Safety Analysis of Extruding W-Beam Guardrail Terminal Crashes

Report from Joint AASHTO-FHWA Task Force on Guardrail Terminal Crash Analysis

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EXECUTIVE SUMMARY

This report documents a joint effort between the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) to assess the safety performance of extruding w-beam guardrail terminals (also called guardrail end terminals and guardrail end treatments). The Joint Task Force on Guardrail Terminal Crash Analysis (Task Force) was assembled to answer the following questions:

- Are there performance limitations with the ET-Plus 4-inch extruding w-beam guardrail terminal and other extruding w-beam guardrail terminals (e.g., SKT and FLEAT)?
- If yes, what are the next steps to further analyze or address these performance limitations?

The purpose of this effort was to determine whether there is any evidence of unique performance limitations of the ET-Plus 4-inch guardrail terminal and the degree to which any such performance limitations extend to other extruding w-beam guardrail terminals. This study does not constitute a full in-service evaluation because the available data did not provide a representative sample of terminals in service or a representative sample of terminals that were struck. As a result, the effort does not provide relative comparisons of the in-service safety performance of individual terminal types or an indication of the frequency of occurrence of the individual performance limitations.

The report provides background information on guardrail terminals and covers the data on extruding w-beam guardrail terminals analyzed by the Task Force and independent experts. The data include information received from records and crash reports from States, the public, and interested safety organizations submitted in response to an FHWA *Federal Register* Notice and Request for Information (79 FR 77595 (Dec. 24, 2014)); from FHWA Division Offices; national databases such as the Fatality Analysis Reporting System (FARS), National Automotive Sampling System Crashworthiness Data System (NASS CDS), the National Motor Vehicle Crash Causation Study (NMVCCS), and the multi-state Highway Safety Information System (HSIS).

The FARS and HSIS analyses provided estimates of the frequency and severity of crashes with guardrails. The FARS analysis indicates that fatal crashes with guardrails involving passenger cars and light trucks represent less than one percent of the almost 33,000 fatalities nationwide that occurred in 2013. In the same year, passenger car and light truck fatalities in which the most harmful event was a collision with a guardrail face or guardrail end (which includes all types of crashworthy guardrail terminals and non-crashworthy terminals such as blunt ends and turn-downs) represent 0.6 percent and 0.2 percent, respectively, of total highway fatalities. The HSIS analysis indicates that the majority of crashes when guardrails were coded as the most harmful event resulted in property damage only (75 percent for guardrail face and 61 percent for guardrail end).

The combined number of crashes FHWA received through its external outreach and that it could glean from the crash records contained in national databases for guardrail terminals was 1231 (the complete list of the crashes received is contained in Appendix D). FHWA conducted an initial screening of these cases to determine whether they contained sufficient detail to evaluate:

- the type of terminal involved in the crash,
- the role the terminal played in the crash, and
- the performance of the terminal during the crash.

The cases received varied considerably in the level of detail each contained. FHWA was able to review several data sources that became available before the Task Force was formed, and through the initial screening, was able to keep the effort on schedule. FHWA shared with the Task Force the methodology used to screen the cases and forwarded to the Task Force those cases that provided sufficient information to allow them to evaluate the role the terminal played in the crash. These cases concentrated on crashes involving severe or fatal injuries, occupant compartment penetration or deformation, rollover, or where the outcome appeared to be unusual or extreme. Out of the 1231 cases, 161 cases were selected for the Task Force's detailed review and analysis. These cases that comprised the focus of the review were viewed as the most likely to show potential performance limitations and represented a limited sample across five different guardrail terminals. The data in this assessment were skewed toward severe crashes involving ET terminals; a limited sample of SKT and FLEAT cases were captured.

The information provided for the 1231 crash cases was inconsistent and prevented an in-depth analysis of each crash. For some cases, there was enough information to allow a reasonably informed evaluation of the performance of the terminal. However, the conclusions should not be interpreted as definitive. The limitations highlight the need for well-designed in-service performance evaluations of all guardrail terminals with a comprehensive sample representing all crash severities (fatal, serious injury, moderate injury, minor injury, and property damage only crashes). Nevertheless, from this analysis of the 161 crashes which were predominantly ET-Plus 4-inch devices (ET 2000, ET-Plus 5-inch, SKT, and FLEAT devices also were included), some performance limitations could be gleaned in two broad areas for extruding w-beam guardrail terminals: impact conditions and installation conditions. The evidence did not suggest that these performance limitations are limited to the ET-Plus 4-inch device.

Based on the analysis, the Task Force developed the following conclusions and recommendations to address the identified w-beam guardrail terminal performance limitations.

Conclusions

1. **Guardrail Terminal Crash Test Impact Conditions and Field-installed Conditions -** The review of guardrail terminal performance based upon the limited number of crashes confirms what is acknowledged in National

Cooperative Highway Research Program (NCHRP) Report 350[1] and the AASHTO Manual for Assessing Safety Hardware (MASH)[2] – there are real-world impact conditions that vary widely from the crash test matrices as related to vehicle type and sizes, first point of vehicle impact, vehicle non-tracking, and vehicle speed. Also, there are different installation and maintenance practices in place that can affect safety performance. Within the roadside safety community, it is recognized that even with the "best" practice of terminal design, with the wide variety of traffic and field conditions and applications, there will be crashes that exceed the performance expectations for the terminals. In addition, roadside features such as ditches, curbing, uneven terrain, and steep slopes in the vicinity of the terminal factor into the ability to mitigate the severity of the outcome of a guardrail terminal crash event. These terrain features can contribute to an increased likelihood of rollover during or after the impact event.

2. **Performance Limitations** – Performance limitations are factors in a real-world crash environment that can contribute to the unsuccessful performance of a roadside safety hardware device. As indicated in MASH, guardrail terminals "are generally developed and tested for selected idealized situations that are intended to encompass a large majority, but not all, of the possible in-service collisions." Satisfactory performance can typically be expected for collision conditions similar to the test conditions. However, the performance of these devices is dictated by physical laws, vehicle stability, vehicle crashworthiness, and the site conditions of these real-world crashes. The more the crash conditions differ from the test conditions, the more likely it becomes that performance will be outside of the desirable limits.

   Through its analysis, the Task Force identified several performance limitations for all types of extruding w-beam guardrail terminals reviewed in this study. The limitations fall into two general categories: 1) impact conditions, and 2) installation conditions. For impact conditions, the primary performance limitations that were identified include: 1) side impacts, 2) head-on/shallow-angle corner impacts, and 3) head-on/shallow-angle high-energy impacts. For installation conditions, the performance limitations identified include: 1) hardware installation/maintenance/repair issues, 2) grading issues, and 3) placement that does not conform to accepted guidance and practice. These installation conditions can adversely affect the safety performance of these devices, but it is unknown to what extent, since terminals are crash tested under ideal, controlled conditions.

3. **NCHRP Report 350 Crash Test Criteria** – NCHRP Report 350 crash test matrices do not specifically address the performance limitations the Task Force identified. It appears that side impacts, head-on/shallow-angle high-energy

[1] TRB's National Cooperative Highway Research Report 350 – Recommended Procedures for the Safety Performance Evaluation of Highway Features,

[2] AASHTO's Manual for Assessing Safety Hardware, 2009.

impacts, and head-on/shallow-angle corner impacts may lead to safety performance issues. However, the data analyzed did not allow for an assessment of how frequently these situations occur (i.e., they may be limited or they may appear on a regular basis) in the field. The shallow angle impact test condition is addressed in the MASH crash test criteria, but side impacts and front corner impacts are not specifically addressed in MASH. This points to the need to conduct in-service performance evaluations on roadside safety hardware including guardrail terminals; these evaluations are critical to determine whether crash-tested hardware have performance limitations that are not detected by the testing process and should be used to amend the crash test criteria in subsequent updates.

4. **Crash Testing of Extruding W-beam Guardrail Terminals** – The Task Force considered additional crash testing of all existing NCHRP 350-compliant extruding w-beam guardrail terminals but concluded that such testing would not be informative because the performance limitations identified for these terminals fall outside of the NCHRP 350 testing matrices.

Recommendations

The Task Force developed the following recommendations:

1. **Fully Implement MASH Compliance for New Installations of Guardrail Terminals** – This action is related to the roadside safety community setting a date by which new installations of guardrail terminals should be consistent with the MASH crash test criteria. MASH testing incorporates changes in the crash matrix details that will be more discerning for guardrail terminals. More specifically, MASH addresses impacts that occur at shallow angles, which is an important element in two of the performance limitations identified in this report. Each successive version of crash testing guidelines is meant to encourage manufacturers to advance the state of the practice and to develop safety devices that work with a changing vehicle fleet under a wider range of conditions. Because of the extensive development and testing required, it typically takes many years after roadside safety hardware guidelines are established for products meeting those guidelines to be widely available on the market. However, in the six years since MASH was published, there have not been a significant number of MASH-tested devices developed and brought to market. Therefore, in order to encourage the expanded development and installation of MASH-compliant devices, the Task Force supports the roadside safety design community to expeditiously transition to the MASH criteria for all new installations of guardrail terminals.

2. **Conduct In-Service Performance Evaluations of Guardrail Terminals** – The Task Force recommends that comprehensive in-service performance evaluations of guardrail terminals be conducted at the national and State levels. As previously highlighted in this report, the Task Force's assessment did not involve a complete in-service evaluation and concentrated on a limited group of mostly higher severity crashes, specifically focused on crashes with the ET-Plus terminal. The findings of this report should be considered by the National Academies' National Research

Council (NRC) committee that is conducting a project entitled "In-Service Performance of Energy-Absorbing W-beam Guardrail End Treatments." The intent of the NRC committee is to conduct exploratory work to determine what data are available, in sufficient quantity and quality, to allow for meaningful in-service evaluation studies of guardrail terminals.

3. **Expand Documentation of Guardrail Crashes** – The Task Force recommends that AASHTO and FHWA encourage public agencies to thoroughly document guardrail crashes in order to allow for conducting more comprehensive in-service evaluations. Photographic evidence of an impacted guardrail and damaged vehicle(s) involved in a crash is extremely valuable and not typically captured. In addition, the Task Force recommends that AASHTO and FHWA request that the National Highway Traffic Safety Administration (NHTSA) thoroughly document guardrail crashes in its Crash Investigation Sampling System which is being phased in over the next two years as the replacement for the NASS CDS. Also, NCHRP project 17-43, "Long-Term Roadside Crash Data Collection Program," is providing an opportunity to improve data pertaining to roadside safety hardware that helps address this recommendation.

4. **Advance Noteworthy Safety Data and Roadside Hardware Inventory Practices** – The Task Force recommends that the highway safety community and transportation agencies bring forward noteworthy practices for developing and maintaining roadside hardware inventory systems and also those that link crash data to the location and type of roadside safety devices. This linking is important and critical to obtain complete information for analyzing roadside crashes. FHWA has a noteworthy practices database established at the following web location where this information could be added in the future: (http://rspcb.safety.fhwa.dot.gov/noteworthy/default.aspx).

5. **Conduct Research on Vehicle Corner Impacts with Guardrail Terminals –** The Task Force recommends that AASHTO and FHWA conduct research to evaluate the performance of vehicle front corner impacts with guardrail terminals to gain a better understanding of these crashes and the circumstances and conditions associated with them. Greater knowledge of this crash type could potentially be used to update future crash testing criteria. As summarized by this report, there were observed performance limitations with extruding w-beam guardrail terminals when the impact occurred at or near the vehicle corner in the headlight area.

6. **Conduct Research on Vehicle Side Impacts with Guardrail Terminals -** The Task Force recommends that AASHTO and FHWA conduct research to evaluate the performance of vehicle side impacts with guardrail terminals to gain a better understanding of these crashes and the circumstances and conditions associated with them. Greater knowledge of this crash type could potentially be used to update future crash testing criteria. As summarized by this report, there were observed performance limitations with extruding w-beam guardrail terminals when the impact occurred on the side of the vehicle. The opportunity for research should be explored with NHTSA to review vehicle standards relative to the strength of the

sides of passenger vehicles and to determine if vehicle side impacts into terminals and other fixed objects can be better addressed.

7. **Promote Proper Placement, Installation, and Maintenance Practices –** The Task Force recommends that appropriate placement, installation, and maintenance practices be shared with the roadside safety community as was recently done through FHWA's May 26, 2015 memorandum. FHWA provides training and technical assistance on these practices, and the Task Force recommends that highway agencies take advantage of these resources. In addition, the Task Force recommends that AASHTO, through its Technical Committee on Roadside Safety, include additional content regarding proper placement, installation, and maintenance of guardrail terminals in the next edition of AASHTO's Roadside Design Guide.

8. **Crash Testing of Extruding W-beam Guardrail Terminals** – The Task Force does not recommend additional crash testing of existing NCHRP 350-compliant extruding w-beam guardrail terminals for two reasons. First, the performance limitations identified for these terminals fall outside of the NCHRP 350 testing matrices, nor is it expected that NCHRP 350 tested devices function under all real-world conditions beyond what is present in the crash test scenarios. Second, as discussed in recommendation #1, the Task Force recommends that the roadside design community move to full implementation of MASH for all new installations of guardrail terminals which will help address an element of some of these performance limitations. Therefore, additional NCHRP 350 crash testing of existing guardrail terminals would be irrelevant since all crash testing since January 2011 has been required under the MASH criteria.

INTRODUCTION

Purpose

This report documents a joint effort between the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) to assess the safety performance of extruding w-beam guardrail terminals. The Joint Task Force on Guardrail Terminal Crash Analysis (Task Force) was assembled to answer the following questions:

- Are there performance limitations with the ET-Plus 4-inch w-beam guardrail terminal and other extruding w-beam guardrail terminals?

- If yes, what are the next steps to further analyze or address these performance limitations?

To address the first question, a broad array of data from different sources was assembled and analyzed. This effort began when FHWA asked AASHTO to include questions regarding the performance of w-beam terminals in a 2012 survey of its Standing Committees on Highways' Subcommittees on Maintenance and Design. The effort expanded to include:

- Analyzing crash information submitted by State DOTs and the public in response to FHWA's *Federal Register* Notice on December 24, 2014 (79 FR 77595).
- National data including the National Motor Vehicle Crash Causation Study (NMVCCS), National Automotive Sampling System Crashworthiness Data System (NASS CDS), the Fatality Analysis Reporting System (FARS), and the multi-state Highway Safety Information System (HSIS) database.
- Reviewing information provided by the State Departments of Transportation (State DOTs) and FHWA Division Offices at the FHWA Office of Safety's request, including crash reports and photographs involving guardrail terminals.
- Reviewing and analyzing the information prepared for the qui tam trial in Texas, including the reports prepared by experts, the relator, Joshua Harman, and Trinity Industries, Inc.
- Data obtained from various sources related to terminal crashes reported by the media.

This report provides a background and some history of roadside safety hardware to set the context and covers the data the Task Force and a group of independent experts analyzed. While a considerable number of crashes involving guardrail terminals were reviewed, the lack of well-documented, detailed records of the crashes limited the breadth and depth of the review. The findings of the analyses of individual crash cases highlight observed performance limitations of extruding w-beam guardrail terminals. The report

concludes with a set of recommendations and next steps to help address these performance limitations.

This effort does not constitute a full in-service evaluation because the available data was not a representative sample of terminals in service or a representative sample of terminals that were struck. As a result, the effort does not provide relative comparisons of the in-service safety performance of individual terminal types or an indication of the frequency of occurrence of the individual performance limitations. This type of comparison requires a well-designed and executed research study to collect all of the necessary data and account for exposure and confounding factors such as proper installation. Clearly, for this effort, a comparison was not possible given the limited available data and because the focus of the data reviewed was mostly on crash cases involving atypical or extreme conditions.

Guardrail Terminal Background

Guardrail design has evolved and improved significantly to reduce the risk of injury or death when a vehicle leaves the roadway. Since the mid-1960s, improvements have been guided both by observation of the performance of existing systems and by increasingly stringent testing of proposed systems.

However, a guardrail is intrinsically a roadside object that may be struck by an errant vehicle, albeit a roadside object that is intended to reduce crash severity by shielding a motorist from a hazard. A guardrail system should only be installed when the risk of impacting it is lower than the risk associated with encountering the objects shielded by the guardrail system.[3]

Guardrail systems are generally designed to accommodate the most common vehicles (i.e., passenger cars, pickup trucks, vans, and sport-utility vehicles) on a roadway and the "worst practical conditions."

When a crash occurs, there are many variables that may affect the outcome, including the impact speed; pavement condition; amount of braking; the angle of departure from the road; and the rate, direction, or amount of vehicle spin. Crash testing cannot replicate every possible scenario, so representative tests are conducted. For example, the AASHTO Manual for Assessing Safety Hardware (MASH) prescribes that crash tests into longitudinal barriers occur at an impact speed of 100 km/h (62 mph) and an impact angle of 25 degrees to represent the "practical worst case" for passenger vehicle impacts into guardrail systems installed on most high-speed highways.

Modern guardrails are intended to reduce the severity of crashes as compared to the trees, utility poles, steep slopes, and other objects they shield. Their primary function is to redirect an impacting vehicle back toward the road. For decades, a major challenge has

[3] *Roadside Design Guide*, 4th Edition, 2011. American Association of State Highway and Transportation Officials.

been to design the terminals of the guardrail to minimize the severity of crashes into the end of a length of a guardrail.

Prior to the 1950s, many terminals consisted of a bent shape of sheet metal that covered the end of the rail, often called a "blunt end." These terminals frequently speared vehicles that ran into them. Moreover, these ends provided little anchorage for the ends of the rail; thus while vehicles impacting the guardrail more than about 30 feet from either end could be safely redirected, a vehicle impacting near the unanchored end of the rail could break through and continue on to the roadside objects it was intended to shield.

The potential risk presented by blunt terminals led to the development of "ramped" or "turned-down" terminals. The concept of these terminals was to secure the leading end down onto the ground where it would not spear into a vehicle. This strategy not only anchored the rail securely, but it essentially eliminated the chance of spearing crashes. It became apparent, however, that this improvement also increased the likelihood of rollover crashes. Rollovers have relatively high injury risks. Even at low speeds, they increase the chance of unbelted motorists being completely or partially ejected and crushed by the vehicle.

The first terminal designed to anchor the guardrail as well as reduce the potential for rollover and spearing was the Breakaway Cable Terminal (BCT). A steel cable connecting the bottom of the first post to the guardrail beam provided an anchor to the barrier. The use of breakaway posts and layout of the terminal on a parabolic flare was designed to allow an errant vehicle to break through the end of the BCT without spearing or rolling over. While this terminal worked effectively for large passenger cars when crash-tested in the early 1970s, later testing with sub-compact cars showed a propensity for spearing.

The roadside design community looked for innovative ways to improve terminal designs. The goal was to develop terminals "soft" enough that the resulting vehicle decelerations were within specified limits for small vehicles, yet "firm" enough to stop larger vehicles. The intended function of the new terminals was to dissipate much of the kinetic energy from the vehicle – which is a function of its mass and speed – by using it to bend, kink, crush, or otherwise deform the elements of the w-beam guardrail. Terminals of this generation are called "energy-absorbing" terminals.

The first energy-absorbing product to reach the market was the Guardrail Extruder Terminal (GET), later named the ET-2000. Together with its successor, the ET-Plus, the Extruder Terminal family comprises the most common energy-absorbing guardrail terminals installed along the Nation's highways. Other extruding, energy-absorbing terminals include the Sequential Kinking Terminal (SKT) and the Flared Energy Absorbing Terminal (FLEAT). Extruding-type terminals are designed to function as follows, depending on the type of impact. During head-on impacts, the vehicle engages the impact head and pushes it down the rail. As the head travels down the rail, it bends and/or flattens the rail and extrudes the rail out the side of the head, essentially moving the rail away from the vehicle. This process dissipates energy from the impacting vehicle.

During angled impacts at the end of the terminal, the rail bends away and allows the vehicle to pass through the system. This behavior is called gating, and it typically dissipates much less energy from the impacting vehicle.

National Statistics

This section highlights some key national statistics to quantify the magnitude and severity of crashes involving guardrail and guardrail terminals.

Fatality Analysis Reporting System (FARS)

FARS is a nationwide census providing annual data regarding fatal injuries suffered in motor vehicle traffic crashes.[4] To assess the national role of guardrail terminals, fatality statistics from FARS involving passenger cars and light trucks were assembled, since these are the vehicle types in the recommended tests for safety performance evaluation of terminals.[5] In FARS, the category "passenger cars and light trucks" includes pickup trucks, sport utility vehicles, and minivans.

Furthermore, the FARS analysis considered fatalities in which either the most harmful event or the first harmful event, as defined in FARS, was collision with a guardrail face or guardrail end.[6] FARS defines *most harmful event* as "the event that resulted in the most severe injury or, if no injury, the greatest property damage involving this motor vehicle." FARS defines *first harmful event* as "the first injury or damage-producing event that characterizes the crash type." The following examples illustrate the difference between the most harmful event and first harmful event.

The first example involves a single-vehicle crash in which a vehicle departs the roadway, hits the end of the guardrail at an angle causing property damage only, and then goes behind the guardrail end as it "gates" and runs down an embankment, causing the vehicle to roll over with the driver sustaining major injuries. The first harmful event in this example is the guardrail impact, while the most harmful event is the rollover event that resulted in the driver being injured.

The second example involves a multi-vehicle crash in which vehicle A sideswipes vehicle B causing property damage to both vehicles. The driver of vehicle B then loses control and crashes into a guardrail causing an unbelted passenger in vehicle B to be ejected and fatally injured. The driver of vehicle A comes to a stop on the shoulder and sustains no injuries. The first harmful event in this example is the collision of the two vehicles, while the most harmful event is vehicle B impacting the guardrail.

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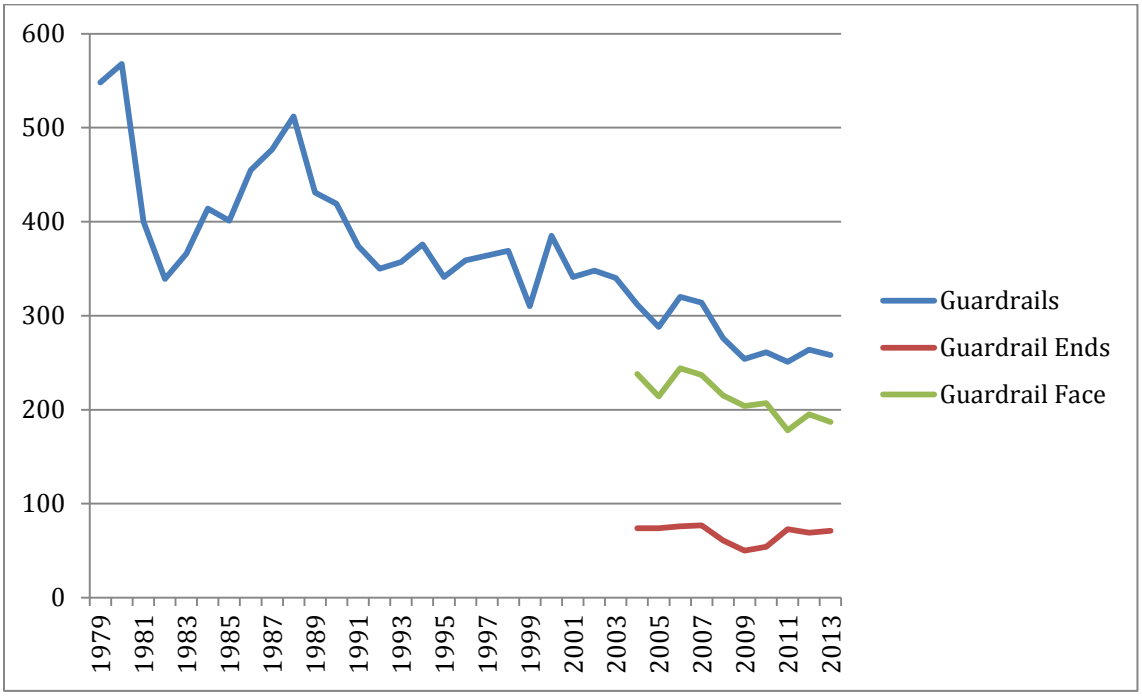
[4] http://www.nhtsa.gov/FARS.
[5] *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, NCHRP Report 350, 1993.
[6] *2013 FARS/NASS GES Coding and Validation Manual*, Publication Number DOT HS 812 094, 2014.

Figure 1 shows the trend from 1979 to 2013 in the annual number of fatalities (on the vertical axis) involving passenger cars and light trucks in which the most harmful event was collision with a guardrail—a decline of 53 percent from 548 fatalities in 1979 to 258 fatalities in 2013. Overall, the total number of motor vehicle fatalities declined 36 percent during the same period.

Figure 1 - Collision with Guardrails as Most Harmful Event in Fatalities involving Passenger Cars and Light Trucks



Source: Fatality Analysis Reporting System

In 2004, FARS began distinguishing between crashes into a guardrail face (i.e., along the length of the guardrail) and crashes into a guardrail end. Comparing passenger car and light truck statistics from recent years (2005- 2008 time period to 2009- 2013 time period), fatalities from crashes into a guardrail face as the most harmful event declined 15 percent, and fatalities from crashes into a guardrail end as the most harmful event declined 12 percent.

As shown in Table 1, during the past 5 years for which data are available (2009-2013), an annual average of 194 fatalities and 63 fatalities involved passenger cars and light trucks colliding with a guardrail face and end as the most harmful event, respectively.

Table 1 - Number of Fatalities in which the Most Harmful Event Involved Passenger Cars and Light Trucks Colliding with Guardrail Face and Guardrail End: 2009-2013

Most Harmful Event	2009	2010	2011	2012	2013	Average
Collision with Guardrail Face	204	207	178	195	187	194
Collision with Guardrail End	50	54	73	69	71	63

Source: Fatality Analysis Reporting System

In 2013, a total of 32,719 fatalities occurred on the Nation's roads for all vehicle types. Fatalities involving passenger cars and light trucks striking a guardrail face and a guardrail end as the most harmful event represent 0.6 percent and 0.2 percent, respectively, of total highway fatalities in 2013.

Table 2 summarizes the number of fatalities involving passenger cars and light trucks during the most recent five-year period for which data are available in which the first harmful event was collision with a guardrail face or guardrail end. On average, from 2009 to 2013, there were 479 fatalities and 132 fatalities per year in which the first harmful event involved guardrail face and guardrail end, respectively.

Table 2 - Number of Fatalities in which the First Harmful Event Involved Passenger Cars and Light Trucks Colliding with Guardrail Face and Guardrail End: 2009-2013

First Harmful Event	2009	2010	2011	2012	2013	Average
Collision with Guardrail Face	508	524	462	460	439	479
Collision with Guardrail End	125	130	136	126	141	132

Source: Fatality Analysis Reporting System

Fatalities in which the first harmful event was collision with a guardrail face or guardrail end represent 1.5 percent and 0.4 percent, respectively, of total highway fatalities in 2013.

Table 3 shows the number of fatalities with most harmful event for passenger cars and light trucks involving collisions with other fixed objects and obstacles (i.e., trees, utility poles, culverts, sign supports) and rollovers off the roadway.

Table 3 - Number of Fatalities with Most Harmful Event for Passenger Cars and Light Trucks: 2009-2013

Most Harmful Event	2009	2010	2011	2012	2013	Average
Collision with Other Fixed Objects	5,926	5,516	5,365	5,636	5,494	5,587
Rollover Off Roadway	4,780	4,566	4,338	4,380	3,921	4,397

Source: Fatality Analysis Reporting System

The number of fatalities with fixed objects and rollover off roadway as the most harmful event is considerably larger than the number of fatalities with guardrail face and end as the most harmful event. Guardrail systems are put in place to help shield motorists from encountering these objects and for other reasons.

Highway Safety Information System (HSIS)

HSIS[7] is a multi-state database that contains crash, roadway inventory, and traffic volume data for a group of seven States. North Carolina is the only State in HSIS that has data for guardrail face and end. The North Carolina data are presented in Tables 4 and 5. The tables include single-vehicle and multi-vehicle crashes involving passenger vehicles (passenger cars and light trucks). For the multi-vehicle crashes, the analysis captures the most severe injury that occurred in the vehicle for which the most harmful event was a collision with a guardrail face or guardrail end. The multi-vehicle cases in which the most severe injury may have occurred in the vehicle for which the most harmful event was not striking the guardrail have been removed. The KABCO scale is used to characterize injury severity.[8]

In summary, during the past 14 years for which data are available (2000-2013), 0.6 percent of guardrail face crashes and 2.3 percent of guardrail end crashes in North Carolina resulted in a fatality or serious injury. The majority of crashes with guardrail faces and ends as the most harmful event resulted in property-damage only.

Table 4 - North Carolina Single- and Multi-Vehicle (Passenger Vehicle) Crashes Involving Collision with Guardrail Face as Most Harmful Event: 2000-2013

Injury Severity	Total Number (2000-2013)	Average Number per Year	Percentage
K	66	4.7	0.2%
A	149	10.6	0.4%
B	2,109	151	5.9%
C	6,499	464	18.3%
O	26,734	1,910	75.2%
Total	35,557	2540	100.0%

[7] http://www.hsisinfo.org

[8] **Fatal Injury (K)**: A fatal injury is any injury that results in death within 30 days after the motor vehicle crash in which the injury occurred. If the person did not die at the scene but died within 30 days of the motor vehicle crash in which the injury occurred, the injury classification should be changed from the attribute previously assigned to the attribute "Fatal Injury."

