesses, the case vehicle was traveling southbound at an estimated speed of 60 mph as it approached the crash site. As the vehicle passed through an intersection, it bottomed out in a drainage gutter. The driver lost control and the vehicle began to yaw CCW. After the vehicle yawed 50 – 55 degrees, the right rear tire debeaded and the rim began to gouge the road surface. This caused the vehicle to trip into a right side leading rollover event. The vehicle rolled six quarter turns, rolling through a fence and coming to rest on its top.

The maximum vertical roof crush was estimated at 3" – 5" in the center of the windshield. The lateral roof crush was estimated to be between 2" – 3" of lateral crush at the left A-pillar. The SCABs and the front and rear side impact air bags deployed during the crash event. The unbelted driver was ejected through the sunroof. He sustained fatal injuries to the head. Neither of the two passengers were ejected or partially ejected. The SCABs may have been beneficial in preventing the right rear passenger from being partially ejected and the right front passenger from being fully or partially ejected. Due to the lack of interior photographs, no determination can be made of any occupant-to-vehicle interior contact points.

Evaluation of RODSS Case No. R06147

This was a single vehicle crash involving the case vehicle, a 2003 Lincoln Navigator SUV. The case vehicle was equipped with four-wheel ABS, dual frontal air bags and rollover protection. This vehicle was not equipped with seat back mounted side air bags. Laminated side glass was installed on both front doors. It was not known if this vehicle was equipped with ESC.

The crash occurred on a two lane roadway during nighttime hours. The roadway was oriented in a southeast/northwest direction and was asphalt surfaced. The travel lanes were separated by

solid yellow lines and both road edges were delineated by solid white fog lines. The area outboard of the right side road edge consisted of a narrow strip of dirt followed by a steep negative sloped dirt surface. This region sloped into a drainage ditch and then sloped upward into a positive slope dirt embankment. The posted speed limit was 30 mph and the weather conditions were clear and the road surface was dry.

The case vehicle was driven by an unbelted 21 year-old male under the influence of alcohol. In addition to the driver, the vehicle was occupied by an unbelted 21 year-old male seated in the right front seat. The case vehicle was traveling westbound at high speed. Due to this high speed, the vehicle could not negotiate the upgrade curve toward the left. The vehicle began to yaw CCW and exited the roadway on the right. Upon exiting the roadway, the two right side tires partially debeaded which resulted in the tires being deflated. The vehicle proceeded down the embankment while it was yawing 20-30 degrees CCW. This maneuver caused the right wheel rim to furrow into the dirt surface and initiate a tripped rollover event. The Lincoln rolled eight quarter turns on its right side. The vehicle came to rest on its wheels on the embankment north of the drainage ditch.

The maximum vertical roof crush was estimated at 6" – 8" at the right upper A-pillar region. The lateral crush was estimated at 2" – 4" at the right A-pillar region. The pre-crash yaw maneuver of the vehicle would be indicative of a vehicle not equipped with ESC. The driver was not ejected or partially ejected. The driver sustained level B injuries. The right front passenger was ejected through the sunroof. He sustained fatal head injuries. The SCABs may have been a benefit in preventing the driver from being ejected. The dual front air bags did not deploy during the rollover event. Due to the lack of interior photographs, no determination can be made of any occupant-to-vehicle interior contact points.

6.1.2 Observations and General Conclusions Drawn From Analysis of RODSS Cases

1. The following observations were made regarding the RODSS data collection process:

    a. The majority of the cases lacked sufficient interior photographs.
    b. There was limited information on injuries and injury sources.
    c. Approximately a third of the cases involved a driver under the influence of alcohol.
    d. The distribution of rollover crashes by time of occurrence (daytime/nighttime hours) was approximately 50/50.
    e. Approximately 16 percent of the cases contained information on vehicle speed. This information was obtained from police estimates and reconstructions.