Suspected Serious Injury (A): A suspected serious injury is any injury other than fatal which results in one or more of the following: 1) Severe laceration resulting in exposure of underlying tissues/muscle/organs or resulting in significant loss of blood, 2) Broken or distorted extremity (arm or leg), 3) Crush injuries, 4) Suspected skull, chest, or abdominal injury other than bruises or minor lacerations, 5) Significant burns (second and third degree burns over 10% or more of the body), 6) Unconsciousness when taken from the crash scene, or 7) Paralysis.

Suspected Minor Injury (B): A minor injury is any injury that is evident at the scene of the crash, other than fatal or serious injuries. Examples include lump on the head, abrasions, bruises, minor lacerations (cuts on the skin surface with minimal bleeding and no exposure of deeper tissue/muscle).

Possible Injury (C): A possible injury is any injury reported or claimed which is not a fatal, suspected serious, or suspected minor injury. Examples include momentary loss of consciousness, claim of injury, limping, or complaint of pain, or nausea. Possible injuries are those which are reported by the person or are indicated by his/her behavior, but no wounds or injuries are readily evident.

No Apparent Injury (O): This is a property-damage only crash. No apparent injury is a situation where there is no reason to believe that the person received any bodily harm from the motor vehicle crash. There is no physical evidence of injury and the person does not report any change in normal function.

Table 5 - North Carolina Single- and Multi-Vehicle (Passenger Vehicle) Crashes Involving Collision with Guardrail End as Most Harmful Event: 2000-2013

Injury Severity	Total Number (2000-2013)	Average Number per Year	Percentage
K	36	2.6	0.6%
A	96	6.9	1.7%
B	730	52	13.0%
C	1,341	96	23.9%
O	3,412	244	60.8%
Total	5,615	401	100.0%

General Data on Guardrail Terminals Supplied by States

On October 10, 2014, FHWA made a request through its Division Offices for information from State DOTs regarding the performance of the ET-Plus device in the field. All 50 States responded with varying levels of information. Some States provided general information, some provided crash statistics, and others discussed individual crashes. Appendix A contains an overview of the information each State provided.

This section focuses on the information from a small group of States (Connecticut, Illinois, Iowa, Massachusetts, Missouri, New Hampshire, North Carolina, and Pennsylvania) that provided crash statistics or information on individual crashes. The information is summarized below as reported by these States.

Connecticut

Connecticut indicated it has approximately 213 ET-Plus units (no distinction was made between the 4-inch and 5-inch versions) in the State with approximately 20 impacts on these units. Of these impacts, Connecticut indicated "all units performed well except in one crash where the unit was destroyed with components sticking up vertically after crash. It is unknown if any injuries were sustained in this crash as the vehicle fled the scene."

Illinois

Table 6 summarizes the total number of crashes for all contracts (i.e., projects) in Illinois between 2006 and 2012 as well as the weighted loss per crash (with weights of 25 for a K/fatal crash, 10 for an A severity-type crash, and 1 for a B-type crash on the KABCO scale) and the corresponding severities for the terminal types identified in those contracts.

Table 6 - Illinois Guardrail Terminal Crashes: 2006-2012

Terminal Type	# of Crashes	Weighted Loss Per Crash	Severities
Contract Data (2006-2012) Total All Types	48		
Crashworthy Terminals	17	0.24	0K, 0A, 4B, 0C, 13 PDO
ET Plus	12	0.25	0K, 0A, 3B, 0C, 9PDO
ET 2000	5	0.20	0K, 0A, 1B, 0C, 4 PDO
Non-Crashworthy	31	0.81	0K, 2A, 5B, 0C, 24 PDO

The weighted loss reported per crash was slightly higher for ET-Plus (no distinction was made between the 4-inch and 5-inch versions) relative to ET 2000. The crashworthy terminals had a lower loss per crash than the non-crashworthy terminals. It is important to note that these crash numbers are small making it challenging to draw statistical conclusions from this data.

In Illinois, the 3-year rolling average, for 2004-2013 data, showed a 23% decline in K&A injuries related to terminals (from 8.5% in 2004 to 6.5% in 2013).

The Illinois DOT monitors damage to terminals and replaces or repairs as necessary. It has had no indication from its district offices, local agencies, or the Illinois State Police of any adverse performance issues to date associated with the ET-Plus terminal.

The Illinois Tollway also responded and indicated it has experienced no adverse performance issues with ET-Plus terminals.

Indiana

The Indiana DOT reviewed terminal crashes that occurred in Indiana from January 1, 2007 through October 21, 2014. Its assessment primarily focused on nine crashes: six of the crashes involved the ET-Plus (4-inch or 5-inch channel), and three crashes involved the SKT-350. In eight of the cases, the State found no apparent evidence that any part of the barrier penetrated the vehicle. In the ninth case, which involved the SKT-350 terminal, the officer's report stated that the guardrail penetrated the vehicle and struck the driver. The precise element on the barrier run that penetrated the vehicle and the specific manner in which it did so were not specified. Indiana's investigation discovered no "undesirable pattern of behavior" of the ET-Plus in either the 4-inch or 5-inch channel design.

Iowa

From January 2010 to September 2014 in Iowa, 3 of 7 fatal crashes and 15 of 26 major injury crashes with guardrails involved a terminal. Out of the 18 fatal and major injury crashes into terminals, none involved an ET-Plus. During the same time period, Iowa did have six low-severity reported crashes (two non-incapacitating injury crashes, two

possible injury crashes, and two crashes without injury) and four unreported crashes involving the ET-Plus. At the statewide level, Iowa estimates that 30 to 40 percent of all guardrail crashes go unreported.

Massachusetts

During the Massachusetts DOT's initial review of some of its most recent crash data, it found four crashes that appeared to involve vehicle impacts with an ET-Plus terminal.

Of the four crashes, the Massachusetts DOT's initial evaluation was that in two of the crashes, it appeared that the ET-Plus terminal performed as designed. One crash resulted in a fatality but the Massachusetts DOT did not believe that the fatality was related to the performance of the ET-Plus terminal, as the terminal appeared to perform as designed but the vehicle rolled over after impact and the occupant was ejected. In the fourth crash, the Massachusetts DOT indicated it appeared that the impacting vehicle did experience some spearing of the vehicle after impact with an ET-Plus, but no injuries to the occupant resulted from the spearing.

In a submission to the *Federal Register* Notice and Request for Information, FHWA also received a report from Massachusetts involving an ET-Plus that was damaged and was unrepaired before a subsequent fatal crash.

Missouri

The Missouri DOT provided results from a study it commissioned from the University of Alabama-Birmingham (UAB), as documented in a report entitled *In-Service Evaluation of FHWA-Accepted Guardrail Terminals*. Following Missouri's submission, UAB revised the report content and changed the title to *Relative Comparison of NCHRP 350 Accepted Guardrail Terminals*. The study was not able to separate the 5-inch ET-Plus units from the 4-inch units based on the Missouri data. The data from the revised UAB study is presented below.

The study used a sample of approximately 1,550 miles of roadway along which there were 2,399 terminals. The most common type of end treatment was the ET-Plus. The entire distribution of observed systems is shown in Table 7 (displayed as Table 5 in the revised UAB study).

Table 7 - Exposure Data for Guardrail End Crash Locations (as titled in the original UAB study)

System	Total	Distribution
ET-2000	961	40.1%
ET-Plus	1,200	50.0%
FLEAT	9	0.4%
SKT	38	1.6%
SRT	191	8.0%
Total	2,399	100.0%

Table 8 (displayed as Table 6 in the revised UAB study) shows A+K and K crashes separately for the different systems.

Table 8 - Simple Probability and Odds Ratios (as titled in the original UAB study)

A+K Crashes				
System	Accidents	Exposure	Probability	Odds Ratio
ET-2000	49	961	0.0510	1.00
ET-PLUS	93	1,200	0.0775	1.52
FLEAT	0	9	0.0000	0.00
SKT	0	38	0.0000	0.00
SRT	14	191	0.0733	1.44
K Crashes				
System	Accidents	Exposure	Probability	Odds Ratio
ET-2000	4	961	0.0042	1.00
ET-PLUS	17	1,200	0.0142	3.40
FLEAT	0	9	0.0000	0.00
SKT	0	38	0.0000	0.00
SRT	2	191	0.0105	2.52

The probability of a guardrail terminal being involved in a crash was calculated using the crash site and exposure data for each of the five crashworthy guardrail terminals. In this study, it was assumed that the occupants of the vehicle would have driven 10 miles on the highway prior to a where a crash occurred. Exposure was defined as the number and distribution of end treatments observed in those 10 miles. Using the ET-2000 as a baseline, an odds ratio was calculated relative to the other systems (i.e., the odds of a terminal being involved versus an ET-2000). The odds ratios of the ET-Plus were found to be 1.52 and 3.40 for A+K and K crashes, respectively, when compared to its predecessor, the ET-2000. The study concluded that the ET-Plus is 1.52 times more likely to be involved in a severe injury than the ET-2000, and the ET-Plus is 3.40 times more likely to be involved in a fatal crash than the ET-2000.

This study was independently reviewed by three experts, and the results of the review can be found at http://www.fhwa.dot.gov/guardrailsafety/peerreview.cfm. The reviewers raised concerns about limitations or flaws in the study's methodology, which led all of them to question the validity of the study's findings and conclusions. The Safety Institute provided a response to FHWA's review which can be found at http://www.thesafetyinstitute.org/the-safety-institute-responds-to-critical-fhwa-review-3/, and Dr. Kevin Schrum's response to the review can be found at http://www.regulations.gov/, Docket Number FHWA-2014-0039, under Kevin Schrum - Comments.

New Hampshire

New Hampshire crash reports do not distinguish which section of a guardrail unit is impacted (i.e., longitudinal section or terminal unit). However, the New Hampshire DOT reported that it is aware of a crash on I-93 in the town of Ashland that impacted a recently installed ET-Plus terminal. Based upon a District office's photos of the post-crash event, the State believes the terminal "coiled" as designed with the impacting vehicle coming into contact with the stiffer longitudinal beam guardrail section where the rail eventually kinked. According to news reports, the rail entered the vehicle and seriously injured the two occupants.

Pennsylvania

Based on available data and a high-level data search of the 1,593 suspected crashes within 1000 feet of ET-2000 and ET-Plus known locations, Pennsylvania found only one case in which the guardrail terminal hit was listed as the only harmful event and involved compartment intrusion from the guardrail. Overall analysis of Pennsylvania's 4,936 guardrail terminal crashes between 2009 and 2013 show that 1.4 percent of such crashes resulted in a fatality. The fatality rate in the State for Trinity extruder terminals (ET-2000, ET-Plus 5-inch, and ET-Plus 4-inch) also was 1.4 percent.

TASK FORCE METHODOLOGY

Overview of Data Sources Used to Assess Crash Cases

FHWA conducted a broad search for data on crashes involving extruding w-beam guardrail terminals with the focus on the ET-Plus 4-inch device. This search included an October 10, 2014 e-mail request to FHWA Division Offices in each State, a December 24, 2014 *Federal Register* Notice and Request for Information, queries of three national databases, multi-state HSIS, inquiries to industry representatives and safety organizations, and media reports.

In total, FHWA received 1231 cases. FHWA conducted an initial screening of these cases to determine whether they contained sufficient detail to evaluate:

- the type of terminal involved in the crash,
- the role the terminal played in the crash, and
- the performance of the terminal during the crash.

Based upon this initial screening, 161 cases were selected for detailed review and analysis. The Task Force was not fully assembled at the time initial screening of certain data sources occurred but was informed regarding the approach taken in identifying the cases for further review. Table 9 summarizes the number of cases initially screened and subsequently reviewed in detail by data source and terminal type. There were some duplicate cases identified across the data sources; for these cases, the one with the most robust data was used for analysis purposes.

Table 9 - Crash Cases Reviewed by Data Source and Terminal Type

Review Phase	Data Source	# of Cases Screened by FHWA	# of Cases Reviewed by Task Force by Terminal Type							
			Total	ET-Plus 4"	ET-Plus 5"	ET-Plus (unknown channel width)	ET-2000	SKT	FLEAT	Unknown or N/A
1A	NMVCCS	78	14	0	2	8	4	(2)**	(1) **	0
2A	Harman	231	14	13	0	1	0	0	0	0
2B	Missouri DOT, First Submission	34	11	7	0	4	0	0	0	0
3A	NASS CDS	56	10	3	3	4	0	0	(1) **	0
3B	Missouri DOT, Second Submission	38	32	24	1	4	3	(1)**	0	0
4A	Delaware DOT	12	8	8	0	0	0	0	0	0
4B	Connecticut DOT	6	6	2	0	1	0	0	0	3
4C	Washington State DOT	162	20	6*	0	13	1	(5)**	0	0
4D	Massachusetts DOT	560	20	0	0	15	0	0	0	5
5A	The Safety Institute	39	10	4	2	2	0	0	0	2
5B	Media and Other Sources	15	4	4	0	0	0	(1) **	(1) **	0
6A	Cases involving SKT and FLEAT Terminals from 1A, 3A, 3B, 4C	--***	12	0	0	0	0	9	3	0
	TOTAL	1231	161	71	8	52	8	9	3	10

* Washington State DOT refers to these terminals as ET-31 terminals, i.e., ET-Plus terminals used with 31-inch guardrail.
**Numbers in parentheses are not included in column total. They indicate the data source of the Phase 6A cases.
***Phase 6A cases were drawn from Phases 1A, 3A, 3B, and 4C. Those cases are included in the number of cases screened by FHWA for those phases.

1A—National Motor Vehicle Crash Causation Survey (NMVCCS). The NMVCCS was a congressionally mandated, on-scene crash study conducted to better understand the "causes" of crashes. NMVCCS investigated a nationally representative sample of crashes between 2005 and 2007. The National Highway Traffic Safety Administration (NHTSA) makes NMVCSS data accessible through http://www-nass.nhtsa.dot.gov/nass/nmvccs/SearchForm.aspx. The database includes crash reports and photos of crash scenes for viewing post-crash conditions of w-beam guardrail terminals as a means to better understand their in-service performance. FHWA searched the database for roadway departure impacts of selected w-beam guardrail terminals. The search yielded more than 700 cases involving roadway departure, including 78 in the vicinity of w-beam guardrail terminals. Among these cases, FHWA identified 14 crashes involving ET-Plus or ET-2000 terminals that were reviewed. In addition, two crashes that involved the SKT and one that involved a FLEAT were reviewed during Phase 6A.

2A—Harman. On December 3, 2014, FHWA received a letter from Boies, Schiller & Flexner LLP, which represents Joshua Harman, transmitting a spreadsheet listing 231 crash cases as well as data on those cases. The letter stated that the data on that

spreadsheet represented "accidents of all 4-inch ET-Plus crashes that we are aware of in which the ET-Plus failed to operate as intended." The data varied by crash. Some included photographs of a damaged terminal and/or photographs of damaged vehicles involved in crashes, and others included supporting documentation such as crash reports, news articles, and legal documents. In its initial screening of these data, FHWA identified 156 crash cases in which the photographic evidence confirmed an ET-Plus 4-inch terminal was involved in the crash. Among these cases, FHWA identified 14 crashes that appeared to involve severe injuries, vehicle compartment intrusion, vehicle occupant compartment penetration, spearing, rollover, snagging of rail, or otherwise appeared to be unusual or extreme; these crashes were targeted for further review. Appendix C provides an overview of the 231 crash cases.

2B—Missouri DOT, First Submission. The Missouri DOT provided information on 34 crash cases involving terminals in the State. The information included crash reports and photographs. In its initial screening of this information, FHWA identified 11 cases involving ET-Plus terminals. The other cases involved other terminal types or terminal types that could not be determined from the available information, or did not involve a terminal.

3A—National Automotive Sampling System, Crashworthiness Data System (NASS CDS). The NASS CDS has detailed data on a representative, random sample of approximately 5,000 minor, serious, and fatal crashes per year involving passenger cars, light trucks, vans, and utility vehicles. Trained crash investigators obtain data from crash sites and then those data are quality controlled and become part of the permanent NASS CDS record available at http://www-nass.nhtsa.dot.gov/nass/cds/. FHWA queried the NASS CDS for the years 2010 through 2013, identified 56 cases in which w-beam terminal systems were impacted during roadway departure crashes, and then conducted photographic analysis of those cases. FHWA could positively identify the terminal type in 35 of these cases. Of these, the 10 cases involving ET-Plus terminals were reviewed, and one involving a FLEAT terminal was reviewed during Phase 6A.

3B—Missouri DOT, Second Submission. The Missouri DOT provided a second submission of information on 38 crash cases. Two of these cases were "identified by motorists in Missouri." The data for the two citizen-identified cases, which each included two photographs, were insufficient for detailed review. The 36 remaining crash cases included 32 cases involving an ET-Plus or ET-2000 terminal. These cases moved forward for detailed review. One case involved an SKT terminal that was reviewed during Phase 6A. In the remaining 3 cases, the terminal type either could not be identified or was not an energy-absorbing type of terminal.

4A through 5A—Crash Cases Submitted through *Federal Register* Notice. In a December 24, 2014 *Federal Register* Notice and Request for Information, FHWA requested data and information regarding the in-service performance of the ET-Plus guardrail terminal, including any data and information concerning vehicle crashes involving the ET-Plus. FHWA specifically sought crash reports, photographs of damaged ET-Plus devices at crash scenes, photographs of vehicles at crash scenes that impacted

ET-Plus devices, and crash reconstruction reports with corresponding data. All comments submitted to the *Federal Register* docket in response to this request are available at https://www.federalregister.gov/articles/2014/12/24/2014-30081/ET-Plus-guardrail-end-terminal. Several entities provided data and information that were sufficient to evaluate the performance of the terminal. These include:

- **4A—Delaware Department of Transportation** provided data on twelve cases, eight of which were reviewed. The data for each case included a crash report and post-crash photos of the terminal.

- **4B—Connecticut Department of Transportation** provided data on six cases, all of which were reviewed. The data included collision reports containing crash narratives, diagrams, pre-crash images from Connecticut's annual network data collection, and pictures taken at the time of repair of the terminal.

- **4C—Washington State Department of Transportation** provided data on 162 cases. FHWA's initial screening of these cases identified 20 cases involving an ET-Plus terminal for further review. In addition, five cases involving an SKT terminal were reviewed during Phase 6A. The data for each case included a police crash report and/or a repair cost estimate that contained photos of the terminals before and after repair.

- **4D—Massachusetts Department of Transportation** provided data on 560 cases. FHWA's initial screening identified 20 cases for further review. The data included a motor vehicle crash report, documentation of the "Scope of Work to be Performed to Repair Insured Damage to Highway Appurtenances," and photos of the terminal before and after repair.

- **5A—The Safety Institute** provided data on 39 cases. FHWA's initial screening identified 10 cases for further review. The initial screening determined that some of the cases already had been reviewed as part of the Harman submission; others lacked sufficient data to positively identify the terminal type and evaluate the performance of the terminal.

- **5B—Media and Other Sources.** FHWA identified 15 crash cases through media outlets and other sources. The data available for these cases varied. Among these cases, FHWA was able to gather sufficient information on four cases for detailed review. Some of the additional information was gathered from State highway agencies.

- **6A—Cases Involving SKT and FLEAT Terminals from 1A, 3A, 3B, 4C**. FHWA identified 10 cases for further review among those from NMVCCS, NASS CDS, Missouri DOT, and Washington State DOT that involved an SKT or FLEAT terminal.

Crash Case Review Process

The crash case review process included six primary components:

1. Initial screening of all crash case data by FHWA staff
2. Detailed analysis of selected crash cases by FHWA staff
3. Detailed analysis of selected cases by independent expert reviewers
4. Detailed analysis of selected cases by State DOT representatives on Task Force
5. Task Force discussion of key cases
6. In-person meeting of the Task Force and independent expert reviewers

Component 1: Initial Screening of All Crash Case Data by FHWA

For each of the data sources, FHWA conducted an initial screening of the crash cases. The primary purpose of the initial screening was to determine whether there were sufficient data to evaluate:

- the type of terminal involved in the crash,
- the role the terminal played in the crash, and
- the performance of the terminal during the crash.

A variety of information is important in order to accurately determine whether a terminal performed as intended, including data on:

- type of terminal, type of vehicle, speed, angle of impact, initial impact location on vehicle, and orientation of the vehicle,
- speed at which the vehicle was rotating or spinning just prior to impact,
- damage to the vehicle,
- type and severity of injuries,
- condition of the shoulder and/or roadside at the time of the crash,
- installation and maintenance history of the terminal, and
- condition of the terminal prior to and after the impact.

Accurate information on these details, along with an analysis of the guardrail terminal and involved vehicle(s), would be necessary in order to effectively determine whether the placement, installation, or maintenance of the guardrail terminal had an unintended effect on the severity outcome of the crash.

The types of data sources that might provide such information include:

- Crash report describing the level of injuries, sequence of events prior to and during the crash, and documenting the speed and path of the vehicle prior to, upon, and after impacting the terminal.
- Photos of the crash scene.
- Photos of the terminal, from multiple angles, immediately after the crash (and before rescue or maintenance crews have started clearing the crash scene) with sufficient resolution to determine the type of terminal.

- Photos of the vehicle that impacted the terminal with sufficient resolution to identify which part of the vehicle impacted the terminal and what damage the vehicle incurred.

The post-crash photos must be viewed with caution. After crashes, rescue or maintenance crews need to clear the deformed rail and/or terminal from the roadway. Post-crash photos may not show the vehicle and rail damage locations immediately after impact.

None of the cases provided the complete information necessary to make a full, definitive evaluation of the crash. For some cases, however, there was adequate information to allow a reasonably informed evaluation of the performance of the terminal. Those cases for which the available data were not deemed sufficient to permit a reasonably informed evaluation did not move forward to the next phase of review.

Over time, the review focused increasingly on cases that were most likely to provide evidence of performance limitations in terminals, i.e., cases that resulted in a fatality or serious injury outcome and/or may have involved occupant compartment deformation, occupant compartment penetration, spearing, rollover, sudden deceleration, snagging of rail, or otherwise appeared to be unusual or extreme. Therefore, many cases in which the "terminal appeared to perform as intended" and in which the crash outcome was less severe did not move forward to the next phase of review.

Appendix D includes a listing of all cases screened by FHWA, identifies those cases sent forward to the independent expert reviewers and the State representatives on the Task Force for detailed review, and summarizes the reason the remaining cases were not sent forward. Appendix E includes several examples of those remaining cases to illustrate typical reasons cases were not sent forward to the Task Force for review.

Component 2: Detailed Analysis of Selected Cases by FHWA

FHWA staff conducted detailed reviews of the data available for those cases passed forward from the initial screening. The reviewers documented their evaluation of the type of terminal and the behavior of the vehicle and terminal during impact. FHWA also recorded a summary assessment of the performance of the terminal in one of five categories:

- **Device appeared to perform as intended**: The terminal functioned in an "acceptable manner" typical of other similar crash events and/or in original crash tests, as depicted in the as-presented evidence.
- **Unexpected**: The terminal did not function in a manner typical of other known similar crash events, as depicted in the as-presented evidence.
- **Extreme condition**: The terminal could not function as intended due to the extreme impact conditions (e.g., non-tracking side impact or a large truck crash) imparted by the impacting vehicle, as depicted in the as-presented evidence.
- **Unknown**: There is no reasonable explanation for why the terminal functioned in the manner depicted in the available evidence.

- **N/A**: The provided information is inconsistent or not applicable, and no summary assessment can be rendered.

There were many discussions over the course of the review on the meaning of "perform as intended" and similarly for other assessment categories. As noted under the section that discusses Component 5 of the effort, these summary assessments simply provided a "first cut" of the device's performance, and the Task Force did not view them as a conclusive determination of the outcome of the cases.

Component 3: Detailed Analysis of Selected Cases by Independent Expert Reviewers

FHWA contracted with the University of North Carolina Highway Safety Research Center (UNC HSRC) to manage a review of the 161 crash cases by independent expert reviewers and charged the Center with selecting as reviewers three individuals who:

- Had expertise suitable for reviewing the crash cases. Relevant areas of expertise included design, installation, and maintenance of guardrail terminals and evaluation of roadside hardware in-service performance.

- Had no conflicts of interest. They were not to have any vested interest in any particular type of guardrail terminal. Furthermore, they were not to have any affiliation with manufacturers or vendors of guardrail terminals, with any organization involved with the development and testing of guardrail terminals, or with any parties to any lawsuits related to guardrail terminals.

The UNC HSRC selected as reviewers:

- Dr. Hampton (Clay) Gabler, Professor, Department of Biomedical Engineering and Mechanics, Virginia Polytechnic Institute & State University; Member, TRB Standing Committee on Roadside Safety Design
- Dr. Douglas Gabauer, P.E., Associate Professor, Bucknell University; Member, TRB Standing Committee on Roadside Safety Design
- Mr. James A. Mills, P.E., Principal, Pavement Analytics, LLC; roadway design consultant; retired Section Leader for the Roadway Design Office Criteria and Standards Section, Florida Department of Transportation

The independent expert review process was conducted as follows:

- After completion of the detailed reviews by FHWA staff, FHWA transmitted a review form, instructions, and data files to the UNC HSRC.
- The UNC HSRC transmitted the review form and data files to the reviewers and instructed them on their task, as described in greater detail below.
- The reviewers completed their evaluations independently and transmitted their review results to the UNC HSRC. (The reviewers knew there were other reviewers, but did not know their identities until the in-person meeting.)
- The UNC HSRC transmitted the reviewers' results, anonymized as Reviewers A, B, and C, to FHWA.

This process was repeated for each of the data sources. Figure 2 provides an example of the instructions FHWA provided to the UNC HSRC for one of the data sources.

Figure 2 - Sample Instructions to Independent Expert Reviewers

Independent Expert Reviews of Crash Cases Involving Guardrail Terminals
Phase IIIA
Instructions to Reviewers

Background:
The Federal Highway Administration (FHWA) is conducting a safety analysis of guardrail terminals. As part of that analysis, FHWA identified crash cases from several sources that may have occurred within the vicinity of a terminal of interest. For each case, FHWA staff assessed the type of terminal in the vicinity of the crash; what, if any, role the terminal played in the crash outcome; whether or not the terminal appears to have performed as designed/intended; and whether the available data suggest any design issues with the terminal.

Phase IIIA Review:
Phase IIIA involves a review of 10 crash cases from NHTSA's National Automotive Sampling System (NASS) Crashworthiness Data System (CDS). FHWA identified these cases in the vicinity of a terminal of interest from the online NASS CDS Case Viewer. FHWA is providing a review form that provides a hyperlink to the online NASS CDS case file, a summary of FHWA staff's evaluation, and a cell for reviewers to document their assessment of the crash case. Within the online case file, reviewers have several options to view *Text and Images Only*, create a *Print Friendly Version of Case*, or *Download Case*.

Reviewers should understand that FHWA is providing links to data directly from the source. These data do not include information on the pre-crash condition of the terminal, or what may have been done to the damaged terminal by first responders or maintenance workers. There is no information on whether the terminal was installed or maintained correctly, or whether it had been damaged and left unrepaired prior to the crash in question, beyond evidence that may be visible in the post-crash photos.

FHWA seeks independent expert review of these 10 cases, including FHWA staff's written evaluation. Pertinent questions include:

- The type of terminal in the vicinity of the crash.
- What, if any, role the terminal played in the crash outcome.
- Whether or not the terminal performed as designed/intended.
- Whether the available data suggest any design issues with the terminal.

Estimated Level of Effort:
FHWA's estimate of the time required to review the 10 cases is approximately 1 hour per case. FHWA estimates an additional 4 hours may be required for each reviewer to document their findings.

Component 4: Detailed Analysis of Selected Cases by State DOT Representatives on Task Force

For each data source, FHWA transmitted the data files for the same selected crash cases to the State DOT representatives on the Task Force. The Task Force agreed to the screening method FHWA used to screen the cases down to the 161 cases for the Task Force's review. In addition, FHWA provided the Task Force members both the FHWA and independent expert reviewer evaluations in a format that enabled individual members to decide whether they wished to view those evaluations before, during, or after their own review of the cases.

The AASHTO co-chair of the Task Force divided the nine State DOT representatives into two groups and randomly assigned each case to one of the groups. Some State DOT representatives, however, elected to review all of the cases. The AASHTO co-chair developed a review form that each State DOT representative completed for each case. The review form requested the information listed in Table 10 for each case. In this form, terminal performance had three categories:

- As intended
- Not as intended
- Not applicable/no assessment can be made

The State DOT representatives completed their reviews independently and submitted their completed review forms to FHWA. FHWA compiled the individual reviews in a spreadsheet.

Table 10 - Data Elements on State DOT Representatives Review Form

- Maximum injury level of crash
- Posted Speed Limit of facility
- Terminal type
- Terminal post type
- Terminal head engaged during crash?
- Terminal performance (Three categories)
- Not as Intended Description
- Crash: Other impact prior to or after collision with barrier
- Crash: Rollover after impact
- Crash: Occupant unbelted
- Crash: Occupant ejected
- Crash: Impact into side of vehicle
- Crash: Impact into rear of vehicle
- Crash: Shallow impact angle
- Crash: Outcome could have been worse without barrier present
- Weather conditions: Raining at time of crash
- Weather conditions: Snowing at time of crash
- Weather conditions: Snow/ice present
- Weather conditions: Buildup of snow/ice under rail
- Vehicle: Not representative of TL-3 test vehicle
- Vehicle: Modifications made to vehicle
- Vehicle: Excessive speed
- Vehicle: Vehicle rolling at impact
- Vehicle: Vehicle pitching at impact
- Vehicle: Vehicle sliding at impact (non-tracking)
- Vehicle: Occupant compartment penetration
- Terminal: Rail rupture
- Terminal: Rail bending back onto itself (kinking/knuckling)
- Terminal: Rail travel impeded through terminal head
- Terminal: Minimal extrusion of rail through head
- Terminal: Excessive ground slope
- Terminal: Excessive flare rate
- Terminal: Curved flare used instead of straight flare
- Terminal: Straight flare used instead of curved flare
- Terminal: Lack of grading blister/shelf
- Terminal: Installed behind curb
- Terminal: Rail too high
- Terminal: Rail too low
- Terminal: Missing/wrong hardware
- Terminal: Damaged prior to impact
- Terminal: Buildup of soil under rail
- Other
- Additional Comments

Component 5: Task Force Discussion of Key Cases

FHWA identified cases in which at least one of the FHWA staff, independent expert reviewers, or State DOT representatives categorized the terminal's performance as "not as intended," "unexpected," or "impacted under extreme conditions." The Task Force discussed those cases during weekly conference calls with the goal of identifying performance limitations.

It became apparent during the early discussions of individual cases that the two or three word summary statements about a terminal's performance were useful for screening the cases that merited further attention, in the form of group discussion, but that they had limited value beyond initial screening. Because of the myriad of complicating factors and the lack of detailed information on conditions before and during impact with a terminal, the summary statements were insufficient for characterizing the cases. As the discussions continued, the Task Force increasingly focused on the central issue of its charge: performance limitations.

Component 6: In-Person Meeting of Task Force and Independent Expert Reviewers

On May 4-5, 2015, the Task Force members and the independent expert reviewers met to review and discuss the key 161 crash cases. The group spent considerable time reaching consensus on whether or not terminals exhibited performance limitations in individual cases, identifying commonalities in performance limitations across cases, and developing meaningful categorizations of observed performance limitations. The Task Force findings are organized according to this categorization.

TASK FORCE FINDINGS

Review of Crash Cases

At the in-person meeting, the Task Force and the independent expert reviewers met to discuss whether there are performance limitations associated with extruding w-beam guardrail terminals. The group reviewed and discussed cases the Task Force and expert reviewers identified that exhibited potential performance limitations of extruding w-beam guardrail terminals. During review of the cases, the group came to a consensus on the potential performance limitations the cases exhibited, and which cases best illustrated each limitation based on the available information. Through review of the cases, a final set of performance limitations emerged from the analysis.

The Task Force's analysis nevertheless had inherent limitations. For a number of cases, it was not possible to determine whether performance limitations existed due to the limited available information. It was not always possible to infer pre-crash conditions or to conclusively determine a terminal's behavior during a crash from post-crash photography and reporting. Pre-crash photos of the terminal were rarely provided, and many cases lacked post-impact photos of the vehicle or of the terminal that were of sufficient quality to be useful. Finally, some cases completely lacked any photos.

Finally, the Task Force's review and analysis of crash cases were not intended to be full crash reconstructions. None of the Task Force members or expert reviewers are certified crash reconstructionists.

Performance Limitations

Performance limitations are factors in a real-world crash environment that can contribute to the unsuccessful performance of a roadside safety hardware device. As indicated in MASH, guardrail terminals "are generally developed and tested for selected idealized situations that are intended to encompass a large majority, but not all, of the possible in-service collisions." Satisfactory performance can typically be expected for collision conditions similar to the test conditions. However, the performance of these devices is dictated by physical laws, vehicle stability, vehicle crashworthiness, and the site conditions of these real-world crashes. The greater the crash conditions differ from the test conditions, the more likely the possibility that performance will be outside of the desirable limits.

As noted in both NCHRP Report 350 and MASH, even the most carefully researched roadside hardware device has performance limitations dictated by many factors. Limitations may be exhibited once these devices, having met all recommended test and evaluation criteria, are installed under real-world conditions. As noted, seemingly insignificant site conditions such as curbs, slopes, and soft soil conditions can contribute to the unsuccessful performance of a safety feature for some impact conditions. It is to be expected that certain features, meeting all recommended test and evaluation criteria, will have untested "windows of vulnerability" in service.

In its review of cases, the Task Force identified several potentially harmful occurrences associated with certain guardrail terminal crashes. These occurrences include: sudden deceleration, rollover, occupant compartment penetration, and occupant compartment deformation. Crash cases noted as having these occurrences were used to help identify performance limitations.

Both sudden deceleration and rollover of a vehicle can result in injuries through occupant contact with interior surfaces of the vehicle or through ejection of an occupant from the vehicle. Occupant compartment penetration involves a portion of the guardrail entering the passenger area of the vehicle and can result in injuries through occupant contact with the penetrating rail. Occupant compartment deformation occurs when the force of a guardrail impact deforms the interior structure of a vehicle's passenger area. Injuries can result from occupant contact with the intruding structure.

Members of the Task Force identified six primary performance limitations of extruding w-beam guardrail terminals. These limitations are classified into two general categories: impact conditions and installation conditions.

The impact conditions that the Task Force identified as performance limitations include:

- Side impacts
- Head-on/shallow-angle corner impacts (i.e., head-on impacts near the corner of the vehicle in the headlight region)
- Head-on/shallow-angle high-energy impacts

The installation conditions identified as performance limitations include:

- Hardware installation/maintenance/repair issues
- Grading issues
- Placement that does not conform to accepted guidance and practice

The following section discusses the impact conditions that were identified as performance limitations. The findings are based on the Task Force's observations during its review of the crash cases combined with the collective engineering judgment of the Task Force members. There is a general description first of these impact conditions followed by crash cases exhibiting the different impact conditions.

Impact Condition: Side Impact

Side impacts include crashes where any side portion of a vehicle is the first portion of the vehicle to make contact with a guardrail terminal. This situation typically occurs after a vehicle has lost control and leaves the roadway in a rotating or non-tracking manner. Side impacts into terminals may result in four potentially harmful occurrences: occupant compartment penetration, occupant compartment deformation, sudden deceleration, and rollover.

Side impacts pose a risk of occupant compartment deformation, especially in those cases where first contact occurs at one of the doors. Extruding w-beam guardrail terminals were developed to absorb a certain amount of energy over a certain distance. This requires them to exert a very strong force to slow an impacting vehicle. In a frontal impact, these

strong forces act well in front of the occupants in a space that includes crumple zones, an engine, and significant frames and structures. When the same high forces are applied to the side of a vehicle, there is often very little structure to resist these forces, and significant deformation can occur. Additionally, an occupant may be in very close proximity to the powerful impact with the terminal.

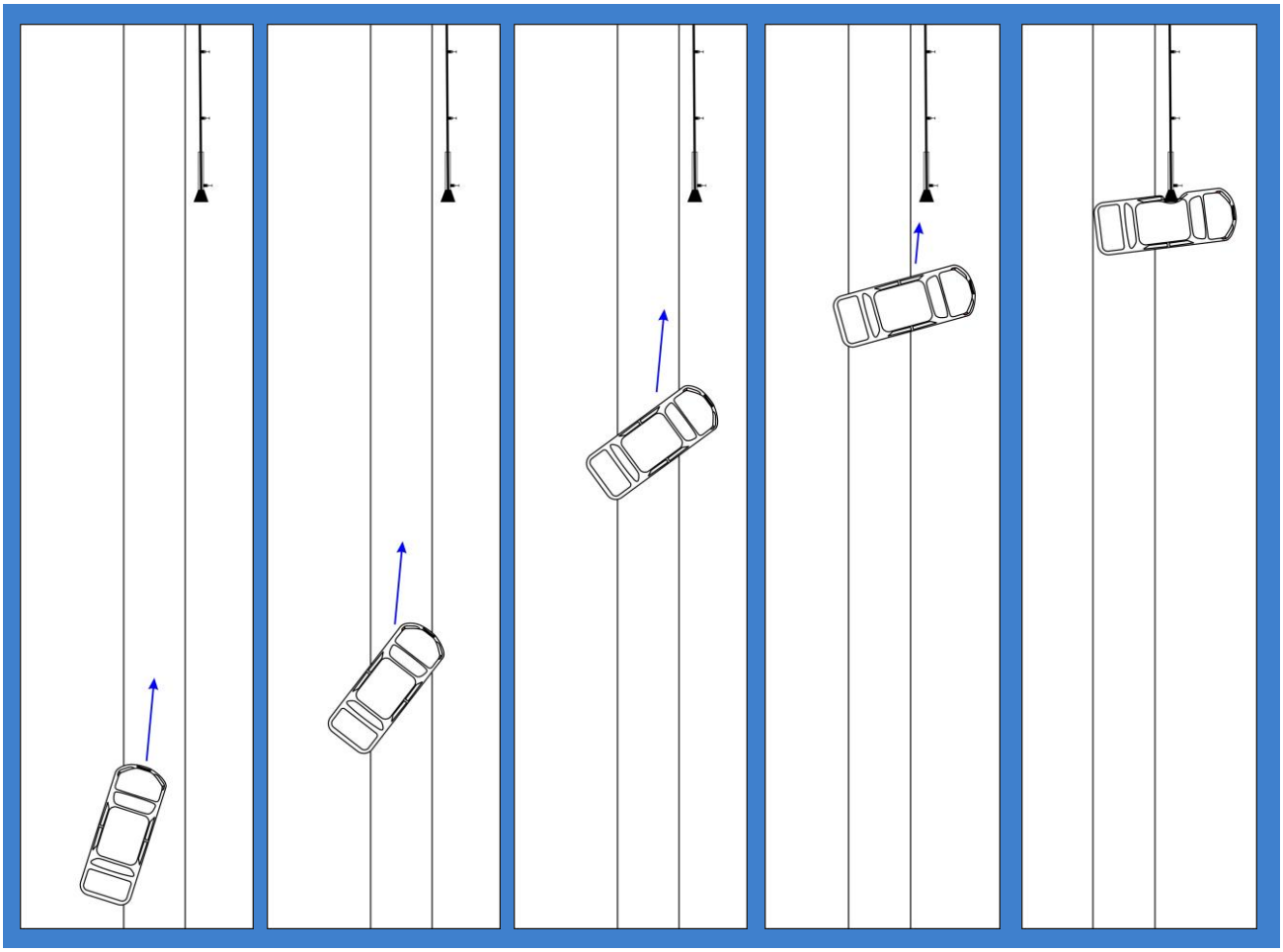
Because side impacts are typically associated with vehicle rotation, they have the potential to stop the process of guardrail extrusion very early in an impact event by bending or knocking the impact head out of line with the downstream run of guardrail. Once this occurs, a kink in the rail can form, and the kink may make contact with, and penetrate through, the side of the vehicle. Penetration risk is increased because the side of the vehicle presents a wider target for a kink to penetrate into than does the front of a tracking vehicle. Additionally, the sides of most passenger vehicles are relatively weak, whereas the front of most vehicles provides the protection of an engine block, bumper, suspension, and firewall. The vehicle's rate of rotation, the direction of the vehicle's momentum, the initial point of contact, and the vehicle's speed can each affect whether a guardrail kinks, how much guardrail is extruded before it kinks, and where the kink contacts the vehicle, if at all.

Seat belts and most airbags are designed to restrain motorists against forward motion. But unless the vehicle is equipped with side airbags, sudden decelerations experienced during a side impact may result in occupants moving sideways and striking one of the vehicle's pillars.

Side impacts have an increased risk of rollover because a vehicle in a lateral skid is subject to higher lateral tire forces and may be more prone to tripping on the terminal. In addition, portions of the terminal that come into contact with the vehicle may act as a fulcrum to introduce a tripping moment on the vehicle.

The images in Figure 3 show one possible sequence of events during a side impact that can result in occupant compartment deformation.

Figure 3 - Possible side impact scenario



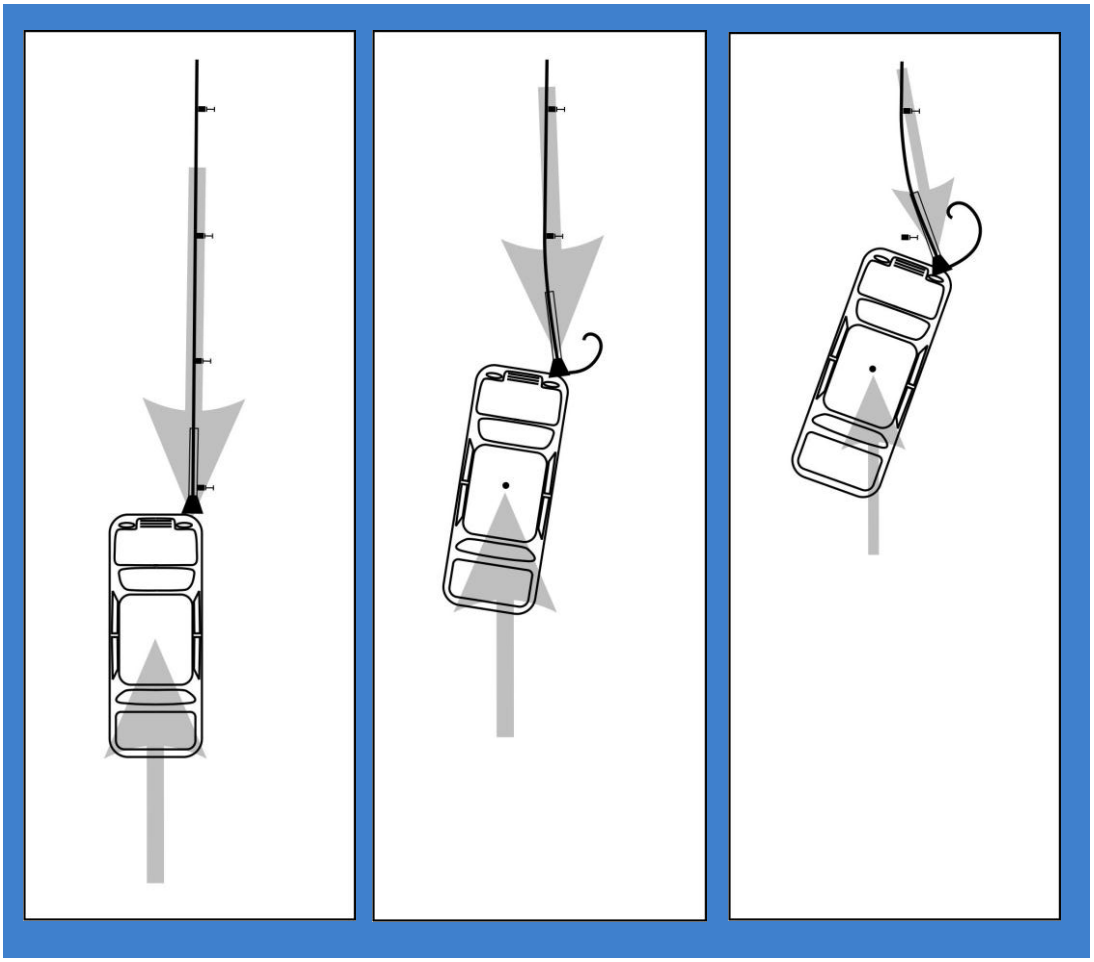
Impact Condition: Head-on/Shallow-Angle Corner Impacts

The next impact condition that may indicate a performance limitation of extruding w-beam guardrail terminals is a head-on impact that occurs near the corner of the vehicle. These types of crashes occur when a vehicle encounters a terminal in a head-on or nearly head-on manner (i.e., at a shallow angle), and when first contact with the impact head takes place near one of the edges of the front of the vehicle, in one of the headlight regions. These impacts differ from crash tests in NCHRP Report 350 or MASH in that the initial contact occurs farther outboard on the front of the vehicle than the quarter point.

Head-on impacts near the corner of the vehicle have the potential to become problematic because the force of the vehicle pushing on the guardrail (located at the vehicle's center of gravity) is significantly out of line with the opposing force of the guardrail pushing on the vehicle. This induces a rotation of the vehicle (as highlighted in Figure 4) that bends the impact head to the side, which kinks the rail at the end of the inlet chute. The impact head may then fold across the front of the vehicle, subjecting the vehicle to the kink and

the entirety of the downstream run of guardrail. With the loss of the energy-absorbing function of the impact head, as the vehicle continues its movement downstream, the rail may either push farther into the vehicle, or form kinks downstream of the impact due to buckling of the rail.

Figure 4 – Rotation induced by corner impact



Figures 5 and 6 depict the difference between kinking of the guardrail due to bending, and kinking of the guardrail due to buckling. An angle impact at the nose of the terminal will likely push the terminal to the side, causing the system to bend, creating a kink in the rail as shown in Figure 5. Figure 6 shows a load applied at the nose of the terminal but the w-beam rail that is downstream does not have the necessary stiffness to resist bending. In either case, the terminal is no longer able to travel down the rail and absorb the energy of the crash. The vehicle may continue forward and come in contact with the kink in the rail.

Figure 5 - Example of kinking of the guardrail due to bending

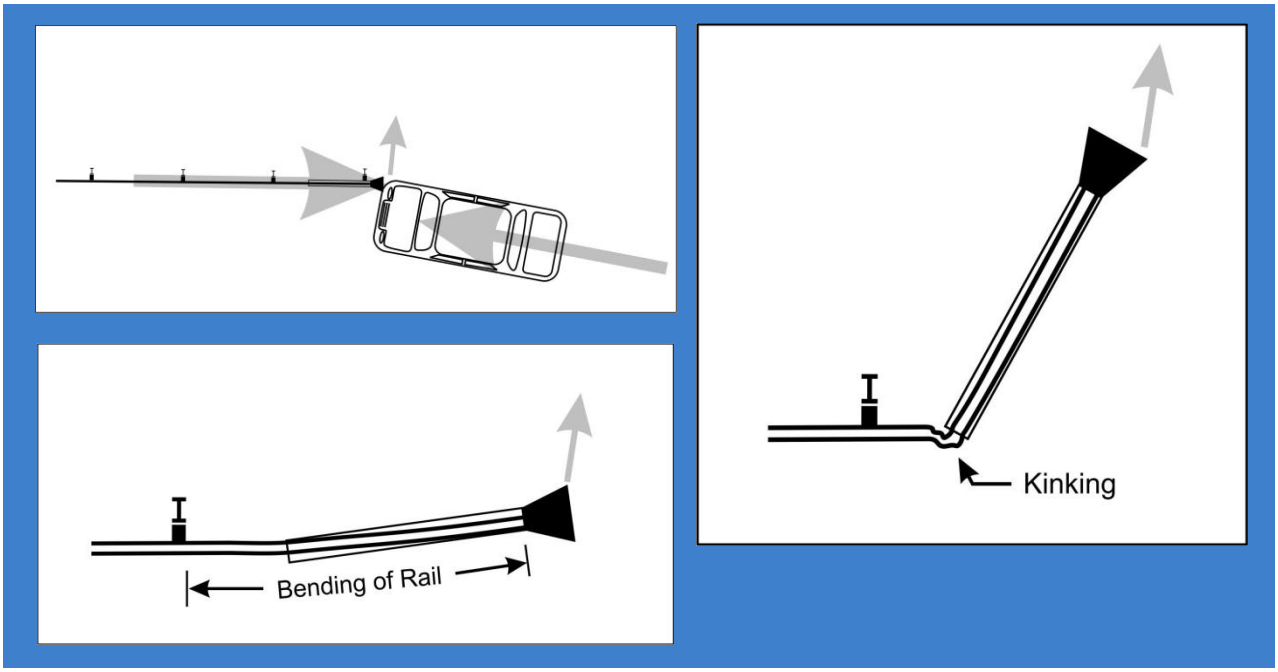
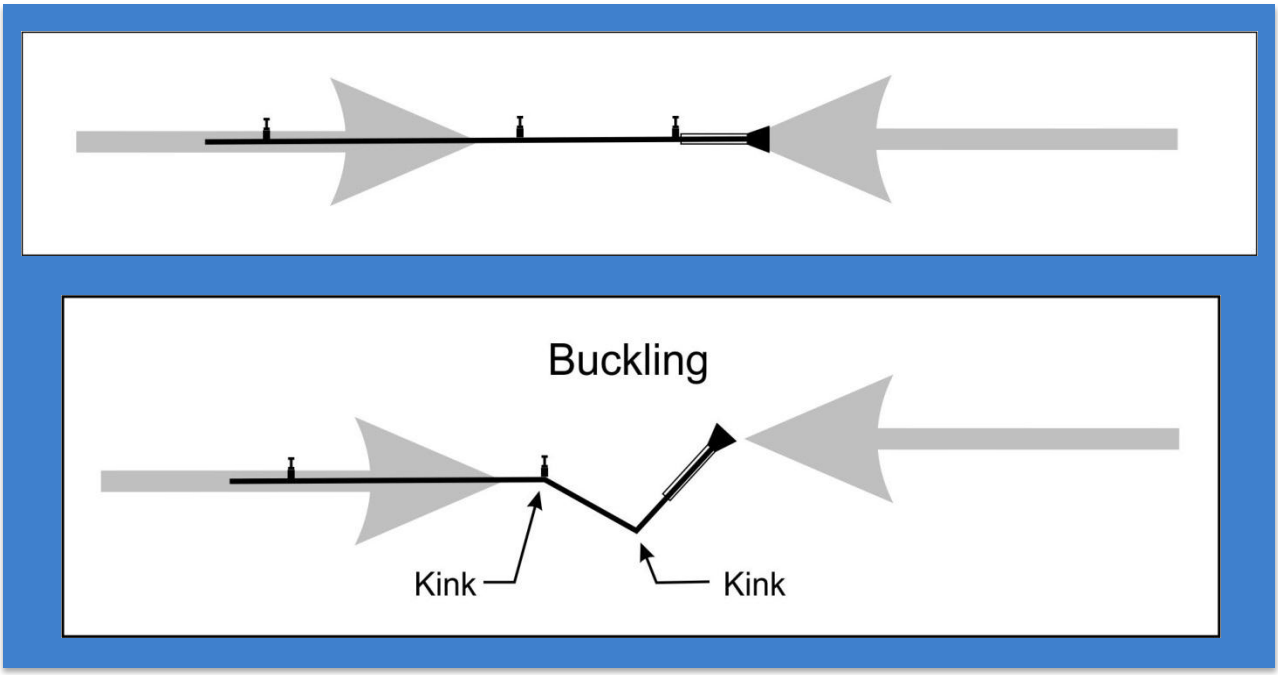


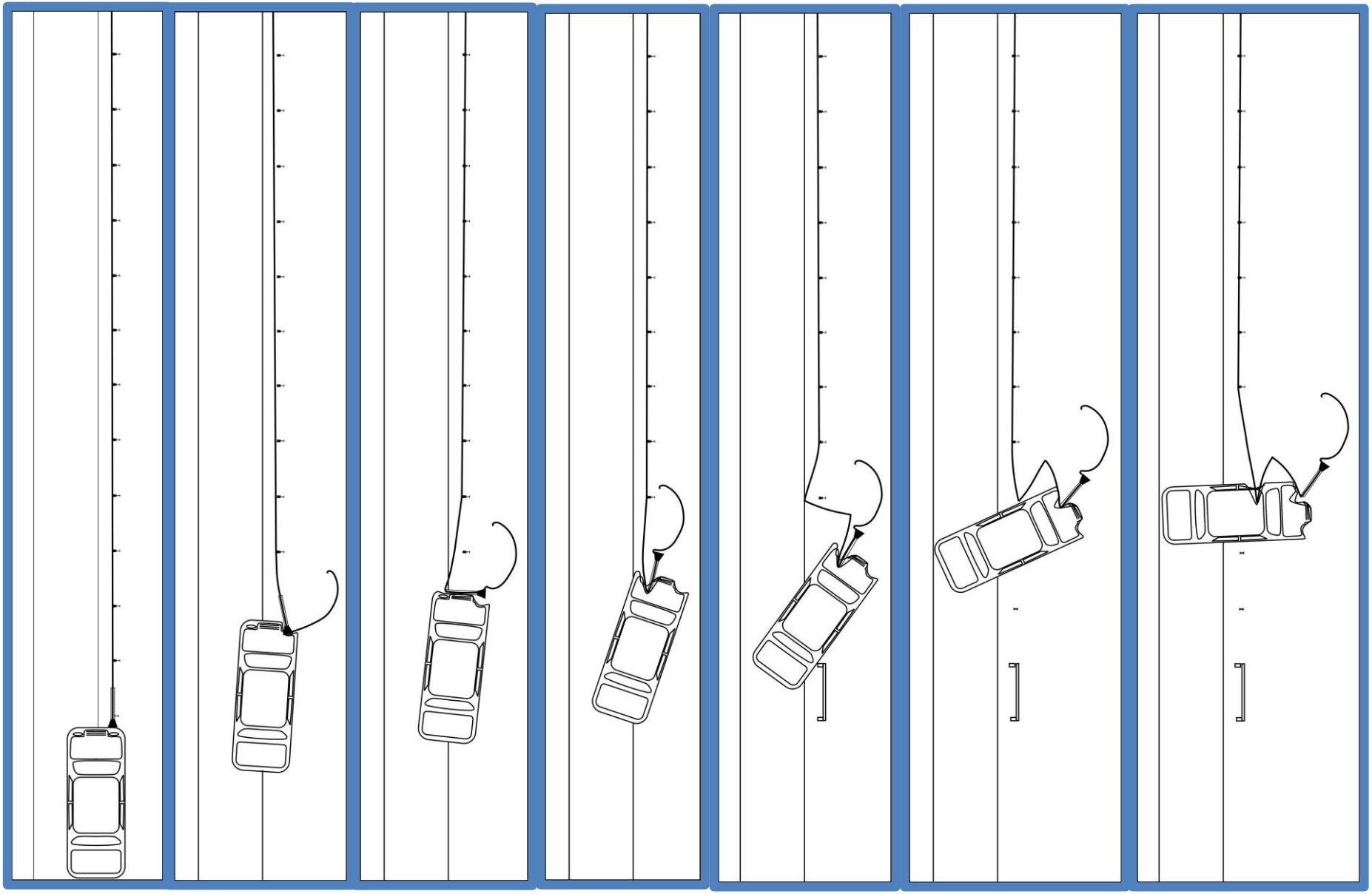
Figure 6 - Example of kinking of the guardrail due to buckling



The reaction of the vehicle to these corner-type impacts will vary based on mass and speed. However, in general, smaller mass vehicles have a lower moment of inertia and will rotate about the rail more readily, which may expose the side of the vehicle to either the first kink in the rail or a subsequent, downstream kink. Higher mass vehicles have higher moments of inertia and tend to rotate about the rail more slowly.

The images in Figure 7 show one possible sequence of events during a head-on corner impact with a smaller mass vehicle that could result in occupant compartment deformation and/or penetration. The degree of offset, the direction of the vehicle's momentum, the initial point of contact, and the vehicle's speed and mass will each affect the outcome of the crash.

Figure 7 - Head-on/shallow-angle corner impact scenario

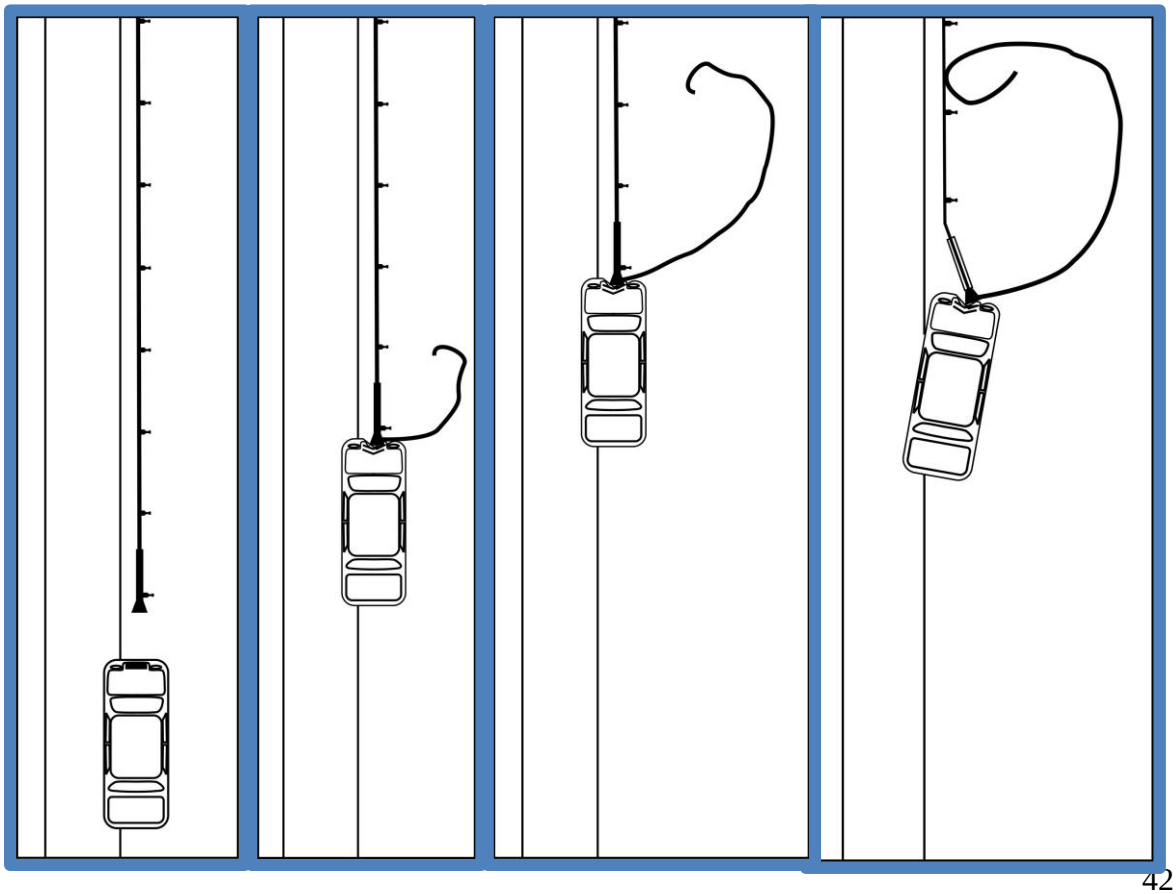


Impact Condition: Head-on/Shallow-Angle High-energy Impacts

Another impact condition that may indicate a performance limitation of extruding energy-absorbing terminals is a head-on/shallow-angle high-energy impact. These types of crashes occur when the kinetic energy of the impacting vehicle exceeds the test level 3 impact conditions of NCHRP Report 350 under which the terminal was crash tested, and the angle of impact is shallow or nearly head-on. The kinetic energy can be exceeded through an impact involving a vehicle with high mass, a vehicle with excessive speed, or a vehicle with both high mass and excessive speed. In general, "excessive speed" is defined as speeds above 62 mph (100 km/h) and "high mass" is defined as vehicle mass greater than 4,400 pounds (2000 kg).