2. The following conclusions can be drawn from the RODSS cases analyzed:

    a. The seat belts were beneficial in preventing full occupant ejections during the rollover crashes. Also, there were no cases of seat belt failure (e.g., web tearing, anchor point failure, etc.) reported.
    b. In approximately 10 percent of the cases, roof intrusion was the source of fatal injury.

c. The critical pre-crash event in 63 percent of the RODSS cases analyzed involved a single vehicle departing the roadway.
d. There were more than three times as many ejections through the side windows in vehicles equipped with SCABs without rollover sensing than in vehicles equipped with SCABs with rollover sensing
e. There were some ejections through SCAB deployed windows. There were five ejections in vehicles equipped with SCABs without rollover sensing and there were two ejections in vehicles equipped with SCABs with rollover sensing. The five ejections which occurred in vehicles equipped with SCABs without rollover sensing can be attributed to the SCABs being designed for side impact applications only. In addition their inflation times are much shorter compared to SCABs with rollover sensing. In regards to the two ejections involving the deployed SCABs with rollover sensing, one of the cases involved a deployed SCAB with a ruptured tether. It is not clear what caused the left front tether to rupture during one of the ejection events.
f. There were some cases where the SCABs did not deploy. There were eight ejections in vehicles in which the SCABs without rollover sensing did not deploy and two ejections in vehicles in which the SCABs with rollover sensing did not deploy. There was also a case where the SCABs with rollover sensing did not deploy during a rollover event in which none of the occupants were ejected. Based on examination of available photographs and crash summaries, it was not clear whether the SCABs without rollover sensing would have been expected to be deployed. As stated previously, these SCABs were designed for side impact applications only. It was not clear what caused the non-deployment of the SCABs with rollover sensing.

7.0 Viability of the RODSS Data Collection Process to Gain Insight into Rollovers and Other Crash Types

An analysis was conducted to assess the viability of the RODSS data collection process to gain insight into rollovers and other crash types. The analysis consisted of the following:

a. Assessment of the utility of using local crash reconstructions for high interest crash cases
b. Areas for improvements to the data collection process

7.1 Assessment of RODSS Database to Determine Practicality

a. The local crash investigations did not generally provide occupant injury or interior photographs. This prevents the data collection technique from supporting occupant injury mitigation studies.
b. The local crash investigations do provide good detail on the crash scene and reasonable coverage of the vehicle(s) involved.

c. Local crash investigations could be practical method for collecting data for other crash types. Crashes need to be high severity to insure that local crash investigations will be available, but the data collection methodology should apply.
d. Confidentiality and privacy considerations need to be considered and negotiated up front in the planning stage for any follow up studies. The scene photographs were key to understanding the crash kinematics. The inability to include them in the final database greatly reduced the benefits from this study.

7.2 Suggested Improvements to the RODSS Data Collection Process

The following improvements are suggested to improve the data collection process:

a. Identifying cases from FARS was effective as these were generally investigated.
b. Improvements to VIN decoder for better vehicle attribute identification and case selection.

8.0 Lessons Learned

Here is a list of the lessons learned from the research conducted on the RODSS project.

1. The PARs do not always indicate whether or not photographs were taken and whether a reconstruction was initiated.
2. The reconstruction reports were provided in various levels of detail. Some were full reconstruction reports containing in-depth PARs which included detailed interviews, laboratory (including blood alcohol concentration (BAC)) and medical reports, officer's opinions and conclusions, speed estimates (not common), detailed scene schematics, and a detailed reconstruction of the crash dynamics. In addition, some of the reconstruction reports provided printouts obtained from the vehicle's Event Data Recorder (EDR) using the Bosch Crash Data Retrieval software. Other reports were not as detailed.
3. Some police agencies did not provide the reconstruction reports since these were classified as internal documents only. Internal reports are typically written for the following reasons:

    a. As a response to crashes involving serious injury and fatality
    b. To determine fault and to criminally charge appropriate party
    c. To protect/determine culpability of State/County roads, signage, and vehicle

4. Some of the photographs/images were incomplete and others were unusable (e.g., dark/nighttime photographs/images, scene without case vehicle, views of undercarriage only, etc.).

5. Certain police departments contacted by the CDRC did not wish to participate in this project. On the other hand, police agencies from states such as California, Colorado, Maryland, New York, and Florida were very helpful in providing the information requested by the CDRC.