Head-on/shallow-angle high-energy impacts into terminals may result in the impacting vehicle remaining engaged with the impact head for an extended time period. With extruding terminals that are designed to absorb energy while being pushed along the rail, it is likely very rare that a vehicle's path and the terminal's resistance would remain perfectly aligned. Therefore, the longer the vehicle remains engaged with the impact head, the chances increase for minor perturbations in the extrusion process to develop, resulting in misalignment of the impact head with respect to the direction of the vehicle's momentum. As observed during crash tests, extruding energy-absorbing terminals have an inherent ability to correct and overcome minor misalignments. However, any misalignment beyond a certain threshold can cause the rail to bend.

Figure 8 - Head-on/Shallow-angle high-energy impact scenario

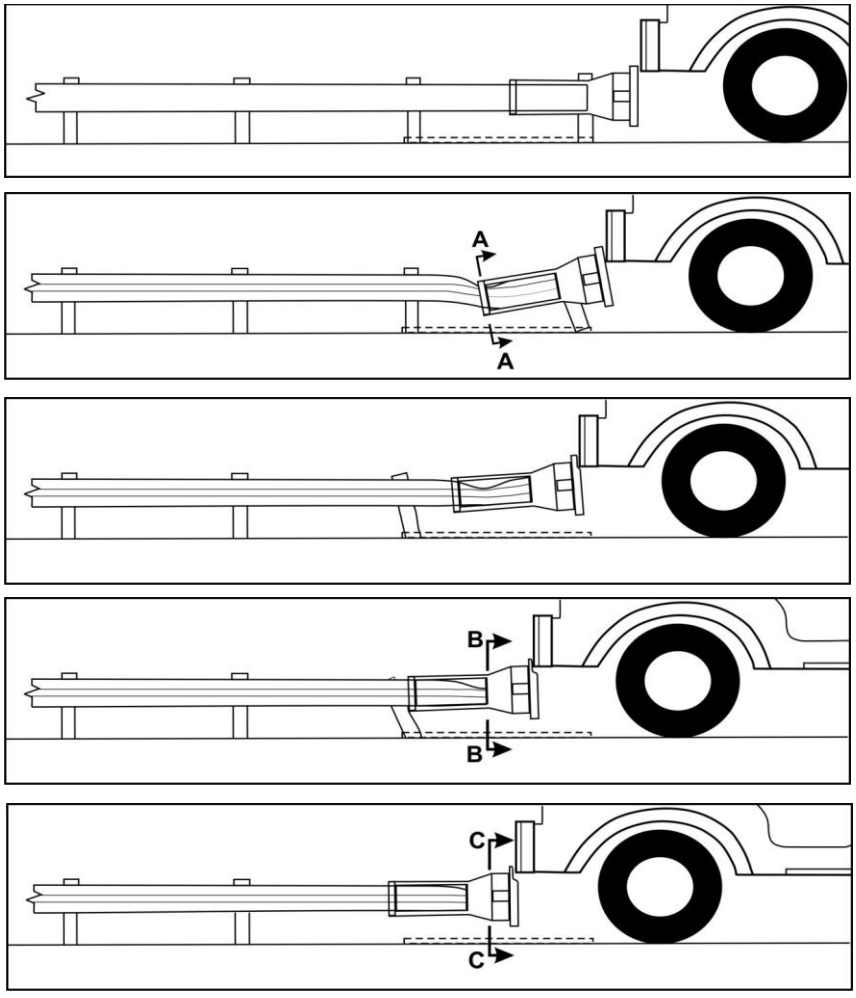


The images in Figure 8 show one possible sequence of events during a high-energy, head-on/shallow-angle impact that may result in occupant compartment deformation and/or penetration. The angle of impact, the initial point of contact, and the vehicle's speed and mass will all affect the outcome of the crash.

Minor perturbations in the extrusion process may occur due to several factors, including the vehicle traveling over downed posts, steering or braking inputs applied by the driver, rail splices and bolts passing through the impact head, or damaged sections of rail passing through the impact head. The Task Force noted one phenomenon that had the potential to damage the rail during an impact event: vertically out-of-plane impacts.

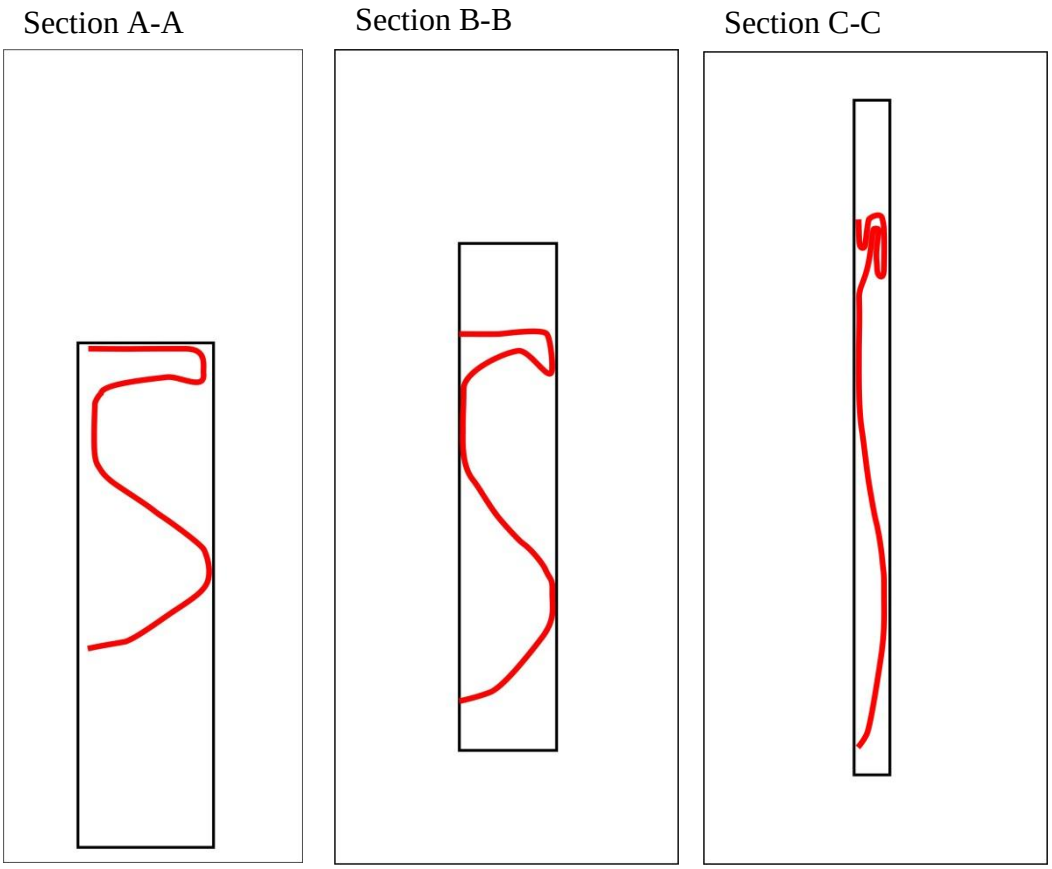
As illustrated in Figure 9, high contact on an extruding terminal's face could induce a rotational force that will cause the inlet end of the chute to move downward. The same can also be true of a low impact moving the chute upwards as contact is made. If the rotation is forceful enough, the top corrugation of the w-beam may be crushed down or the bottom corrugation may be crushed up. In an extreme case, rotation from a high contact may cause the bottom of the inlet end to strike the ground underneath the terminal, potentially stopping the extrusion process.

Figure 9 - Example of a vertically out-of-plane impact



The cross-section drawings in Figure 10 correspond to the illustrations in Figure 9. The cross-sections in red represent what may happen to the w-beam rail as it passes through an extruding terminal after the top of the w-beam is deformed by the inlet end of the terminal early in the crash event.

Figure 10 - Example sections of a vertically out-of-plane impact
(see Figure 9 for section cuts)



Crash Cases Exhibiting Performance Limitations: Impact Conditions

This section summarizes the detailed reviews of crash cases that best illustrate the performance limitations related to impact conditions. Table 11 lists the 15 crash cases that illustrate the identified performance limitations. The crash narratives for the cases were developed based on all available information for a particular crash (not just the narrative the police officer or crash investigator provided). The set of illustrations the Task Force developed for these cases depicts its interpretation of the likely sequence of events in the crash. The Task Force developed illustrations for crash cases for which enough information existed to approximate (i.e., likely not exact) **one possible** scenario

for the sequence of events. These illustrations for **all of the crash cases in the report should not** be interpreted as crash reconstructions. They were inferred from photos of crash scene, damaged terminal, and damaged vehicle but some assumptions were made given the limitations of the data available.

Table 11 - Crash Case Performance Limitations and Potentially Harmful Occurrences

Primary Performance Limitation	Case #	Device Type	Vehicle	Injury Severity	Potentially Harmful Occurrence
Side Impact	1A004	ET-2000	Sedan	PDO*	Sudden deceleration
	2B002	ET-Plus 4-inch	SUV	Fatal	Rollover
	2B010	ET-Plus 4-inch	Sedan	Unknown	Sudden deceleration
	3A007	ET-Plus 5-inch	Pickup	Unknown	Rollover
	3A010	ET-Plus 4-inch	Sedan	Unknown	Occupant compartment deformation
	5A002	ET-Plus 4-inch	Sedan	Fatal	Rollover
	6A002	SKT	Sedan	Incapacitating	Sudden deceleration
Head-on / Shallow-angle Corner Impact	2A018	ET-Plus 4-inch	Truck	Unknown	Penetration
	2B008	ET-Plus 4-inch	Sedan	Serious injury	Penetration
	2B009	ET-Plus 4-inch	Sedan	Fatal	Penetration
	5A001	ET-Plus 5-inch	SUV	Incapacitating injury	Penetration
	6A020	FLEAT	Pickup	Minor injury	Penetration
Head-on /Shallow-angle High-energy Impact	1A009	ET-Plus 5-inch	Pickup	PDO	Near Penetration
	5A009	ET-Plus (4-inch or 5-inch)	Truck	Fatal	Penetration
	6A021	SKT	SUV	Fatal	Penetration

*PDO: Property Damage Only

Case #1A004

- Performance Limitation Type: Side impact
- Data Source: NMVCCS
- Device Type: ET-2000 with wood posts
- Vehicle Type: Mid-size passenger car
- Injury Severity: Property Damage Only

Narrative:

This single-vehicle crash occurred during daylight hours on a right-curving entrance ramp to a 4-lane divided interstate highway with a speed limit of 70 mph. At the time of the crash, it was cloudy and the roadway was wet from a recent rain event.

The subject vehicle, a 2007 Pontiac G6 sedan, lost control negotiating the curved entrance ramp. The available evidence suggests the vehicle fishtailed and began to rotate clockwise, skidded off the right side of the highway, left side leading, and struck an ET-2000 terminal with its left rear side. Approximately 10 feet of rail was extruded through the impact head before the terminal gated and allowed the vehicle to pass through. The force of the impact with the terminal deformed the left rear passenger door, door frame, and quarter panel. The vehicle then rotated back in the counterclockwise direction, slid down an embankment, and came to rest.

While there were no injuries associated with this particular crash, it does demonstrate the extreme forces involved in such an impact. Injuries could have resulted from intrusion of the door panel, contact with the side window glass, or sudden deceleration. The potentially harmful occurrence in this case appears to be sudden deceleration.

The non-tracking side-impact conditions of this crash were beyond what would be tested under NCHRP Report 350 and MASH.

Photos:

Photo 1 - Approach to terminal and final rest of vehicle

Photo 2 – Close-up of end terminal

Photo 3 - Damage to vehicle

Figure 11 – Police Report Crash Diagram

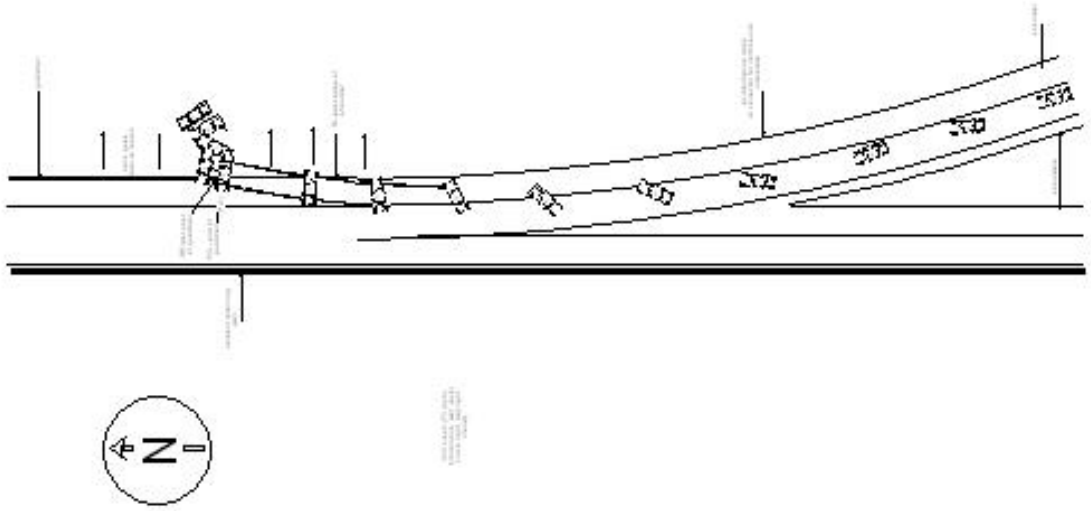
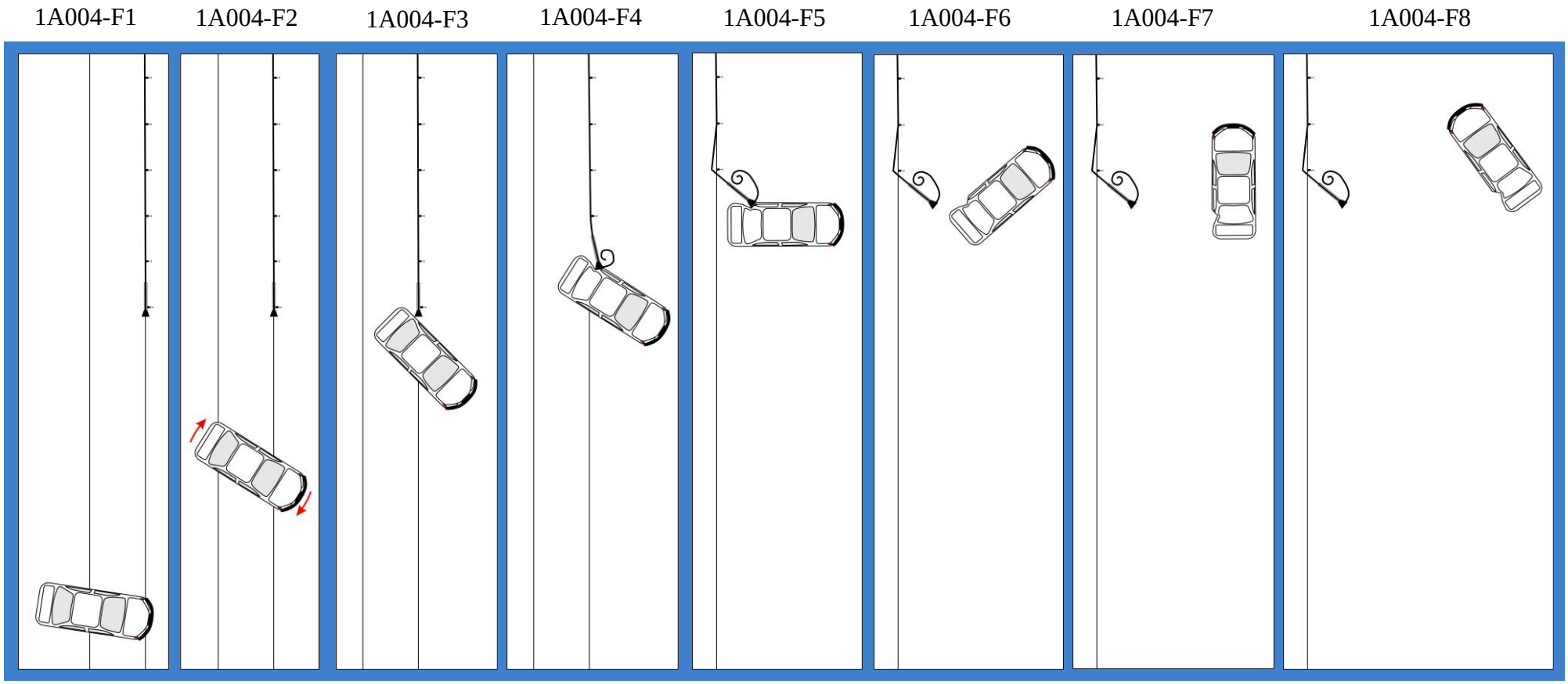


Figure 12 - Illustration of one possible crash sequence



Case #2B002

- Performance limitation Type: Side impact
- Data Source: Missouri DOT
- Device Type: ET-Plus 4-inch with steel posts
- Vehicle Type: Small SUV
- Injury Severity: Fatal

Narrative:

This crash occurred approximately one hour before sunrise on a clear, mid-January morning. The subject vehicle, a 1987 Ford Bronco II, was traveling on a tangent, dry, four-lane divided interstate highway when it was impacted from the left by another vehicle traveling in the same direction.

The available evidence indicates this impact caused the subject vehicle to lose control, initiating a clockwise rotation and sending it skidding toward the right side of the roadway, as evidenced by the skid marks shown in Photo 4. The vehicle had rotated nearly one-quarter turn by the time it exited the paved portion of the roadway, where it impacted a 4-inch ET-Plus terminal. The vehicle made first contact with the terminal in the area of the driver's side front tire. This contact with the leading edge of the terminal left vertical indentations in the fender just above the tire, as shown in Photo 5.

Approximately two feet of rail was extruded through the impact head before the angle of the impact bent the rail at the inlet chute, causing a kink to form as shown in Photo 6. This kink contacted the vehicle in the driver's door, crushing the door inward as shown in Photo 7, and initiating a roll. The vehicle rolled over one complete rotation, ejecting the two unbelted occupants. The driver sustained a fatal injury and the passenger sustained an incapacitating injury as a result of the crash.

The potentially harmful occurrence in this case appears to be rollover, and the non-tracking side-impact conditions of this crash were beyond what would be tested under NCHRP Report 350 and MASH.

Photos:

Photo 4

Photo 5

Photo 6

Photo 7

Figure 13- Police Report Crash Diagram

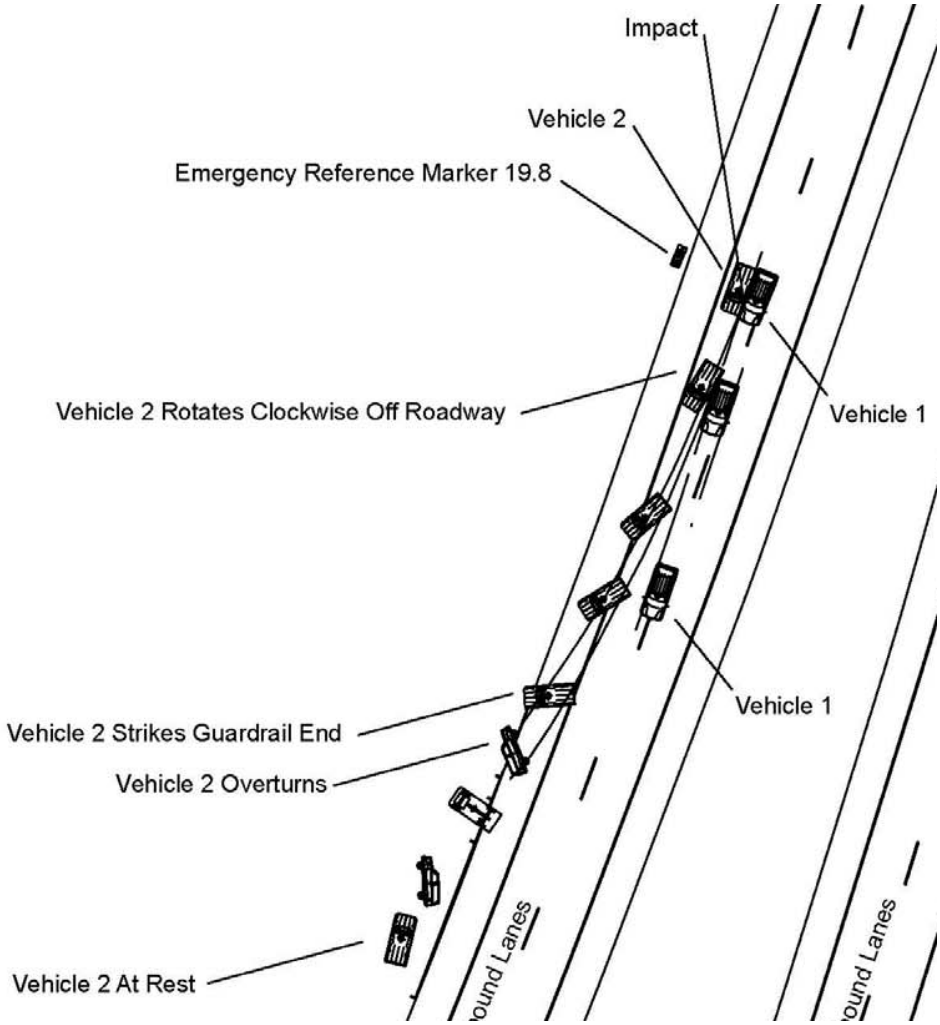


Figure 14 - Illustration of one possible crash sequence (Part A)

2B002-F1 2B002-F2 2B002-F3 2B002-F4

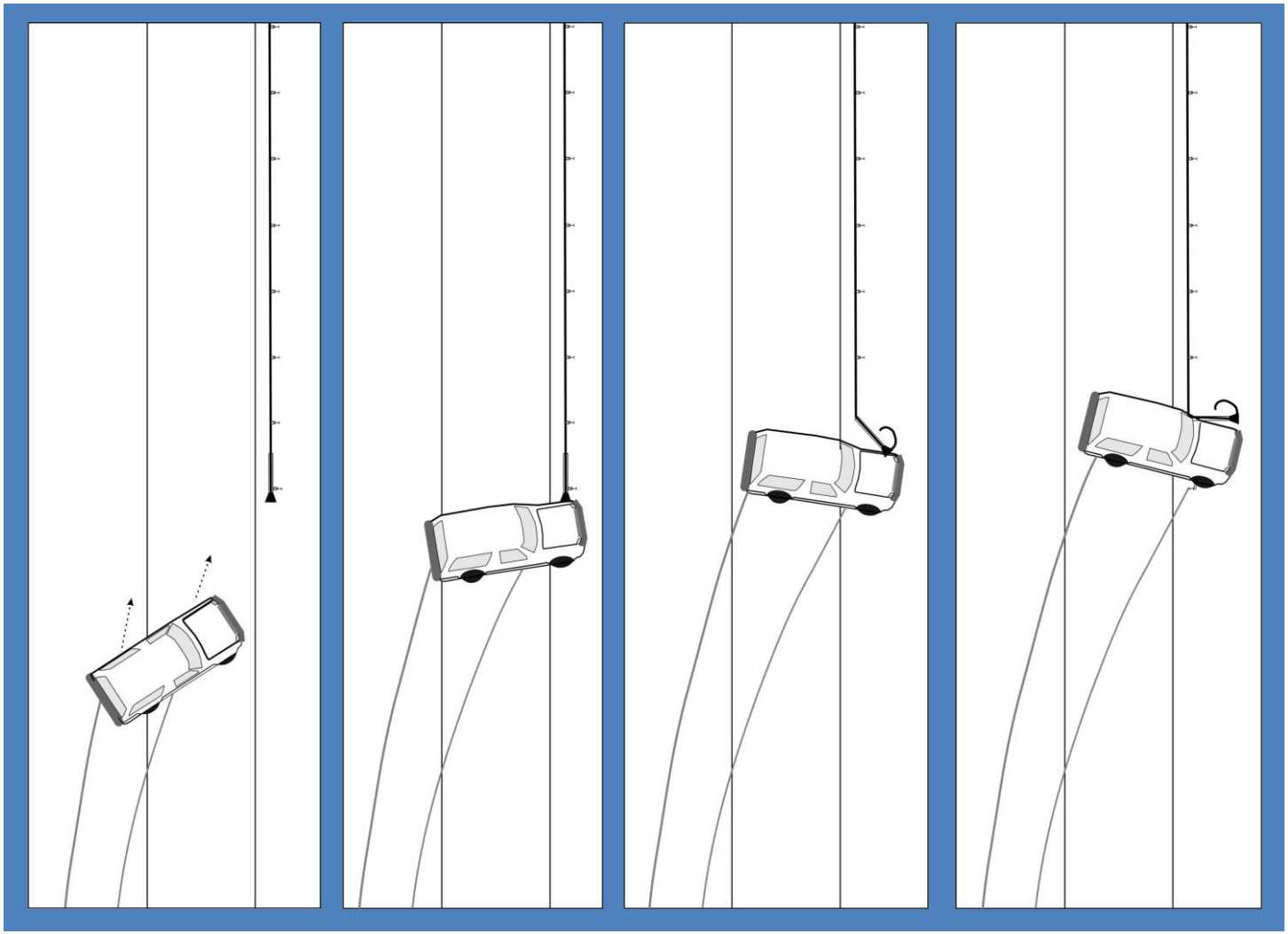
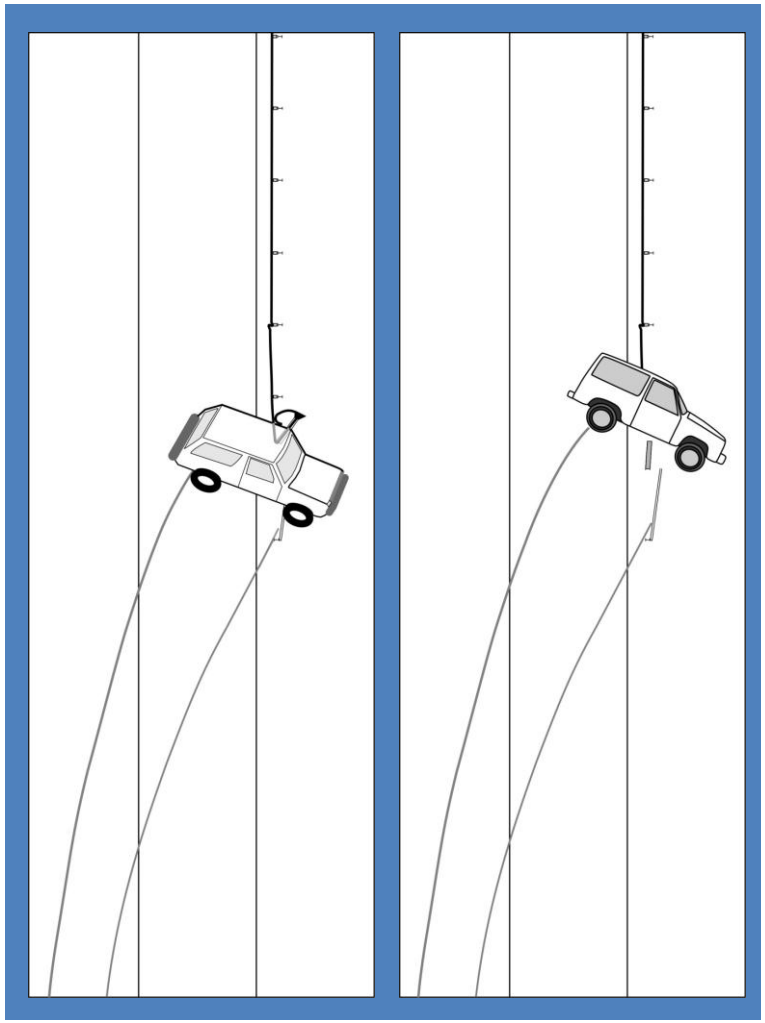


Figure 15 – Illustration of one possible crash sequence (Part B)

2B002-F5 2B002-F6



Case #2B010

- Performance Limitation Type: Side impact
- Data Source: Missouri DOT
- Device Type: ET-Plus 4-inch with wood posts
- Vehicle Type: Mid-size passenger car
- Injury Severity: Unknown

Narrative:

This single-vehicle crash occurred on a suburban interstate facility with four through lanes and one auxiliary (entrance ramp) lane. The speed limit along this portion of interstate is 60 mph. The alignment at the point where the vehicle left the roadway was straight and the grade was nearly flat (-1%). At the time of the crash, in the very early hours of a mid-March morning, the weather was clear and the roadway was dry.

The driver of the subject vehicle, a 2000 Toyota Camry, failed to negotiate a merge into the right travel lane from an auxiliary entrance ramp lane that was ending. The vehicle ran off the road to the right onto the soil shoulder. The available evidence suggests that the driver was attempting to steer the vehicle back onto the roadway when the right side of the vehicle clipped the inside edge of an ET-Plus terminal. Upon making contact with the terminal, the vehicle began to rotate clockwise, and slid along the roadway approximately 200 feet before the driver was able to regain control of the vehicle.

Based on the tire impressions shown in Photos 8 and 9, the available evidence indicates the vehicle appeared to have been heading back toward the roadway at a shallow angle just prior to impact. The initial impact with the inside edge of the terminal head occurred near the handle on the right side front door, just slightly in front of the B-pillar as shown in Photo 10. After impacting the right front door, the vehicle remained in contact with the terminal head, the right rear door was torn away from its hinges and the door was pushed rearward, exposing the rear occupant's compartment. After extruding approximately 8 to 10 feet of guardrail, the system bent and kinked toward the roadway, and the terminal head disengaged from the vehicle. After the photos shown below, a set of illustrations the Task Force developed is presented that depicts its interpretation of one possible scenario of the likely sequence of events in this crash.

The potentially harmful occurrence in this case appears to be sudden deceleration, and the side-impact conditions of this crash were beyond what would be tested under NCHRP Report 350 and MASH.

Photos:

Photo 8

Photo 9

Photo 10

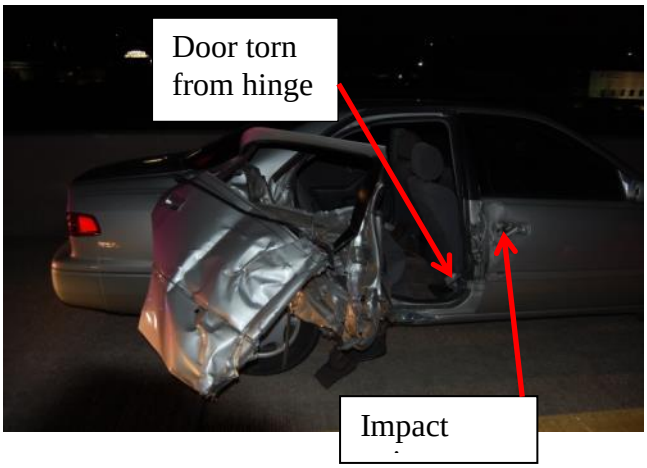
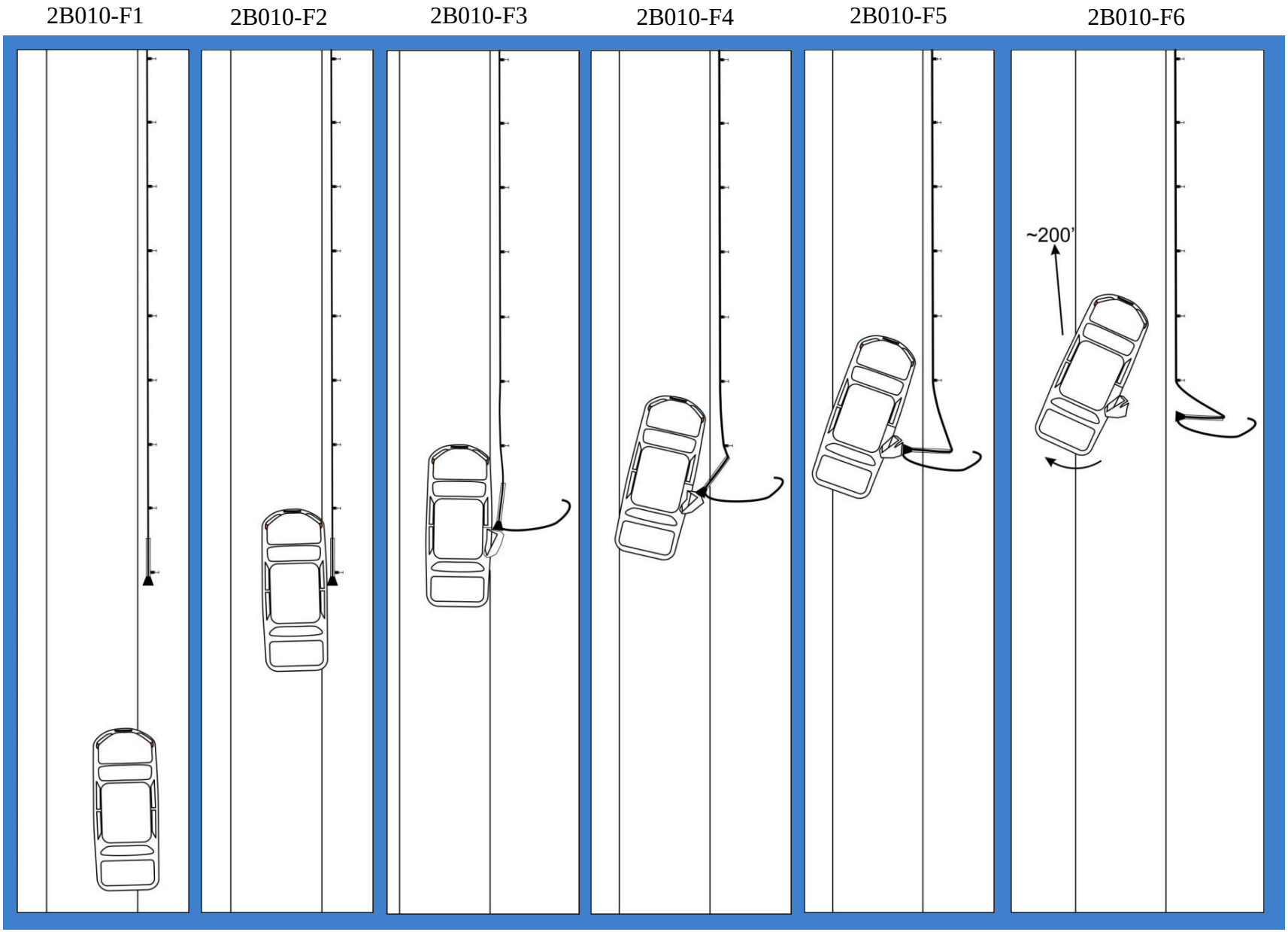


Figure 16 - Illustration of one possible crash sequence



Case #3A007

- Performance Limitation Type: Side impact
- Data Source: NASS CDS
- Device Type: ET-Plus 5-inch with steel posts
- Vehicle Type: Mid-size Pickup Truck
- Injury Severity: Unknown

Narrative:

This single-vehicle crash occurred on a four-lane divided highway at approximately 11:00 a.m. on a November day. The roadway was level and curving to the right, with a posted speed limit of 55 mph. At the time of the crash, the weather was clear, the roadway was dry, and it was daylight.

The driver of the subject vehicle, a 1997 Dodge Dakota, failed to negotiate the curve and departed the roadway to the left. As the driver attempted to steer the vehicle back onto the roadway, the available evidence appears to indicate the vehicle began to rotate clockwise and the left side of the vehicle contacted an ET-Plus guardrail terminal, just forward of the driver's side rear wheel. Contact with the terminal initiated a roll of the vehicle. Approximately 3 feet of guardrail was extruded through the impact head before the vehicle lost contact with the terminal. The truck rolled over and came to rest on its roof in the traveled lanes. The vehicle caught fire.

The available information contained only one photograph of a damaged terminal; the remaining photographs were of an undamaged terminal.

The potentially harmful occurrence in this case appears to be rollover, and the non-tracking side-impact conditions of this crash were beyond what would be tested under NCHRP Report 350 or MASH.

Photos:

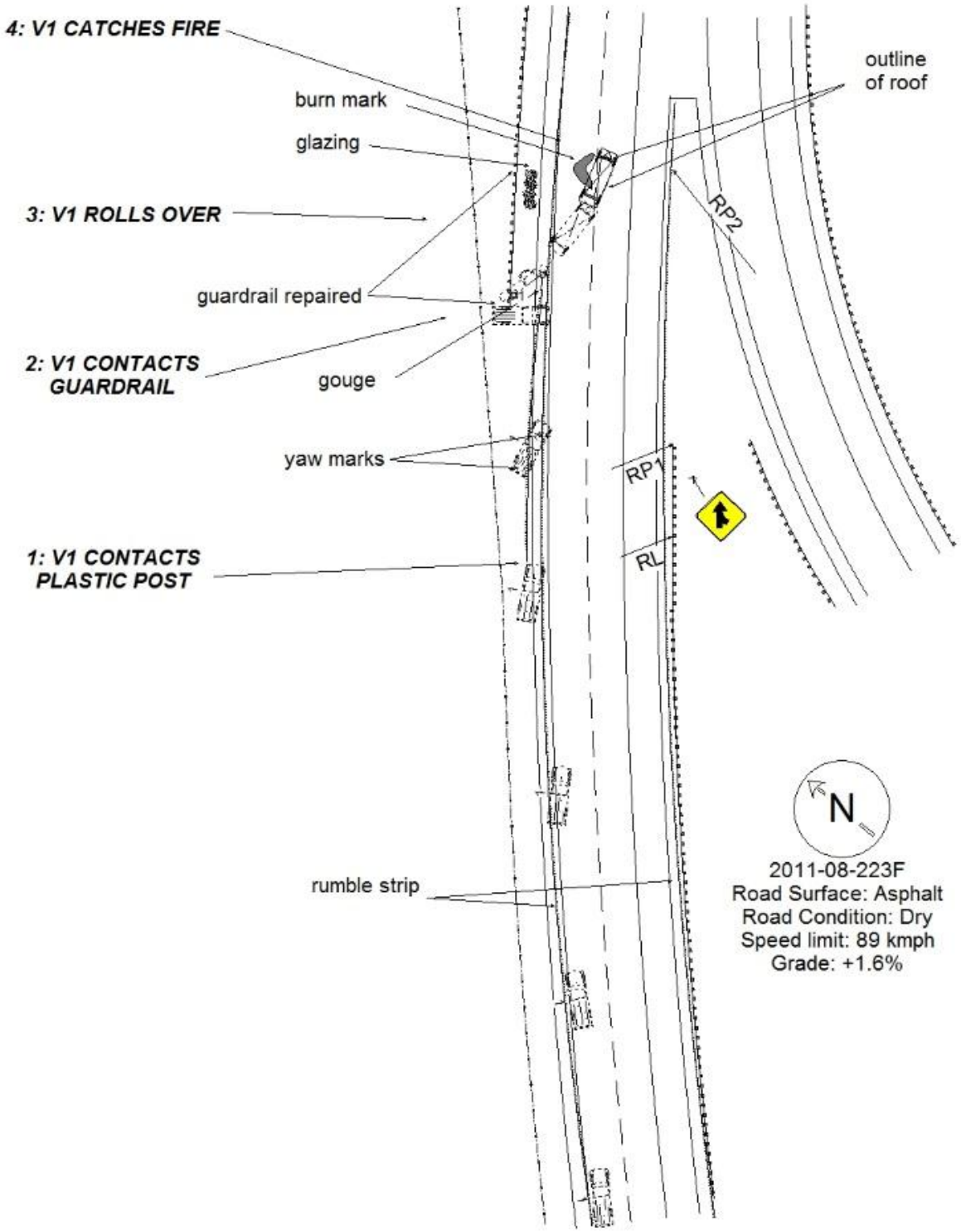
Photo 11 - Repaired terminal at crash site

Photo 12 - On-scene photo of terminal after impact

Photo 13 - Crash scene after impact and vehicle roll

Photo 14 - Damage near the left rear tire, the initial point of contact with

Figure 47 - Police Report Crash Diagram



Case #3A010

- Performance Limitation Type: Side impact
- Data Source: NASS CDS
- Device Type: ET-Plus 4-inch with steel posts
- Vehicle Type: Full-size passenger car
- Injury Severity: Unknown

Narrative:

This single-vehicle crash occurred at approximately 7:00 p.m. on a May evening on a 5-lane divided roadway. The roadway was straight and level. At the time of the crash, the weather was clear and the roadway was dry. It appears there was another vehicle entering the roadway at the on-ramp and the driver of the subject vehicle, a 1993 Oldsmobile Cutlass Supreme, took evasive maneuvers to avoid a collision. The available evidence indicates the driver lost control of the vehicle and began a counterclockwise yaw. The vehicle skidded off the roadway to the right (Photo 15) and struck an ET-Plus terminal. Photo 16 indicates the impact occurred on the right side in the rear passenger door area. The force of the impact deformed the door, and the inside of the door intruded into the occupant compartment.

The terminal extruded approximately 19 feet of rail and halted the counterclockwise yaw. The vehicle remained in contact with the extruder head and began to spin clockwise. As the vehicle spun back onto the roadway, the rail bent and kinked toward the roadway, and the extruder head disengaged from the vehicle. After the photos and Police Report Crash Diagram shown below, a set of illustrations the Task Force developed is presented that depicts its interpretation of one possible scenario of the likely sequence of events in this crash.

The potentially harmful occurrence in this case appears to be occupant compartment deformation. The non-tracking side-impact conditions of this crash were beyond what would be tested under NCHRP Report 350 or MASH.

Photos:

Photo 15 - Skid marks of vehicle at point of impact

Photo 16 – Point of end terminal contact

Photo 17 – Post-impact rail condition

Figure 58 - Police Report Crash Diagram

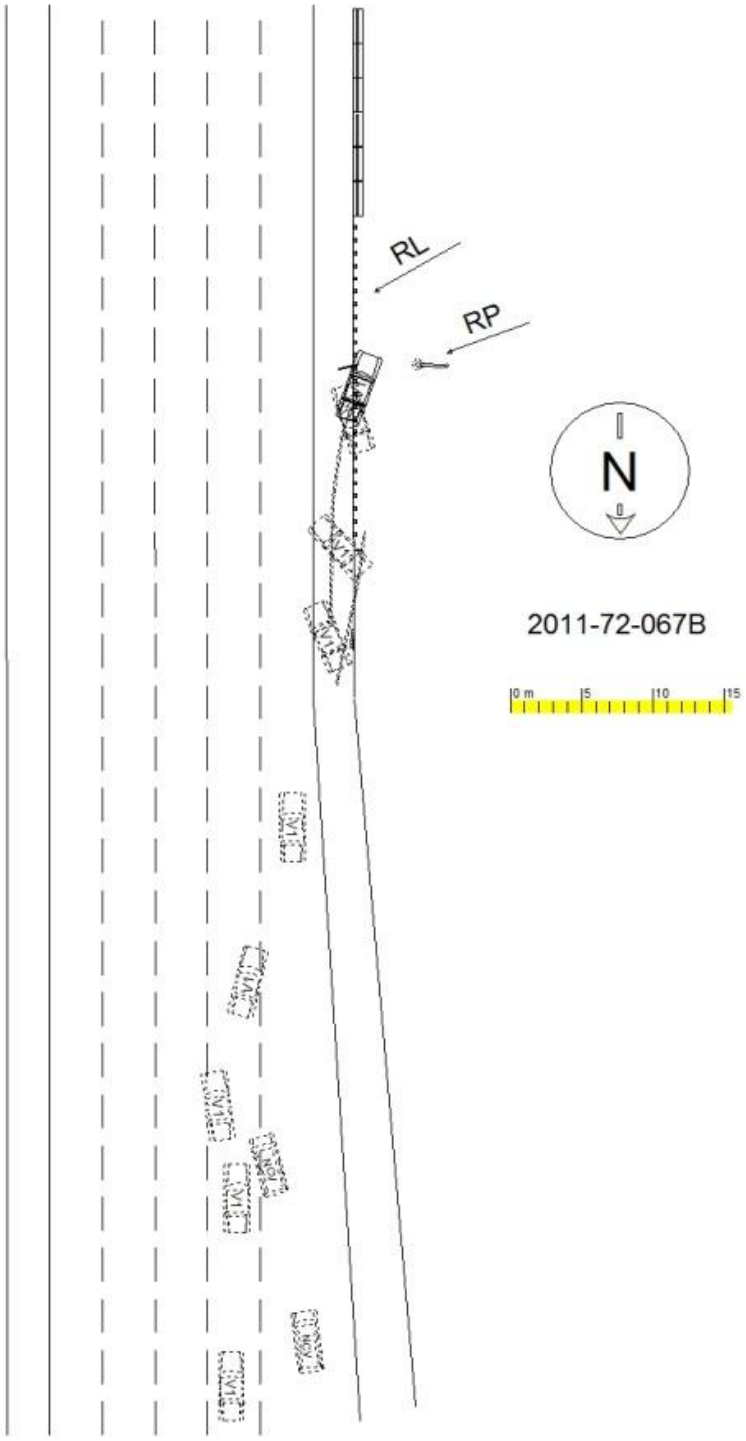
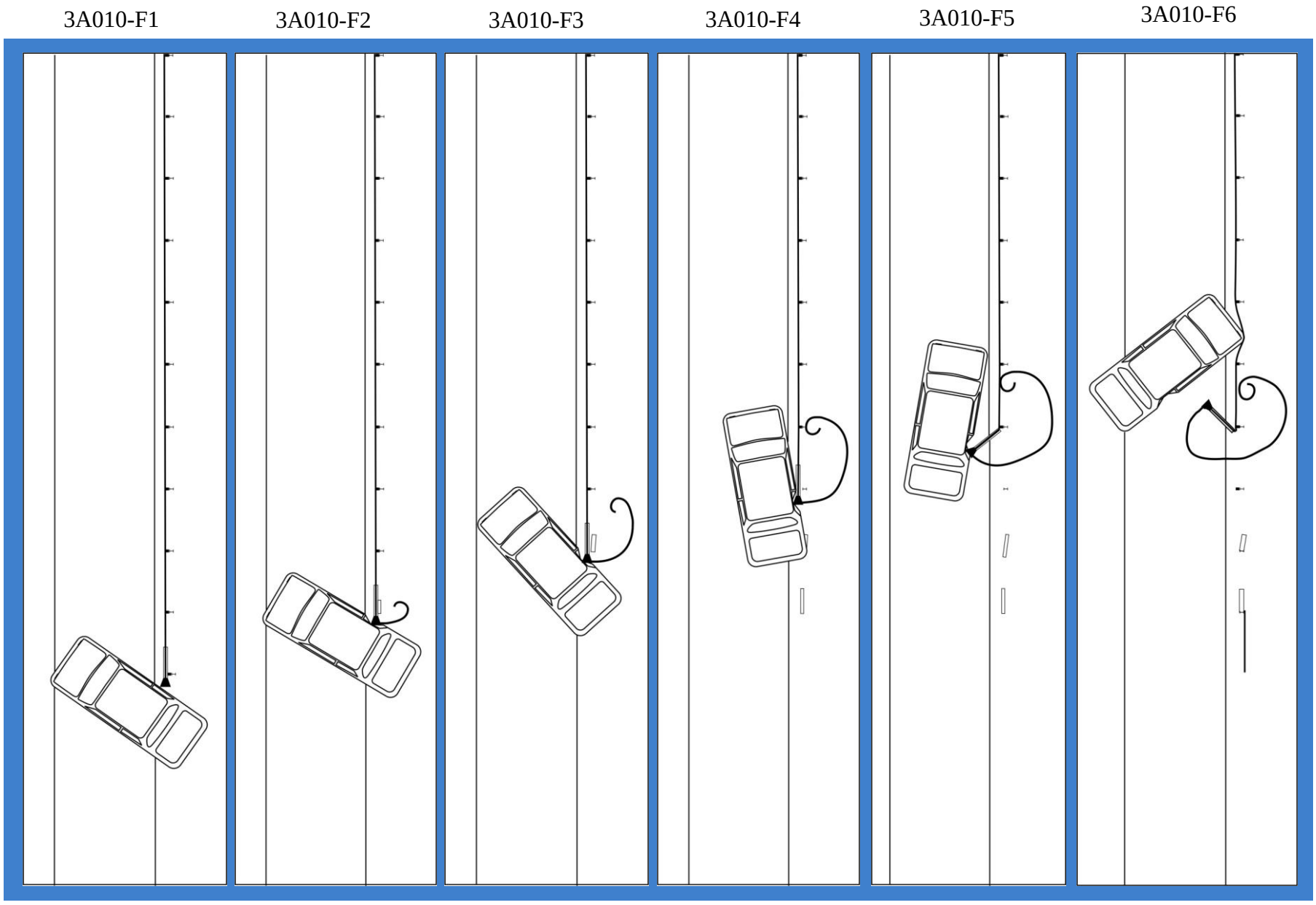


Figure 69 - Illustration of one possible crash sequence



Case #5A002

- Performance Limitation Type: Side impact
- Data Source: Safety Institute and Missouri DOT
- Device Type: ET-Plus 4-inch with steel posts
- Vehicle Type: Full-size passenger car
- Injury Severity: Fatal

Narrative:

This crash occurred mid-morning on a December day on a two-way, undivided roadway. The posted speed limit of the roadway is 65 mph. The roadway curves to the left on an uphill grade, and guardrail lines both sides of the roadway. The crash involved one vehicle, a 1992 Ford Taurus, containing three occupants. At the time of the crash, it was daylight, raining, and the roadway was snow-covered with some ice/frost present.

As the vehicle attempted to traverse the curve, the driver lost control on the icy pavement. The vehicle started to yaw in a clockwise direction, departed the roadway to the right, and struck a guardrail terminal near its front left corner. A minimal amount of rail was extruded through the terminal before the rail bent and a kink was formed. It appears that the kink contacted the side of the vehicle just aft of the rear passenger door. Contact with the kink caused a tripping moment, and the vehicle overturned, coming to rest on its roof, off of the roadway.

A set of illustrations the Task Force developed is presented that depicts its interpretation of one possible scenario of the likely sequence of events in this crash.

The potentially harmful occurrence in this case appears to be a rollover. The non-tracking side-impact conditions of this crash were beyond what would be tested under NCHRP Report 350 or MASH.

Photos:

Photo 18

Photo 19

Photo 20

Photo 21

Photo 22

Figure 20 - Police Report Crash Diagram

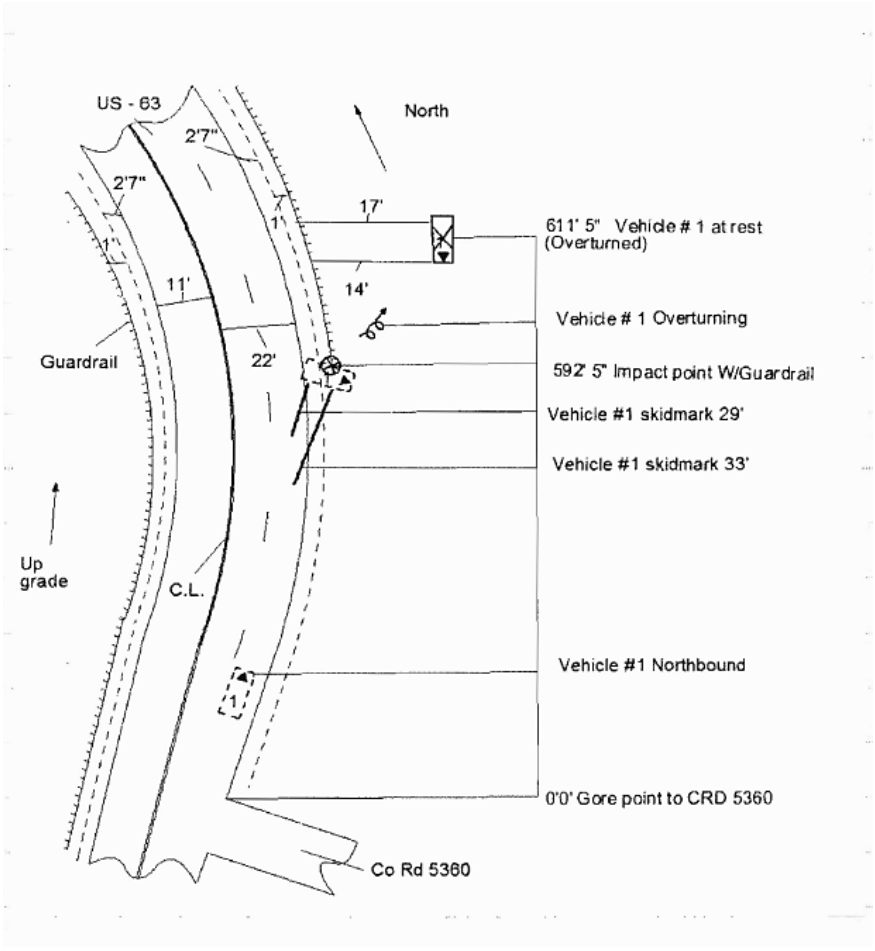


Figure 21 - Illustration of one possible crash sequence (Part A)

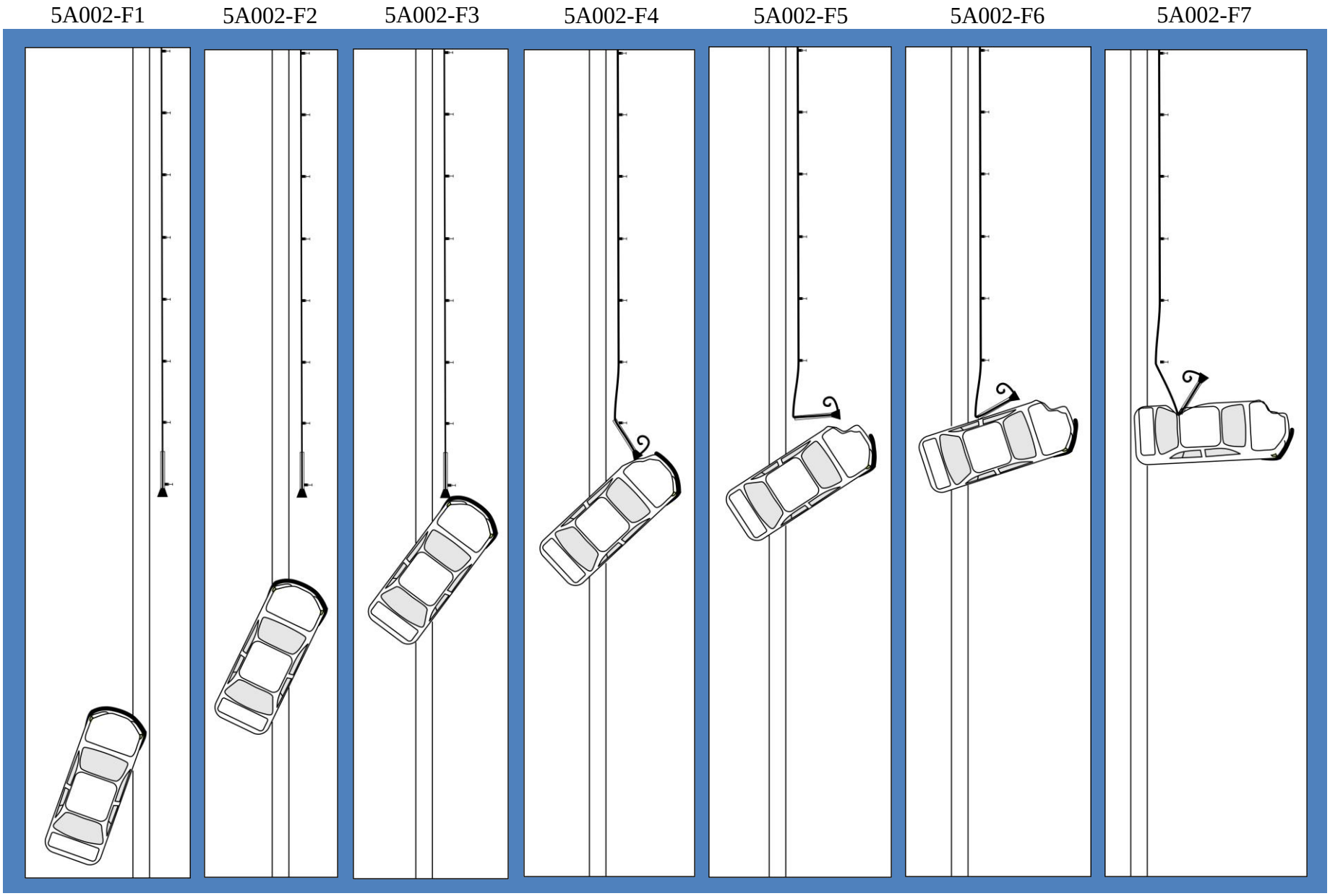
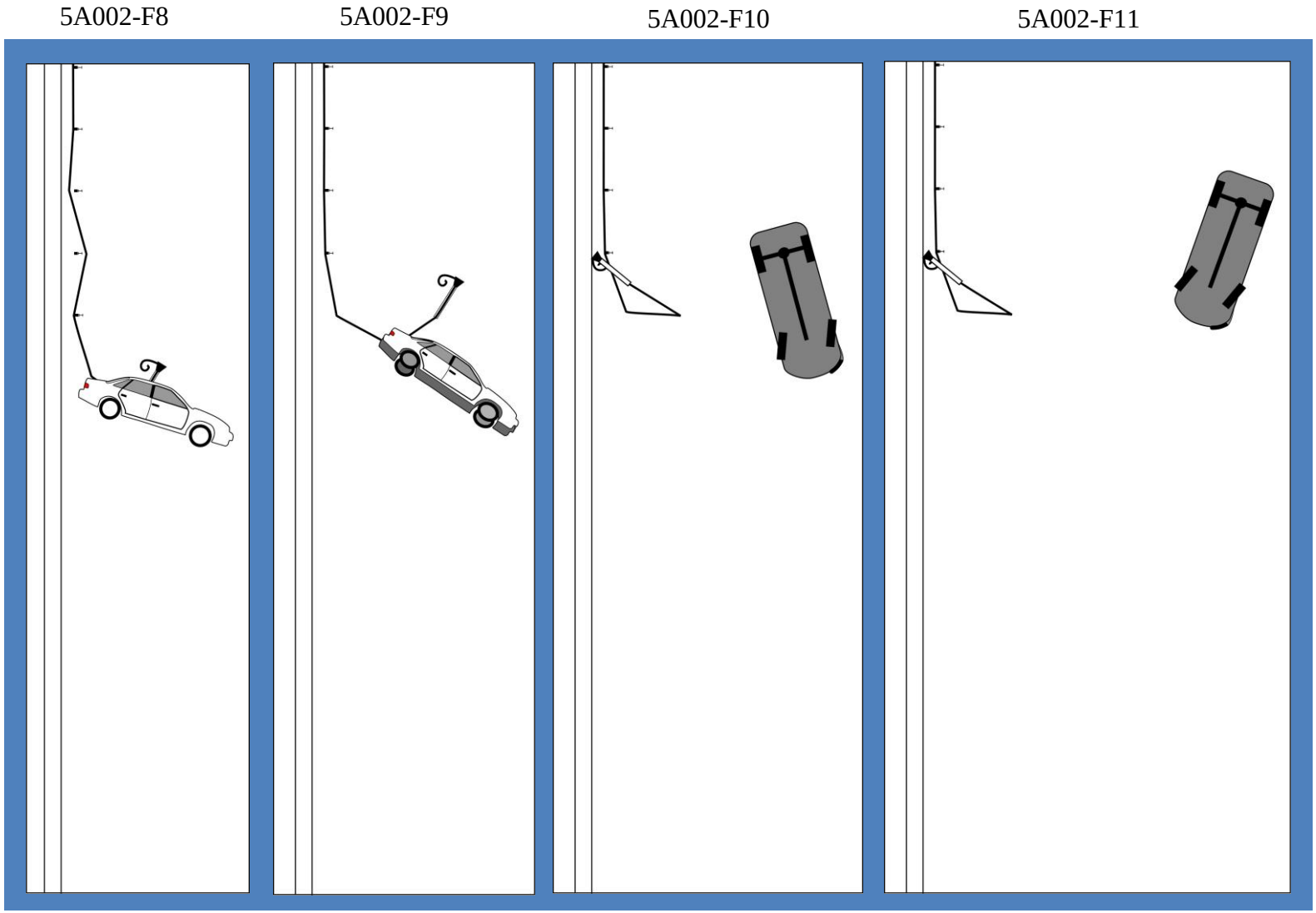


Figure 22 - Illustration of one possible crash sequence (Part B)



Case: 6A002

- Performance Limitation Type: Side impact
- Data Source: NMVCCS
- Device Type: Sequential Kinking Terminal (SKT) with wood posts
- Vehicle Type: Compact passenger car
- Injury Severity: Incapacitating Injury

Narrative:

This crash occurred on a November afternoon on an entrance ramp to a four-lane expressway. The posted speed limit of the expressway was 55 mph. The entrance ramp consists of a 3.3% downward slope and a curve to the right with an approximate 370-foot radius. It was snowing at the time of the crash, with slush accumulation on the shoulders. Photos 19 and 20 show approach views of the crash scene.