6. The CDRC was not able to code all the required information from the PAR. This included information on glazing damage, vehicle curb weight, and also safety equipment availability. Information on glazing damage was obtained from available photographs and in some cases the PAR. Information on curb weight and air bag system availability was obtained from the VIN decoding software (PCVINA) used by CDRC. Information on ESC, traction control, and ABS was obtained from the internet (www.Edmunds.com and www.automotive.com).

Appendix 1. Preliminary RODSS Variable List

Since most of the cases were selected from FARS, it was assumed that the RODSS database would be formatted similar to the FARS database. The preliminary RODSS variable list is shown below. Some of the variables listed are currently coded in FARS. These variables are denoted by their respective FARS alphanumeric label (e.g., A24, V8, D4, P6, etc.).

Environment Variables

A24 – Roadway Alignment
A25 – Roadway Profile
A26 – Roadway Surface Type
A27 – Roadway Surface Conditions
A31 – Light Condition
A32 – Atmospheric Condition

Crash Variables

- Crash type: (e.g., run off road right), critical pre-crash event
- Posted and Estimated Speed
- Pre-Rollover Maneuver
- Pre-impact stability
- Attempted avoidance maneuver
- Pre-impact location
- CDC for rollover
- Rollover type
- Quarter Turns
- Interrupted Rollover (e.g., narrow object contact with roof)
- Rollover Initiation Location
- Object Contacted Class
- Object Contacted
- Location of Tripping Force
- Direction of Initial Roll
- Estimated Distance

Vehicle Variables

V8 – Vehicle Make
V9 – Vehicle Model
V10 – Body Type
V11 – Vehicle Model Year
V12 – Vehicle Identification Number
V16 - Travel Speed (from speed reconstruction)
V17 - Vehicle Maneuver
V18 – Crash Avoidance Maneuver
V19 – Rollover

- Vehicle Damage
- EDR Data
- Cargo / Vehicle loaded/unloaded (Y/N)
- Other Vehicles Involved
- Position of Vehicle when it came to rest (on wheels, roof, or side)
- Presence of ESC/RSC (imputed from VIN or make/model/year)
- Presence of safety belt pretensioners equipped with rollover sensors (imputed from VIN or make/model/year)
- Damage to rollover curtain (e.g., tears, cuts, ground abrasion, etc.)
- Crash severity (amount of side crush for ¼ turn cases, severity of roof crush, extent of roof crush over occupants, one sided roof damage vs. two sided roof damage, near side vs. far side roof damage)
- Maximum crush for the passenger compartment both vertically and laterally and amount of intrusion
- Damage due to roof racks
- Window position (pre-crash)
- Window position (post-crash)
- Glazing Type
  - Laminated Glass
- Sunroof Presence, material (e.g., AS-2), open/closed, post crash status
- Tire details – tread depth, tire pressure, and wheel/tire damage

Driver Variables

D4 – Driver Presence
D12 – Driver Height
D13 – Driver Weight
D14 – Previous Recorded Crashes
D16 – Previous DUI Convictions
- Driver distraction/inattention/impairment

Occupant (s) Variables

P6 – Age
P7 – Sex
P9 – Seating Position
P10 – Belt Use (Y/N)
P11 – Air Bag Curtain Presence and Deployment
P12 – Ejection (Y/N)
- Full or Partial Ejection

P13 – Ejection Path (body part involved, near side vs. far side)
- Ejection area

P14 – Extrication
P16 – Police Reported Alcohol Involvement
P22 – Injury Severity (assuming medical records are available, injuries due to contact with vehicle interior structures and curtain air bag)

- Belt Failure (Y/N)
- Pretensioners Activated (Y/N)
- Size of Window Curtains
- Deployment on time (Y/N)
- Occupant in Child Seat (Y/N)

Appendix 2. Final RODSS Variable List (1 of 4)

The updated and final RODSS variable list is shown below.

Case Summary	Vehicle Information
(11 Variables)	(14 Variables)
Case Number	Vehicle Number
Crash Date	Vehicle Role
Crash Time	Vehicle Model Year
Crash Type	Vehicle Make
Crash Configuration	Vehicle Model
Total Number of Vehicles	Vehicle Body Category
Total Number of Occupants In Case Vehicle	Body Type
Total Number of Occupants In Other Vehicle	Vehicle Identification Number
Number of Events In Crash	Vehicle Curb Weight
Summary	Cargo / Vehicle Loaded
FARS/GES Case Number	Other Occupants
	Other Occupants Injured
	Occupant Ejected
	Injury Severity

Appendix 2 (Continued). Final RODSS Variable List (2 of 4)

Driver Information	Occupant Information
(24 Variables)	(27 Variables)
Vehicle Number	Occupant Number
Gender	Vehicle Number
Age	Occupant Seating Position
Height	Gender
Weight	Age
Safety belt Use	Age Type
Safety Belt Misuse	Height
Curtain Air Bag Present	Weight
Curtain Air Bag Deployment Status	Was Occupant Seated In Child Safety Seat
Vertical Extent of Curtain Air Bag	Safety belt Use
Length of Curtain Air Bag	Safety Belt Misuse
Tether	Curtain Air Bag Present
Damage To Rollover Curtain (s)	Curtain Air Bag Deployment Status
Driver Ejected	Vertical Extent of Curtain Air Bag
Ejection Description	Length of Curtain Air Bag
Body Part Partially Ejected	Damage To Rollover Curtain (s)
Ejection Area	Tether
Ejection Medium	Occupant Ejected
Extrication	Ejection Description
Sail Panel or Coverage To Full A-Pillar Height	Body Part Partially Ejected
Driver Injured	Ejection Area
Injury Severity	Ejection Medium
Injuries Due To Contact With	Extrication
Police Reported Alcohol Involvement	Sail Panel or Coverage To Full A-Pillar Height
	Occupant Injured
	Injury Severity
	Injuries Due To Contact With

Appendix 2 (Continued). Final RODSS Variable List (3 of 4)

Pre-Crash Information	Glazing Information
(15 Variables)	(15 Variables)
Roadway Alignment	Not Applicable Glazing
Roadway Profile	Windshield
Roadway Surface Type	Left Front
Roadway Surface Condition	Right Front
Light Conditions	Left Rear
Weather Condition	Left Rear 2
Posted Speed Limit	Right Rear
Estimated Travel Speed	Right Rear 2
Pre-Event Movement	Left Rear 3
Critical Pre-Crash Category	Right Rear 3
Critical Pre-Crash Event	Back Light
Attempted Avoidance Maneuver	Left Back Light
Pre-Impact Stability	Right Back Light
Pre-Impact Location	Roof
Crash Type	Other

Appendix 2 (Continued). Final RODSS Variable List (4 of 4)

Rollover Information
(33 Variables)
Rollover Type
Rollover Data - Quarter Turns
Interrupted Roll
Pre-Rollover Maneuver
Rollover Initiation Type
Rollover Initiation Location
Rollover Initiation-Object Contacted Class
Rollover Initiation Object Contacted
Rollover Specifics-Location on Vehicle Where Initiating Rollover Force is Applied
Direction Of Initial Roll
Estimated Distance From Tip Point To Final Rest Position
Position of Vehicle When It Came To Rest (On Wheels, Roof, Or Side)
Case Vehicle Damage Severity
Maximum Roof Crush For The Passenger Compartment: Vertical
Maximum Roof Crush For The Passenger Compartment: Lateral
Damage to Roof Due to Presence of Roof Racks
CDC For Rollover
EDR Data
Presence of ESC/RSC (Inputted From VIN Or Make/Model/Year)
Equipped With Rollover Sensors (Inputted From VIN Or Make/Model/Year)
Other Vehicles Involved
LF Tire Deflated
LF Tire Restricted
LF Wheel Tire Damaged
LR Tire Deflated
LR Tire Restricted
LR Wheel Tire Damaged
RR Tire Deflated
RR Tire Restricted
RRWheelTireDamaged
RF Tire Deflated
RF Tire Restricted
RF Wheel Tire Damaged

REFERENCE

1. Communication with Garrick J. Forkenbrock – NHTSA Vehicle Research and Test Center

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