The driver of the subject vehicle, a 1993 Saturn SL2, was entering the expressway via the entrance ramp, attempting to merge into the westbound traffic. The driver attempted to merge, but was unable to find a gap. Upon slowing the vehicle, the driver lost control and the vehicle began a clockwise spin. The vehicle then ran off the road to the right and contacted a guardrail terminal with the front driver's side door.

After impact, the vehicle rotated one-quarter turn, coming to rest facing the wrong direction. There was damage to the driver's side front door as a result of the impact (Photo 25) and minor damage to the left rear corner (Photo 26) from what appears to be additional contact with the guardrail prior to the vehicle coming to rest, as seen on the Police Report Crash Diagram. The terminal extruded a very small amount of rail and gated as the vehicle continued its rotation.

A set of illustrations the Task Force developed is presented that depicts its interpretation of one possible scenario of the likely sequence of events in this crash.

The potentially harmful occurrence in this case appears to be sudden deceleration. The non-tracking side-impact conditions of this crash were beyond what would be tested under NCHRP Report 350 or MASH.

Photos:

Photo 23

Photo 24

Photo 25

Photo 26

Photo 27

Photo 28

Figure 23 - Police Report Crash Diagram

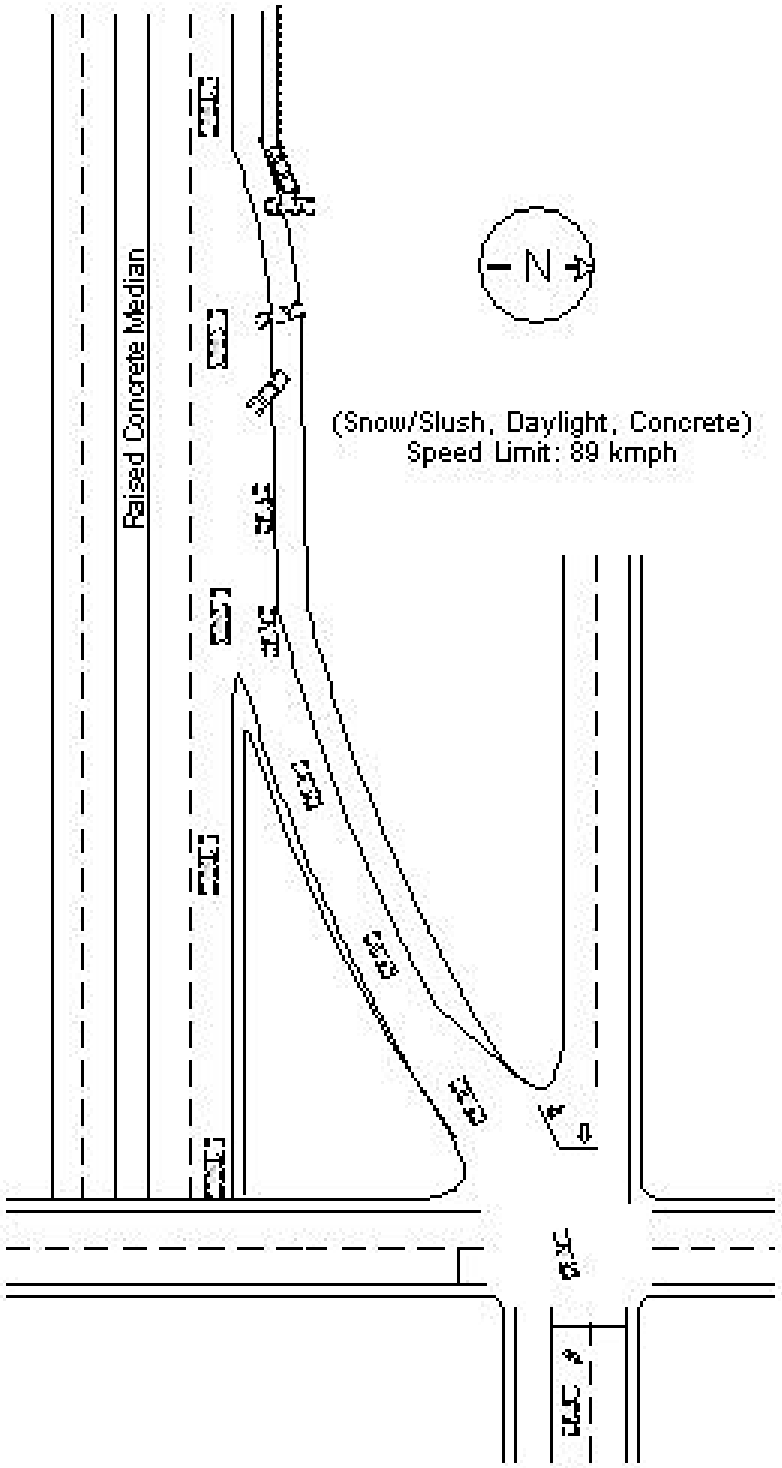
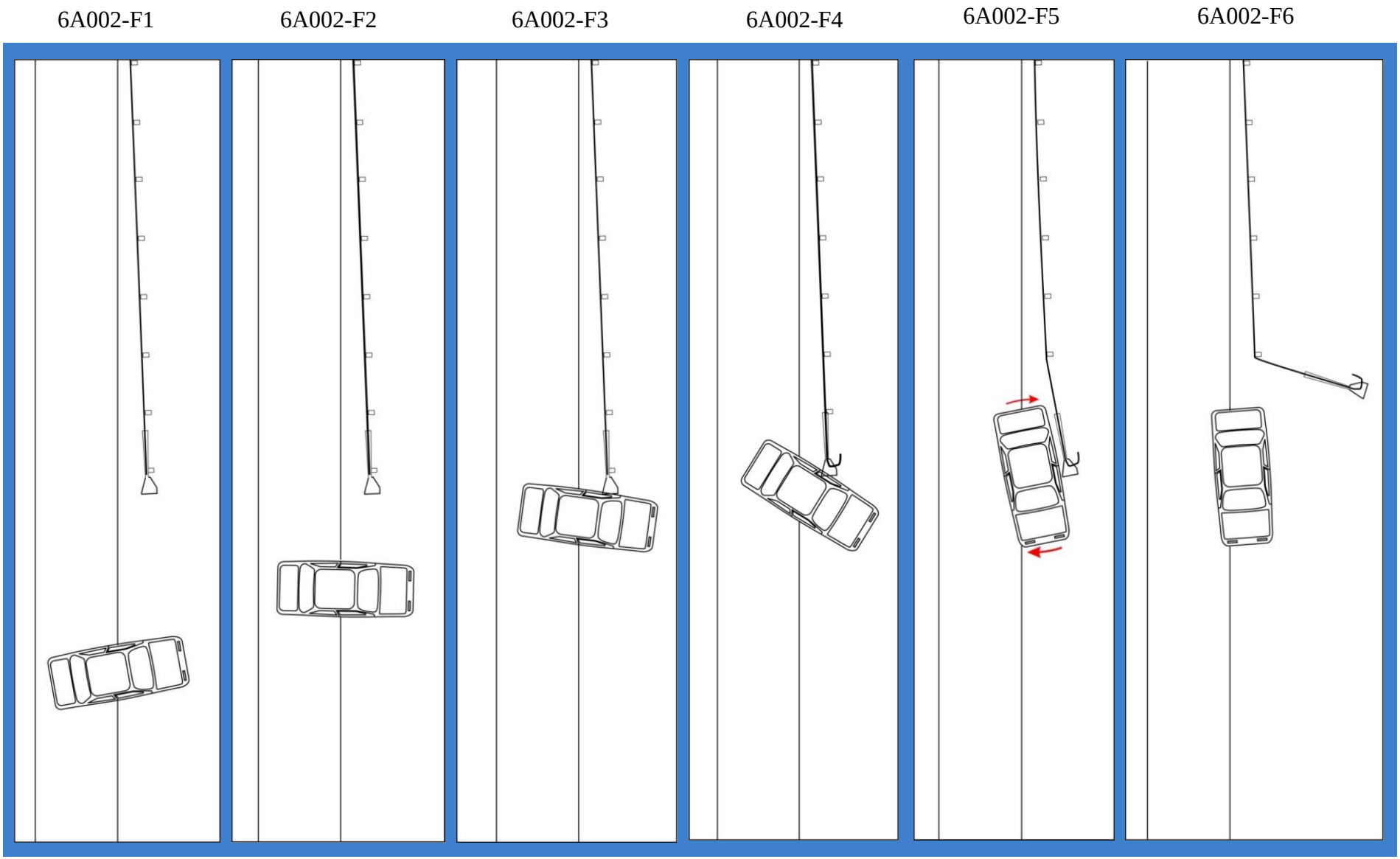


Figure 24 - Illustration of one possible crash sequence



Case #2A018

- Performance Limitation Type: Head-on/Shallow-angle Corner Impact
- Data Source: Harman
- Device Type: ET-Plus 4-inch with steel posts
- Vehicle Type: Small Truck
- Injury Severity: Unknown

Narrative:

A redacted police crash report and numerous photos of the crash site (taken six days after the crash) were provided for this case. However, photos of the installation prior to the crash, photos of the crash scene, and post-crash photos of the vehicle could not be obtained. Nor are the make and model of the subject vehicle known. Given the lack of information, it is not possible to develop a strongly reliable sequence of crash events, but one possible scenario is presented here and is depicted in the illustrations that follow.

This crash occurred on a 4-lane divided interstate in the late afternoon of an October day. The speed limit on the highway was 65 mph. The weather was clear, and the roadway was dry. The driver of the subject vehicle – a small truck according to the police crash report – apparently fell asleep and drifted off the road to the left, striking a 4-inch ET-Plus terminal. The crash report states that the truck ended up on the traffic side of the barrier and pointing roughly upstream, so it is likely that the terminal was first contacted near the left front corner of the truck. The guardrail was pushed through the head until a damaged section of rail reached the reducer portion of the head. Passage of this damaged rail through the reducer caused a brief spike in resistance to the extrusion process. The increased resistance overcame the column strength of the rail, causing it to buckle downstream at the fourth post. Once the rail buckled, it could no longer exert the force necessary to continue pushing the damaged section of rail through the head, and that movement stopped. With the loss of the extrusion process, the vehicle was exposed to the downstream run of rail, and the rail penetrated through the front of the vehicle into the driver's footwell area.

This was the only case the Task Force reviewed for which there appears to have been a high resistance to passage of the rail through the head of the terminal. While this behavior was likely caused by a damaged section of rail, the source and the extent of the damage could not be verified. It is possible that the rail was damaged prior to the impact event, or that it was damaged during the impact event from a vertically out-of-plane impact, as described earlier in this report.

The potentially harmful occurrence in this case appears to be occupant compartment penetration. The offset, head-on nature of this crash is similar to the parameters used in NCHRP Report 350 Test 3-30. However, the vehicle in the subject crash (a small truck) is likely heavier than the 820C test vehicle, and the offset of the impact from the centerline of the vehicle is probably greater.

Photos:

Photo 29

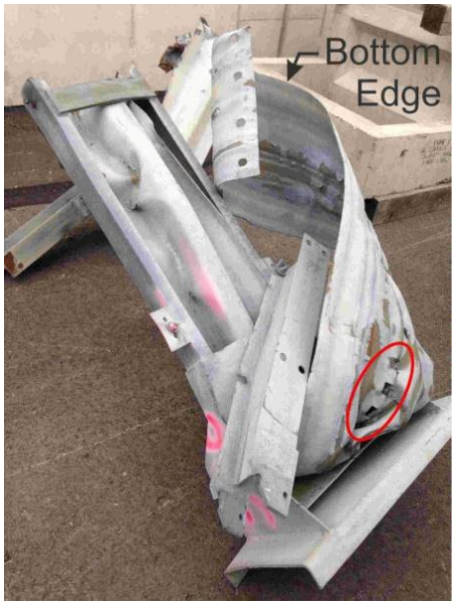


Photo 30

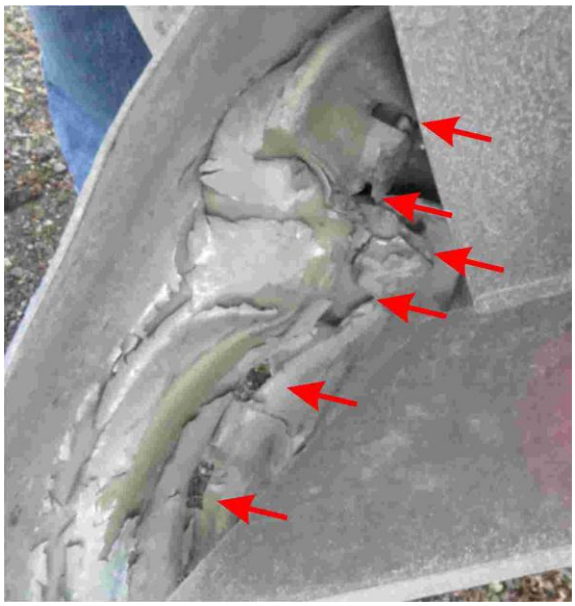


Photo 31

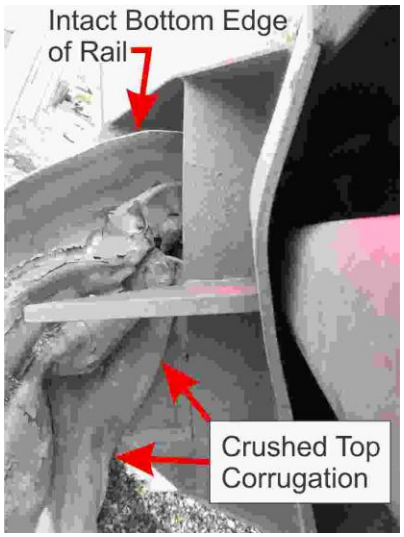


Photo 32- Post 5

Photo 33 - Close-up of Post 5 base

Photo 34- Bowing of reducer sides

Figure 25 – Police Report Crash diagram

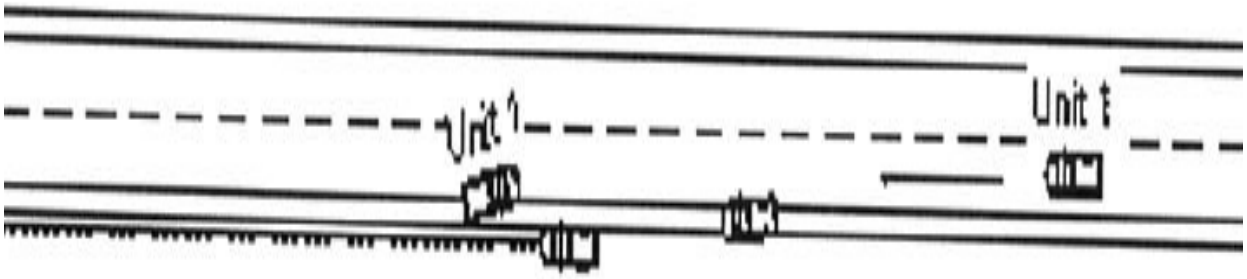


Figure 26 - Illustration of one possible crash sequence (Part A)

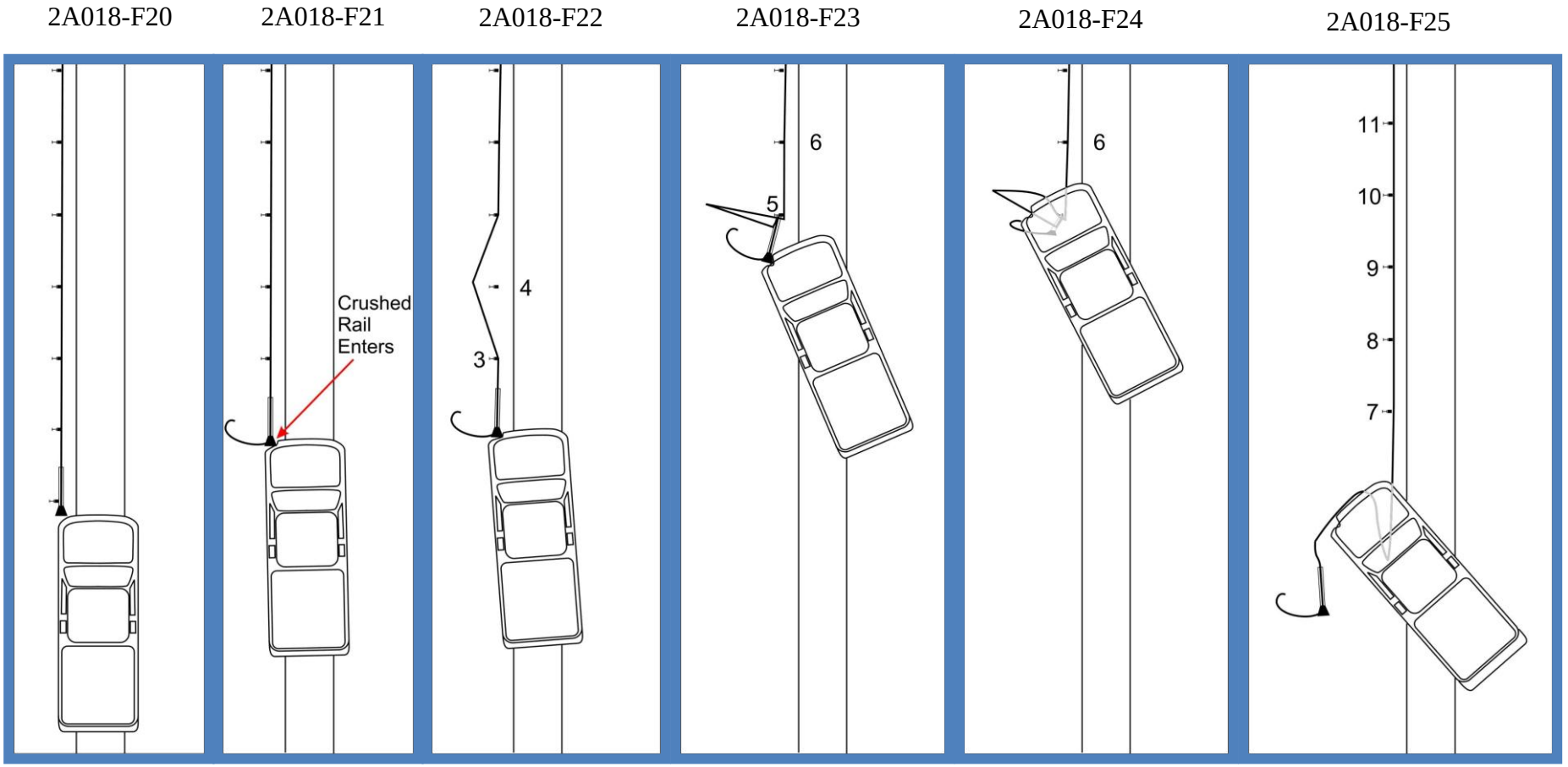
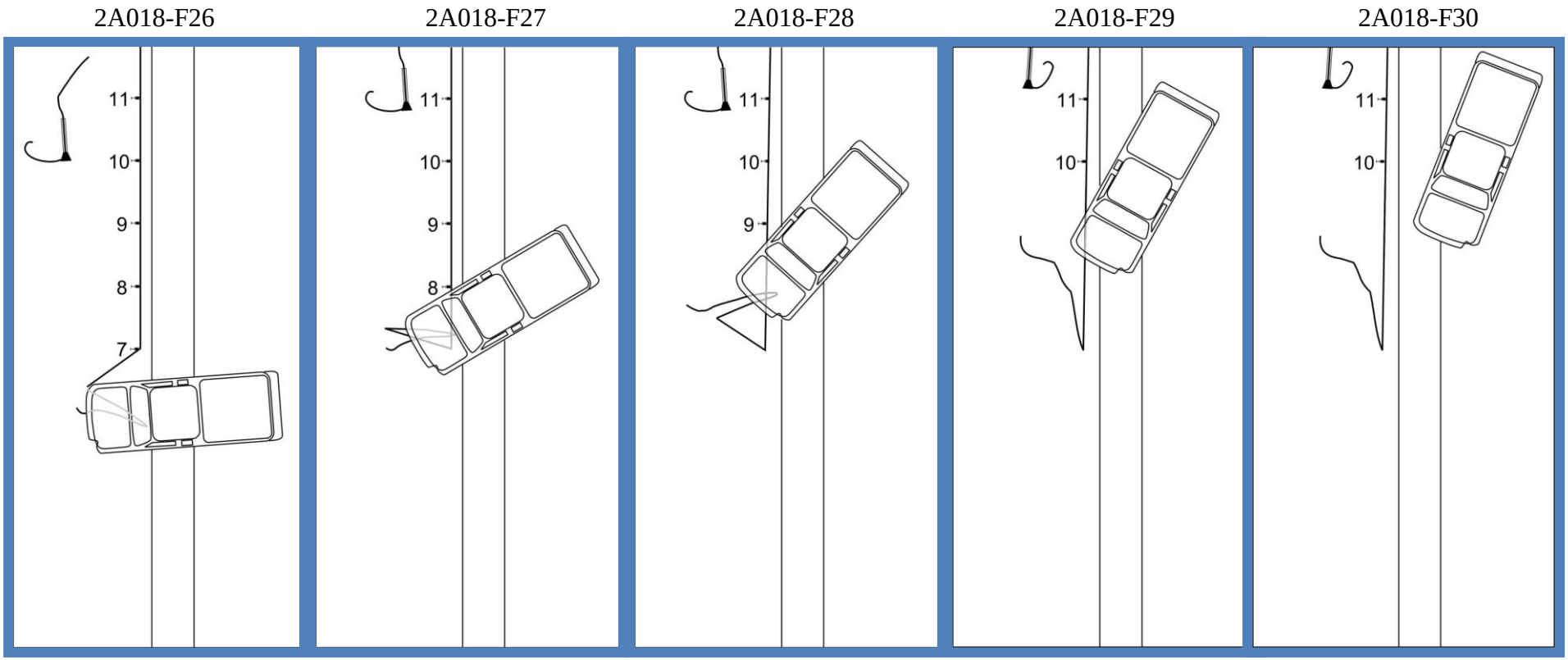


Figure 27 - Illustration of one possible crash sequence (Part B)



Case # 2B008

- Performance Limitation Type: Head-on/Shallow-angle Corner Impact
- Data Source: Missouri DOT
- Device Type: ET-Plus 4-inch with wood posts
- Vehicle Type: Full-size passenger car
- Injury Severity: Serious Injury

Narrative:

This single-vehicle crash occurred on a 65-mph interstate when the driver fell asleep with the cruise control set and drifted off the shoulder on the right side. It was early morning, the weather was clear, the pavement dry, and there was daylight.

Damage to the hood and front of the vehicle, a 2005 Chevy Impala, indicate that the vehicle struck the left edge of an ET-Plus terminal just inboard of the right headlight (Photo 35). Due to the vehicle's relatively moderate weight and the offset nature of the impact, the vehicle began to rotate clockwise about the terminal. Based on the available evidence, it appears this rotation caused a bend to form in the rail at the inlet chute after approximately 15 feet of rail had been extruded (Photo 36). The rail kinked, and the impact head flattened across the front of the vehicle. With the loss of the extrusion process, a second kink appeared to develop downstream and contacted the vehicle just behind the left front wheel (Photo 37). This kink penetrated into the occupant compartment through the lower portion of the driver's side firewall (Photo 38).

The potentially harmful occurrence in this case appears to be occupant compartment penetration. The offset, head-on nature of this crash is similar to the parameters used in NCHRP Report 350 Test 3-30. However, the vehicle in the subject crash is almost twice as heavy as the 820C test vehicle, and the offset of the impact from the centerline of the vehicle is greater. The increased momentum may have resulted in the vehicle not "moving out of the way" of the guardrail as readily. The vehicle's trajectory continued forward which exposed the vehicle to any downstream kinks that may have developed.

Photos:

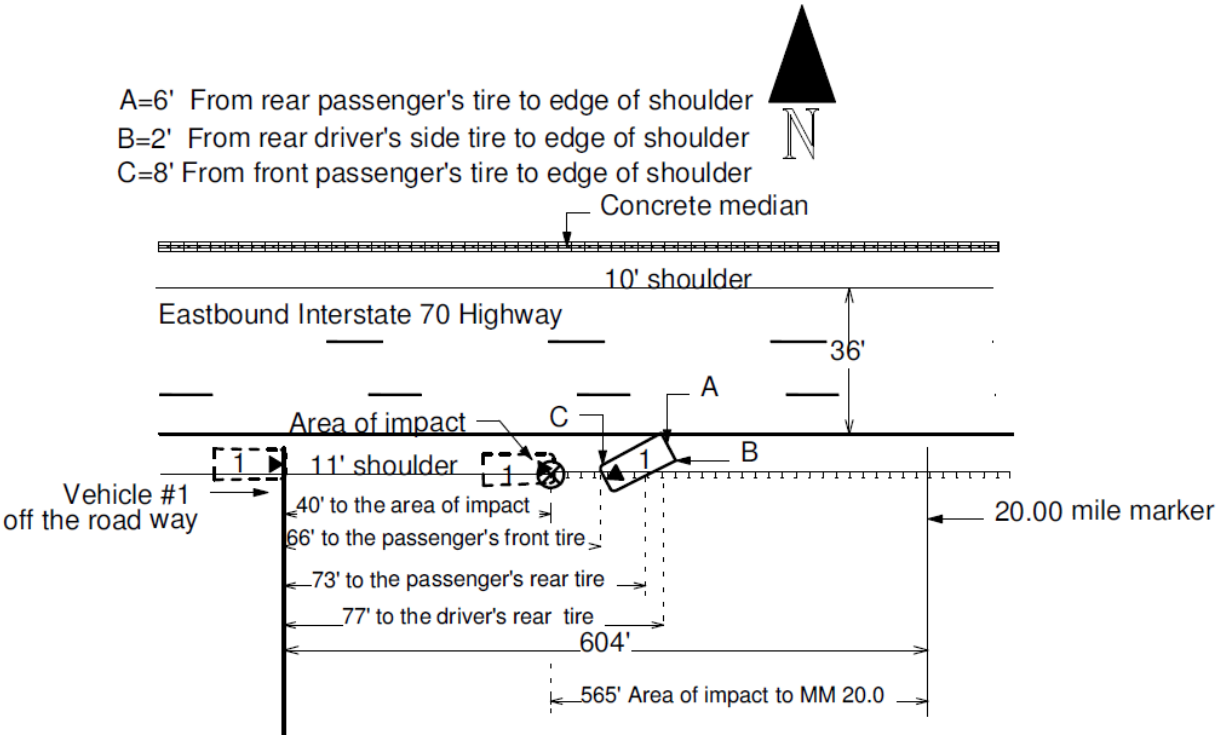
Photo 35

Photo 36

Photo 37

Photo 38

Figure 28 – Police Report Crash diagram



Case #2B009

- Performance Limitation Type: Head-on/Shallow-angle Corner Impact
- Data Source: Missouri DOT
- Device Type: ET-Plus 4-inch with steel posts
- Vehicle Type: Mid-size passenger car
- Injury Severity: Fatal

Narrative:

This single-vehicle crash occurred around 10:00 p.m. on a March night on a straight and level section of interstate highway. At the time of the crash, it was snowing, and the road surface was wet and slushy. Though the speed limit was 70 mph, only four of the timber posts were snapped, suggesting the subject vehicle, a 2001 Toyota Camry, was being operated at a reduced speed. The driver of the vehicle lost control, and the vehicle departed the roadway to the right in a non-tracking fashion, rotating clockwise.

Upon leaving the roadway, the vehicle impacted an ET-Plus guardrail terminal with its front left corner (Photo 39). Based on the available evidence, it appears due to the rotation of the vehicle and its movement away from the road, the impact head was pushed quickly aside, bending and kinking the rail at the inlet end of the chute. The kink made contact with the vehicle near the front edge of the driver's door and penetrated into the occupant compartment (Photo 40).

After the photos and Police Report Crash Diagram shown below, a set of illustrations the Task Force developed is presented that depicts its interpretation of one possible scenario of the likely sequence of events in this crash.

The potentially harmful occurrence in this case appears to be occupant compartment penetration. The offset, head-on nature of this crash is similar to the parameters used in NCHRP Report 350 Test 3-30. It is important to note that the photos suggest a head-on crash, while the police report crash diagram depicts a side impact crash.

Photos

Photo 39

Photo 40

Figure 29 - Police Report Crash Diagram

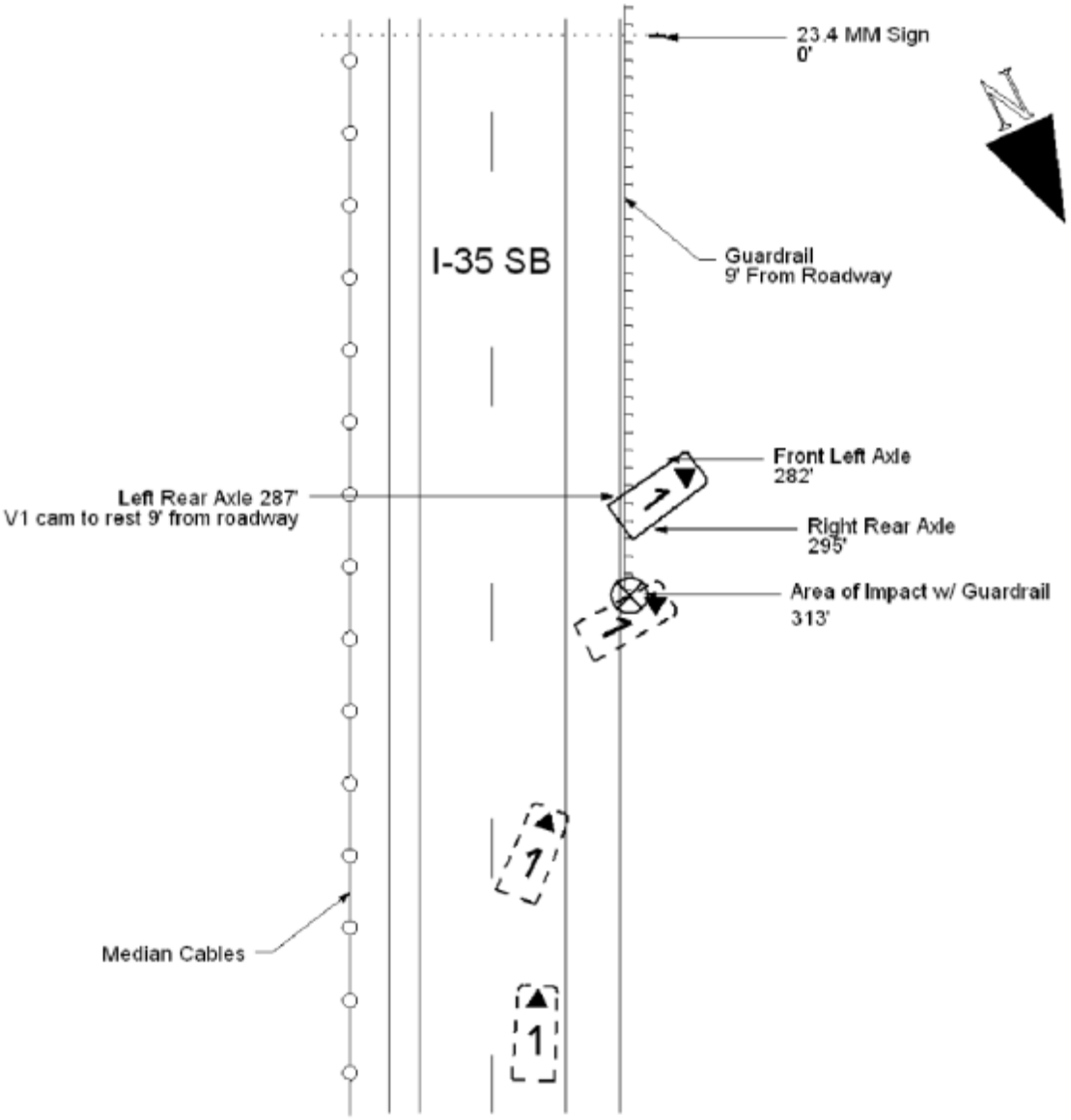
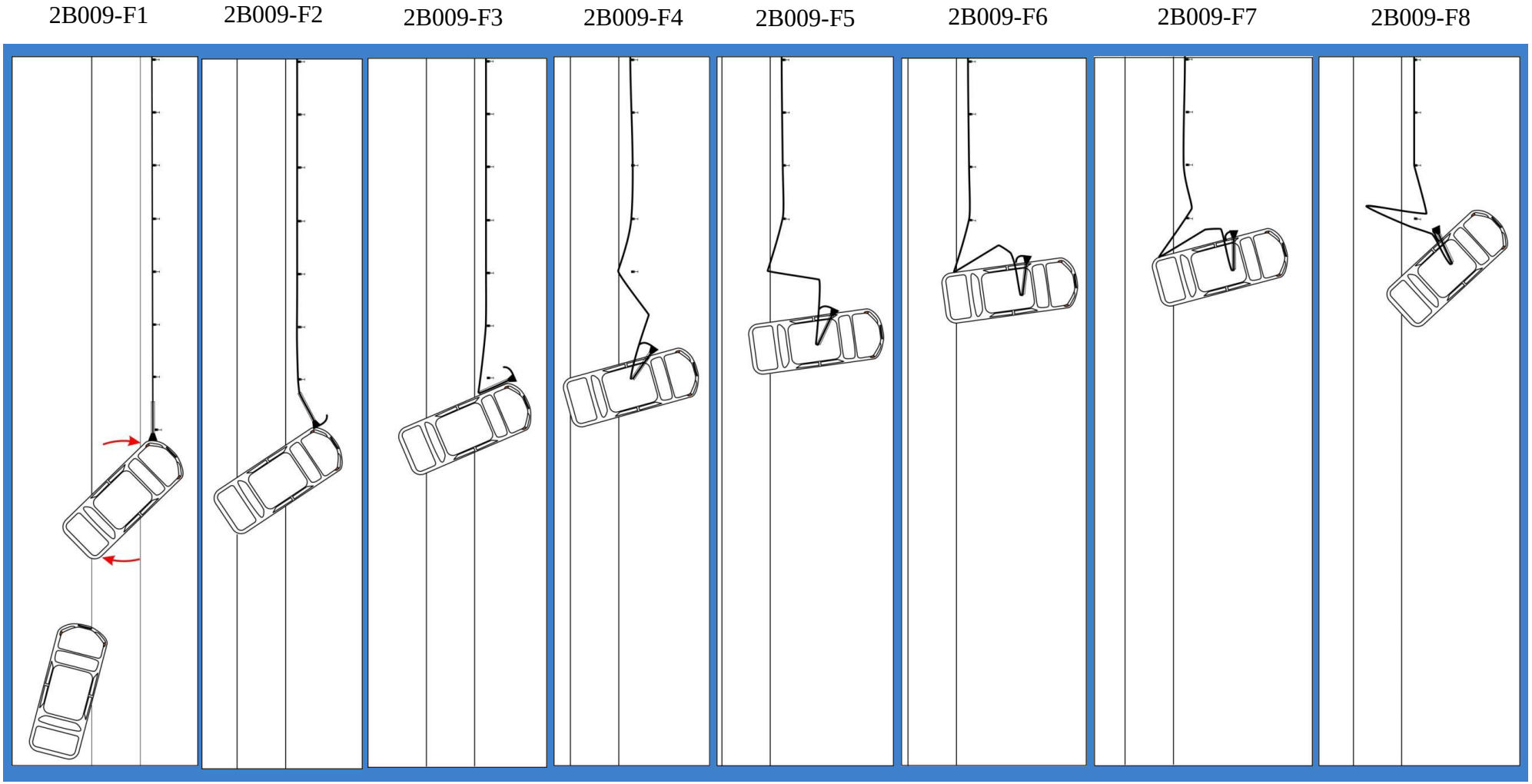


Figure 30 - Illustration of one possible crash sequence



Case #5A001

- Performance Limitation Type: Head-On/Shallow-angle Corner Impact
- Data Source: Safety Institute
- Device Type: ET-Plus 5-inch with wood posts
- Vehicle Type: Full-size SUV
- Injury Severity: Incapacitating Injury

Narrative:

This single-vehicle crash occurred on a rural two-lane highway around 6:00 a.m. on a Saturday morning in late March. The road was essentially straight, but the grade was rising for an overpass. The speed limit was 50 mph. The weather was cloudy and the pavement was wet.

The subject vehicle, a 2001 Chevy Tahoe, was approaching the overpass when it departed the roadway to the right. The lack of any skid marks on the road (Photo #41) to indicate an avoidance maneuver or loss of control suggests that the driver may have fallen asleep, and the vehicle drifted off the road at a very shallow angle.

The vehicle impacted an ET-Plus terminal on its front right side, near the passenger-side headlight. Based on the available evidence, it appears the offset impact induced a clockwise rotation of the vehicle. Approximately 25 feet of guardrail was extruded through the impact head (Photo #42) before the rotation caused a bend to form in the rail at the entrance to the inlet chute. The rail kinked, and it appeared the impact head flattened across the front of the vehicle (Photo #43). With the loss of the extrusion process and the continued forward motion of the vehicle, kinks began to form in the guardrail downstream. At this time, the vehicle appeared to have rotated approximately one-quarter turn, one of the downstream kinks then made contact with the driver's side of the vehicle near the base of the A pillar, and penetrated into the occupant compartment (Photo #44).

After the photos and Police Report Crash Diagram shown below, a set of illustrations the Task Force developed is presented that depicts its interpretation of one possible scenario of the likely sequence of events in this crash.

The potentially harmful occurrence in this case appears to be occupant compartment penetration. The conditions of this crash were beyond what would be tested under NCHRP Report 350. The subject vehicle exceeds the mass of the 2000P test vehicle by approximately 10 percent, and the offset, nearly head-on impact is not represented by any NCHRP Report 350 crash test for a vehicle of this size.

Photos:

Photo 41

Photo 42

Photo 43

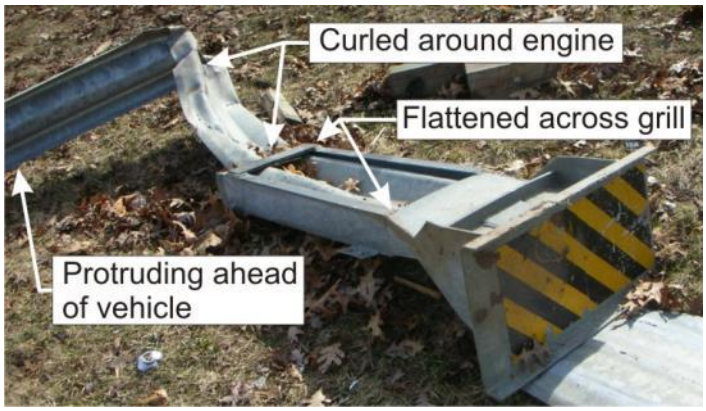


Photo 44

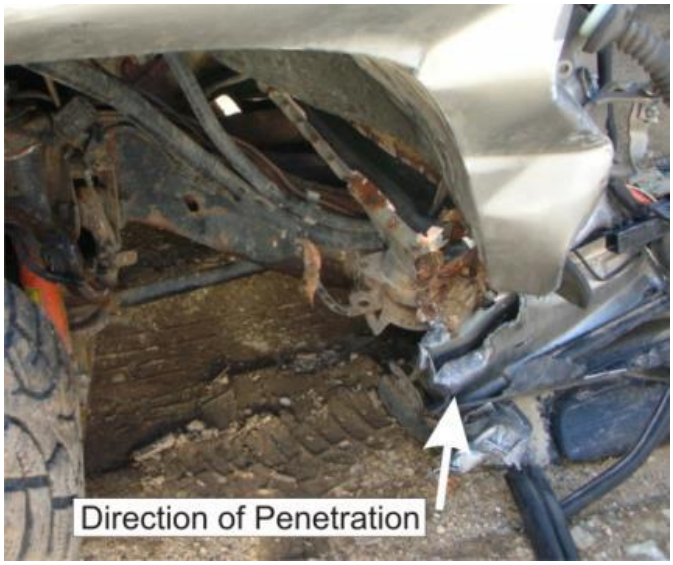


Figure 31 - Police Report Crash Diagram

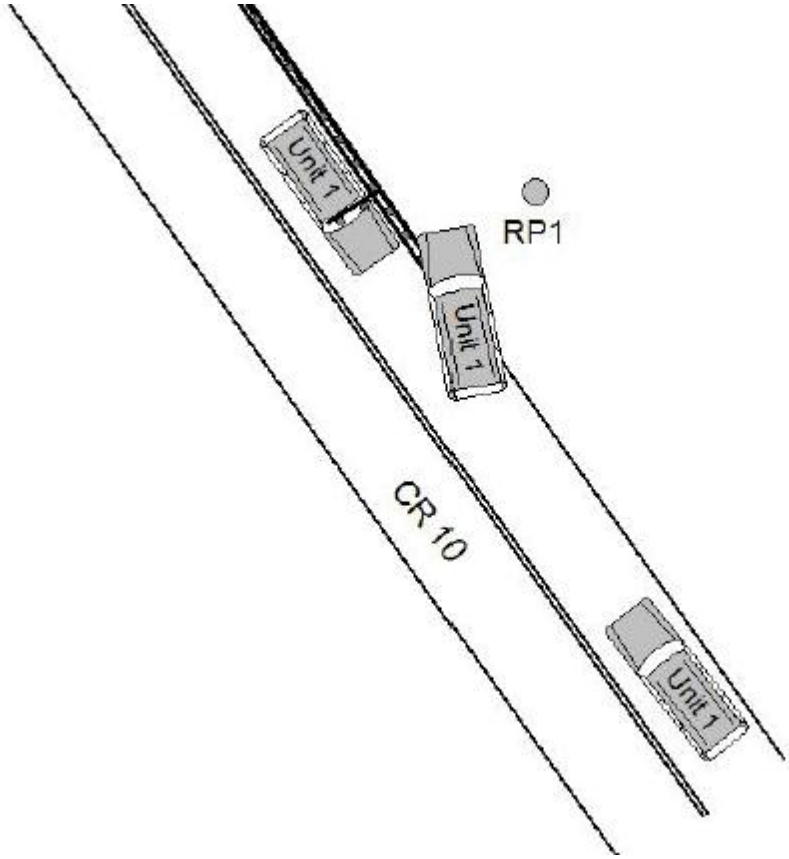


Figure 32 - Illustration of one possible crash sequence (Part A)

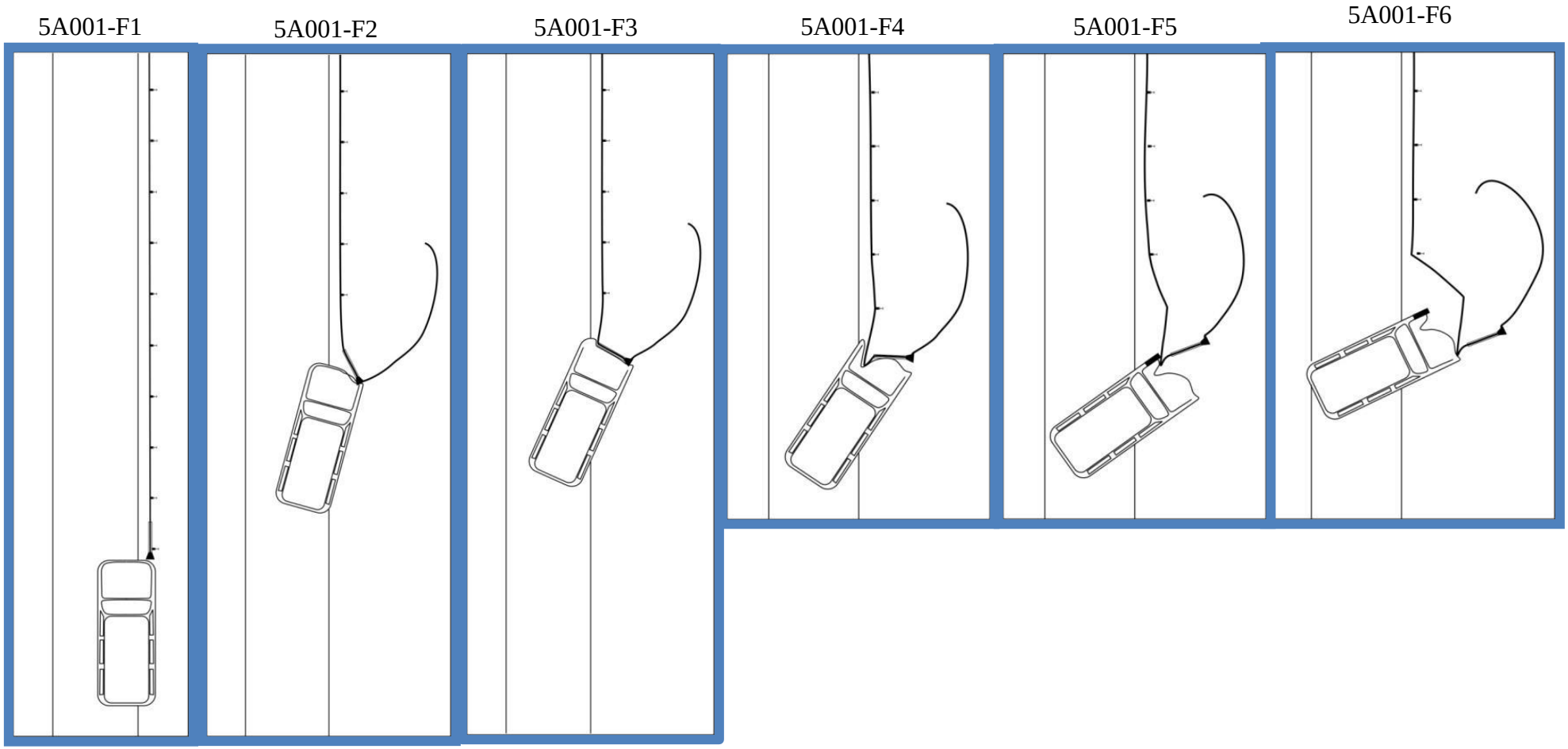
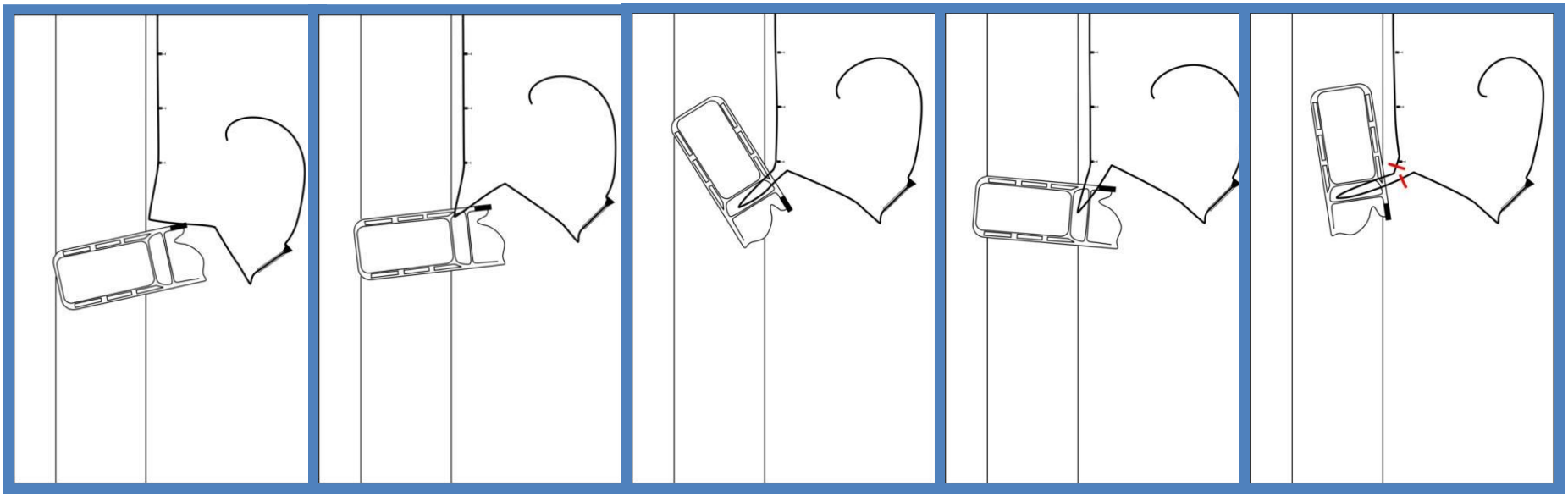


Figure 33 - Illustration of one possible crash sequence (Part B)

5A001-F7 5A001-F8 5A001-F9 5A001-F10 5A001-F11



Case #6A020

- Performance Limitation Type: Head-On/Shallow-angle Corner Impact
- Data Source: FHWA Division Office
- Device Type: Flared Energy Absorbing Terminal (FLEAT) with wood posts
- Vehicle Type: Full-size Pickup Truck
- Injury Severity: Minor Injury

Narrative:

This single-vehicle crash occurred on a 70-mph interstate when the vehicle, a 2006 Chevy Silverado, left the roadway for unknown reasons and drifted off the shoulder on the left side. The crash occurred at approximately 10:00 p.m. on an October night when the weather was clear and the pavement was dry. The estimated speed of the vehicle at the time of the crash was reported as 70 mph. Based on the Police Report Crash Diagram and the tire tracks visible in Photo 45, the impact into the terminal appears to have occurred at a shallow angle.

The initial point of contact was near the front left corner (headlight area) of the vehicle. Based on the available evidence, it appears the FLEAT 350 terminal extruded very little rail before the offset impact kinked and fractured the guardrail. Photo 46 shows the terminal head separated from the rest of the rail and located beyond the final point of rest of the vehicle. This occurrence likely implies the terminal head and the guardrails (up to the first splice) separated in the early stages of the crash and were propelled downstream. It appears that the exposed end of the in-place guardrail penetrated into the occupant compartment through the lower driver's side firewall as the vehicle continued to move forward (Photo 47). Even though the impact occurred on the extreme left corner of the vehicle, the vehicle spun out in a clockwise direction, going behind the guardrail. This may be attributed to the slope of the ground behind the guardrail installation. The vehicle ultimately rotated nearly 180 degrees before coming to a stop behind the rail.

After the photos and Police Report Crash Diagram shown below, a set of illustrations the Task Force developed is presented that depicts its interpretation of one possible scenario of the likely sequence of events in this crash.

The potentially harmful occurrence in this case appears to be occupant compartment penetration. The conditions of this crash were beyond what would be tested under NCHRP Report 350. The subject vehicle exceeds the mass of the 2000P test vehicle by approximately 20 percent, and the offset, nearly head-on impact is not represented by any NCHRP Report 350 crash test for a vehicle of this size.

Photos:

Photo 45 - Approach trajectory of vehicle

Photo 46 - Terminal and rail beyond vehicle point of rest

Photo 47 - Rail visible in driver's side footwell

Photo 48 - Final rest of vehicle

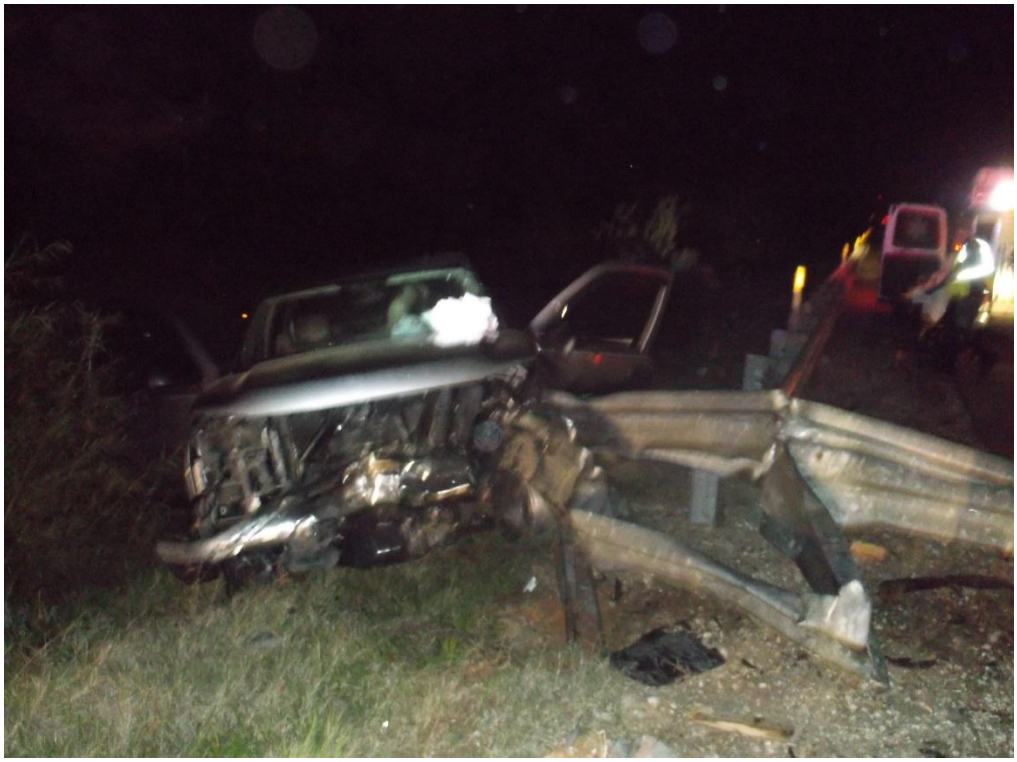


Figure 34 – Police Report Crash Diagram

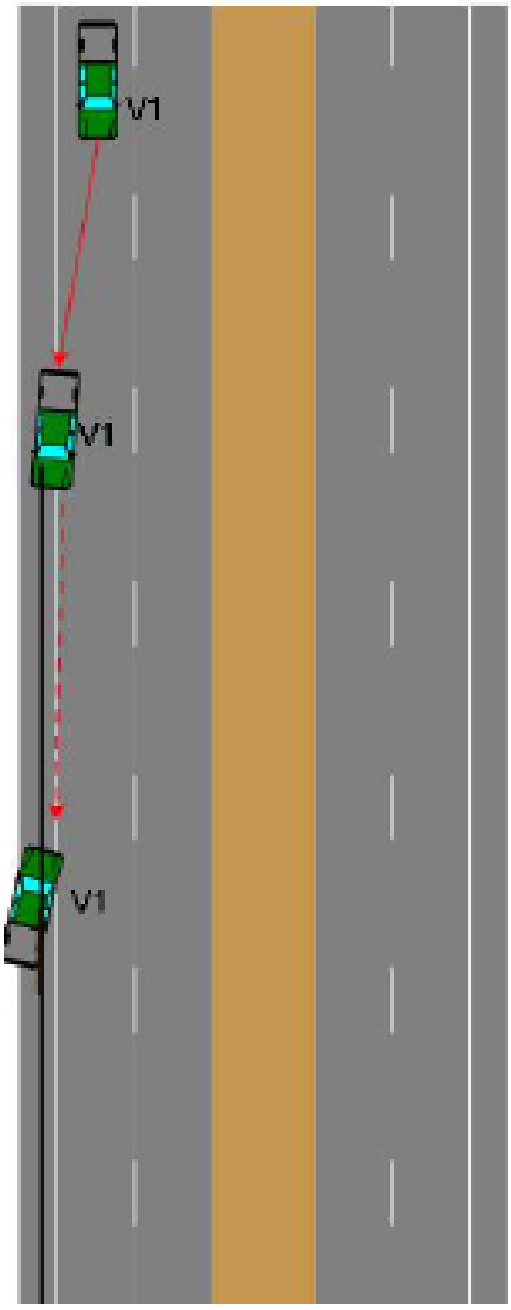


Figure 35 - Illustration of one possible crash sequence (Part A)

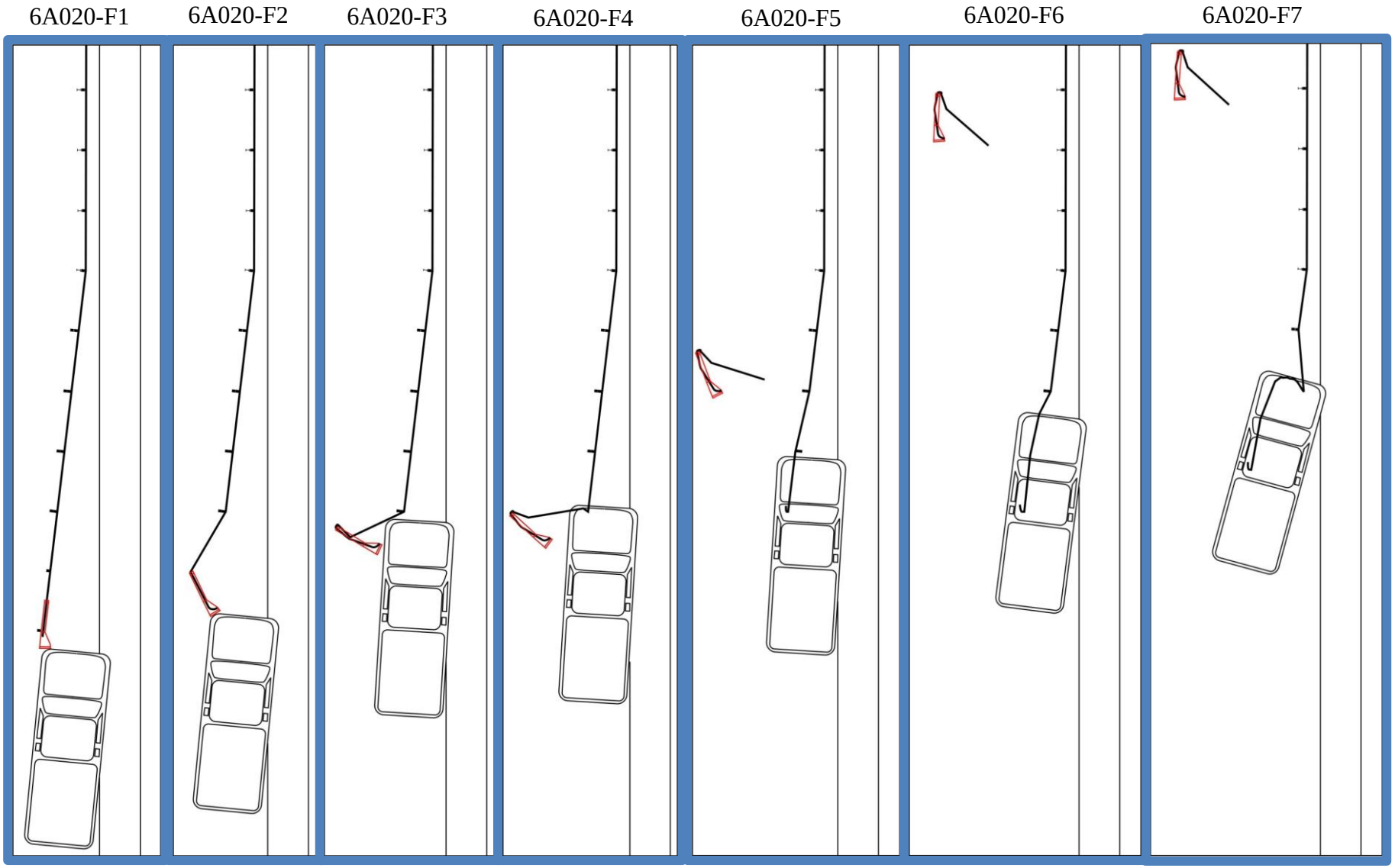
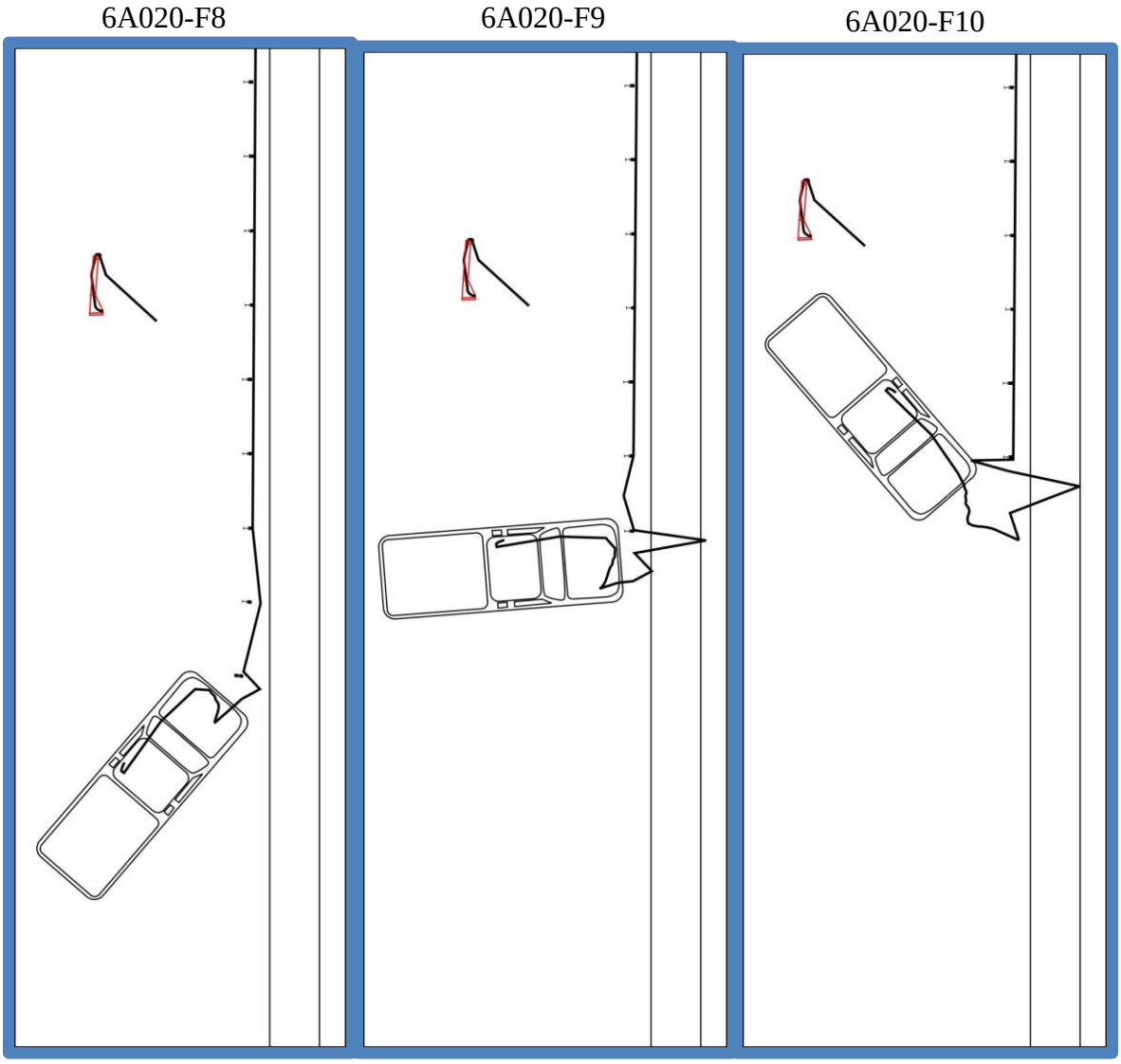


Figure 36- Illustration of one possible crash sequence (Part B)



Case #1A009

- Performance Limitation Type: Head-on /Shallow-angle High-energy Impact
- Data Source: NMVCCS
- Device Type: ET-Plus 5-inch with wood posts
- Vehicle Type: Full-size Pickup Truck
- Injury Severity: Property Damage Only

Narrative:

This crash occurred early on a March afternoon on a divided four-lane interstate within a curve to the left. The speed limit on the highway was 65 mph, and there were no adverse weather conditions at the time of the crash. It appears that the driver of the subject vehicle, a Ford F-150 SuperCab pickup, may have fallen asleep and ran off the right side of the road, impacting a guardrail terminal. No braking was apparent from the post-crash photos, so it is likely that the impact speed was close to 65 mph.

Based on the available evidence, it appears the tire tracks (Photo 49) indicate that the pickup was traveling nearly parallel or at a slight angle to the road at the time of impact, but had its right-side tires approximately 18 inches past the paved shoulder. That offset and the marks left by the terminal head on the front bumper (Photo 50) indicate that the likely primary contact was with the left flange of the terminal face and was approximately one foot to the right of the center of the vehicle. The photo has been marked with a solid white arrow pointing to the deep indentation made by the traffic-side flange of the terminal's face. A dashed white arrow points to the lesser indentation made by the other flange.

The slight clockwise yawing that may have occurred with the initial impact would have been counteracted by the strong final forces on the left front corner of the vehicle (Photo 55). The net result was that the pickup essentially ended up parallel to the highway (Photo 57), but four feet farther away from the shoulder than it was at initial contact.

A set of illustrations the Task Force developed is presented that depicts its interpretation of one possible scenario of the likely sequence of events in this crash.

The potentially harmful occurrence in this case appears to be near occupant compartment penetration. The conditions of this crash were beyond what would be tested under NCHRP Report 350. The subject vehicle exceeds the mass of the 2000P test vehicle by approximately 10 percent, and the impact speed may have been slightly higher than the 62-mph speed used in crash testing.

Photos:

Photo 49

Photo 50

Photo 51

Photo 52

Photo 53

Photo 54

Photo 55

Photo 56

Photo 57

Figure 37 – Police Report Crash diagram

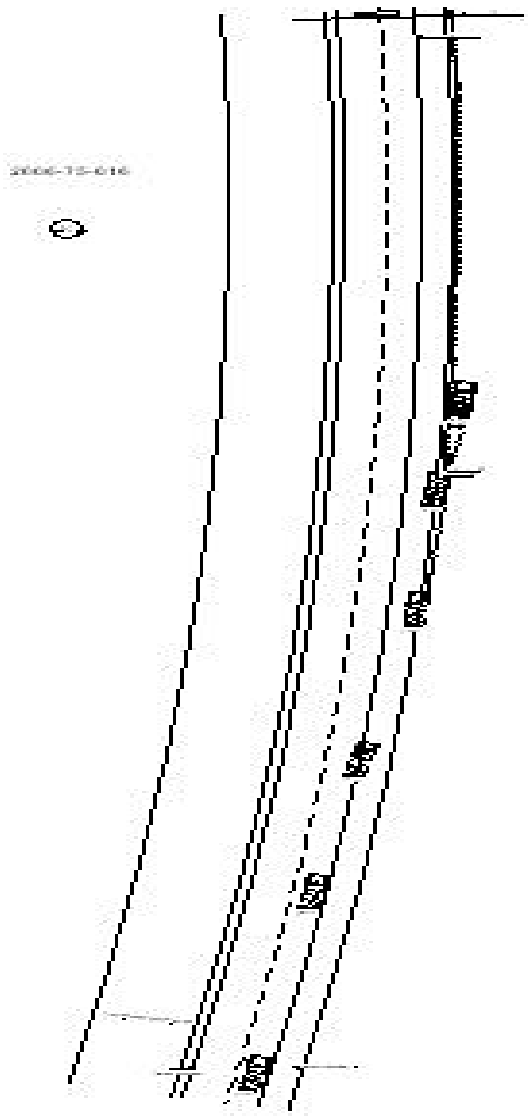
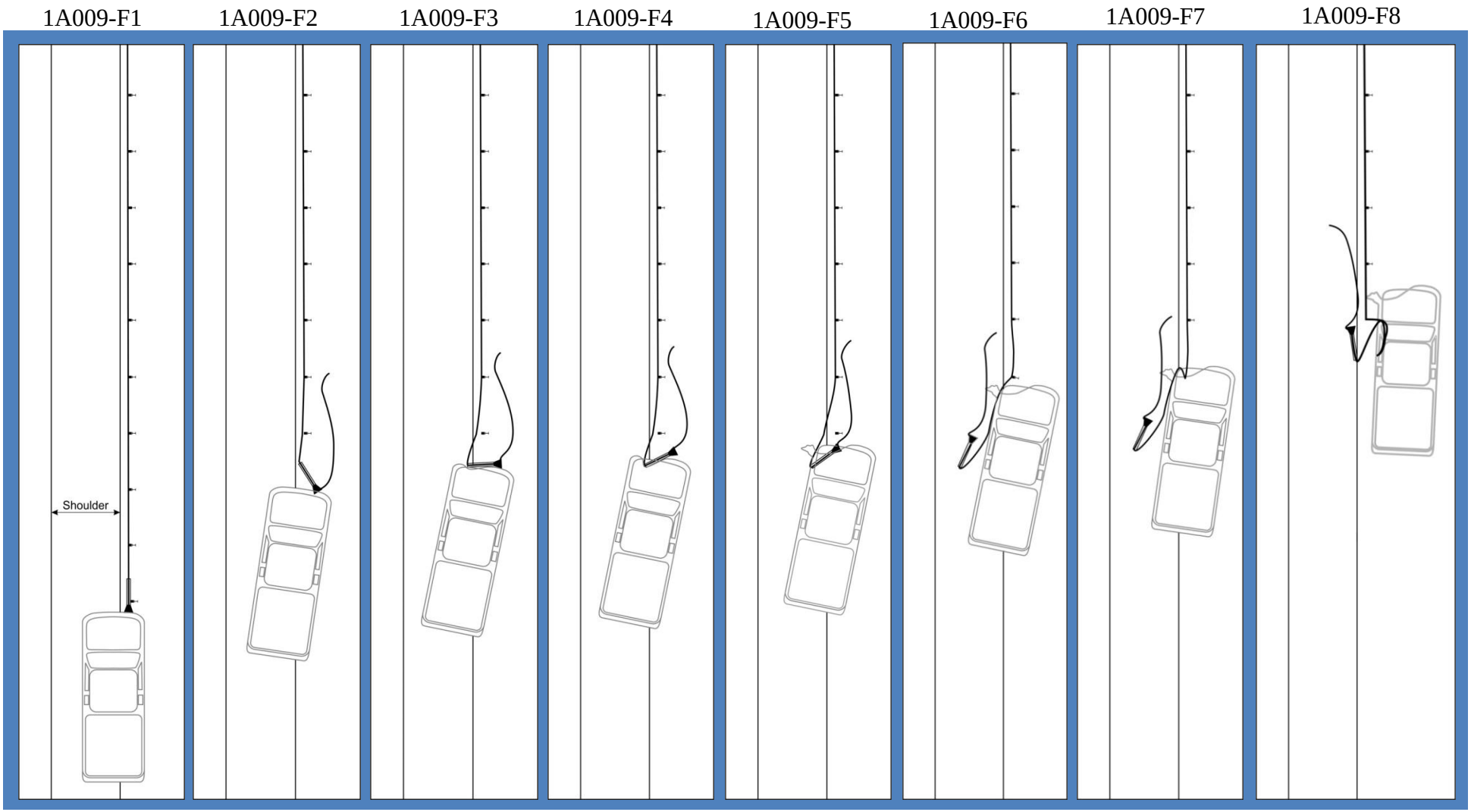


Figure 38 – Illustration of one possible crash sequence



Case: 5A009

- Performance Limitation Type: Head-on/Shallow-angle High-energy Impact
- Data Source: Safety Institute
- Device Type: ET-Plus (unknown dimension)
- Vehicle Type: Single-unit Truck
- Injury Severity: Fatal

Narrative:

This single-vehicle crash occurred at approximately 2:00 a.m. on an April morning. The weather was clear, the pavement was dry, and the roadway was tangent and level. The posted speed limit of the facility was 45 mph. The driver apparently fell asleep at the wheel and drifted off the right shoulder of the roadway.

The subject vehicle, a 2000 Chevrolet Express Single-unit Truck, left the roadway in a tracking manner (no evidence of skid marks or tire marks found at scene) and appears to have impacted a guardrail terminal head-on. The terminal post type is unknown due to the absence of on-site crash photos. Initial contact with the terminal appears to have been made with the front passenger-side bumper (Photo 58). The terminal head extruded an unknown amount of rail before the rail kinked and the terminal head was pushed away from the vehicle.

Based on the available evidence, it appears that several kinks formed after the initial impact and due to the mass of the vehicle (10,000-14,000 pounds), the vehicle continued down the rail with little, if any, yawing. The vehicle contacted one of the kinks in the front driver-side fender just in front of the wheel (Photo 59). The kinked rail penetrated the passenger compartment and continued through to the cargo box of the vehicle (Photo 60). At some point, the rail ruptured/separated at two separate splice joint locations (Photo 61).

The vehicle traveled approximately 100 feet after initial impact with the terminal, yawed slightly in a counter clockwise rotation, then rolled over onto its passenger side largely due to the slope behind the guardrail system.

The potentially harmful occurrence in this case appears to be occupant compartment penetration. The conditions of this crash were beyond what would be tested under NCHRP Report 350. Guardrail terminals are not designed for or tested with single-unit trucks, which can be much heavier than 4400-pound pickup trucks used in terminal crash tests.

Photos:

Photo 58

Photo 59

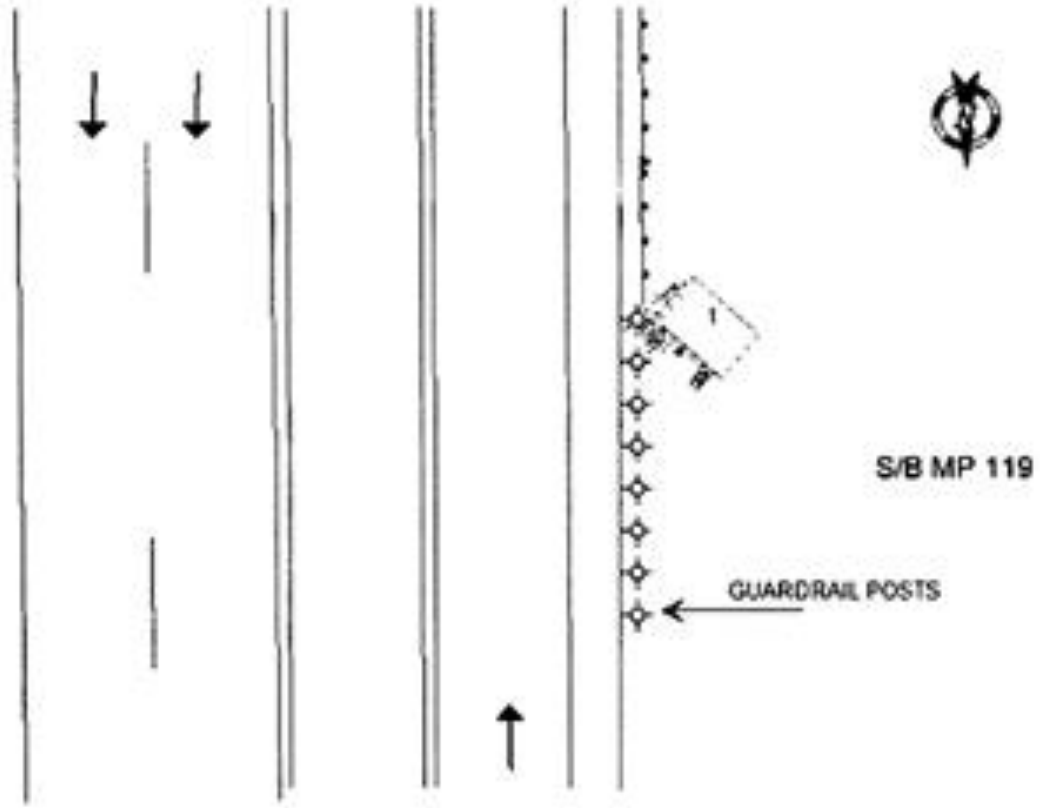
Photo 60

Rail entered passenger compartment through driver-side floor board.

Photo 61

Rail rupture

Figure 79 - Police Report Crash Diagram



Case #6A021

- Performance Limitation Type: Head-on/Shallow-angle High-energy Impact
- Data Source: Safety Institute
- Device Type: Sequential Kinking Terminal (SKT)
- Vehicle Type: Full-size SUV
- Injury Severity: Fatal

Narrative:

This single-vehicle crash occurred on a December afternoon on an 80-mph posted speed limit facility. The weather was cloudy, the pavement was dry, the roadway was straight and on a grade. For unknown reasons, the driver of the vehicle drifted to the left, departed the travel lane, and apparently struck a guardrail terminal head-on.

Information from the crash report indicates that the subject vehicle, a 2014 Jeep Grand Cherokee, struck the terminal at a relatively high rate of speed and made initial contact with the front center of the vehicle. The terminal post type is unknown due to the absence of on-site crash photos. Based on the available evidence, it appears the terminal extruded an unknown amount of rail before the terminal head was pushed away from the front of the vehicle. The police report crash diagram indicates the vehicle began to yaw counter-clockwise as the terminal head was being pushed away from the vehicle. At some point, it appears a kink formed in the rail. According to the police report, a section of the rail penetrated the occupant compartment through the rear passenger-side door.

The photos of the terminal head alone do not provide adequate information to assess the performance of the terminal. The photos appear to indicate both ends of the rail were cut in order for the terminal to be removed. Therefore, it cannot be determined how much rail was extruded through the terminal head.

The potentially harmful occurrence in this case appears to be occupant compartment penetration. The conditions of this crash were beyond what would be tested under NCHRP Report 350. The assumed impact speed of 75-80 mph was significantly higher than the 62-mph speed used in crash testing. This narrative is based on limited information from the crash report and post-crash terminal photos. No photos of the vehicle or crash scene were available.

Photos:

Photo 62

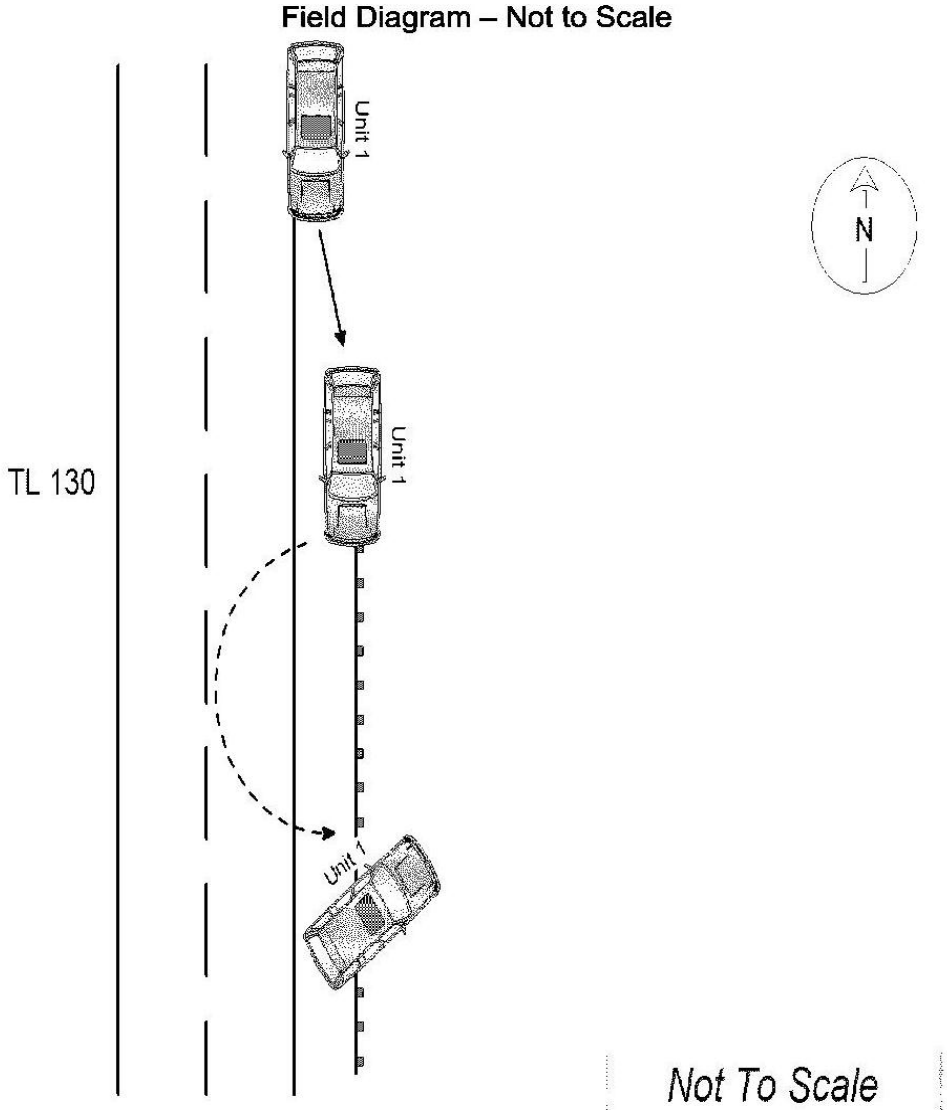
Cut by first responders or maintenance personnel

Photo 63

Photo 64

Cut by first responders or maintenance personnel

Figure 40 - Police Report Crash Diagram



Performance Limitations: Installation Conditions

This section of the report covers placement, installation, and maintenance issues associated with extruding w-beam guardrail terminals. These issues can adversely affect the safety performance of w-beam guardrail terminals, but it is unknown to what extent, because terminals are not crash tested under less-than-ideal conditions. Designers encounter many constraints in the field (i.e., geographical challenges, environmental impacts, and restricted rights-of-way) that inhibit the ability to install these devices under standard crash tested (ideal) conditions. In many cases, it may be preferred to shield a hazard with a barrier installed under less-than-ideal conditions rather than leaving the hazard unshielded.

The Task Force identified placement, installation, and maintenance issues using: 1) reviews of individual crash cases, 2) FHWA's training effort to assist highway agencies with their design, installation, and maintenance practices for roadside safety hardware, and 3) the joint AASHTO-FHWA Task Force report on ET-Plus 4-inch Dimensions, which reviewed dimensions taken from ET-Plus 4-inch devices in the field.

In the review of the crash cases, the Task Force observed a number of placement, installation, and maintenance issues. These issues fall into three categories: 1) hardware installation/maintenance/repair, 2) grading (such as lack of relatively flat graded platform in advance of, and adjacent to, the terminal), and 3) placement (such as terminal located behind curb). Table 12 illustrates these issues with photos from individual crashes. For many of the issues, there is a brief statement about the potential effects on performance. However, it is not clear for these individual crash cases how they ultimately contributed to the outcome of the crash, which is why the performance statements in Table 12 should be viewed as potential effects.

Table 12- Installation Conditions Observed in Crash Cases

Issue		Crash Case Photos
Terminal Located Behind Curb *May affect the stability of the impacting vehicle.*		
Lack of relatively flat graded platform in advance of, and adjacent to, terminal *Terminal can only anchor the guardrail for downstream impacts*.		
Installation did not comply with the manufacturer's drawings	Bolted cable bracket used instead of tabbed bracket. *Terminal may not absorb energy in crash as designed.*	
	Soil tubes protruding more than 4 inches above ground surface. *Vehicle undercarriage may snag on posts causing abrupt deceleration.*	

Installation did not comply with the manufacturer's drawings	Tangent terminal installed on flare.	 
	Flared terminal installed on tangent.	
Terminal placement issues	Within, or just beyond, sloping gore areas.	
Terminal placement issues	Within curves *Energy absorbing terminals need a straight run of guardrail to travel on.*	

Terminal placement issues	Where slopes behind the rail are relatively flat and free from obstacles (i.e., where a barrier may not be warranted) *Barrier may present a higher level of risk than the unshielded condition.*	   

Other placement, installation, and maintenance issues for terminals exist beyond those highlighted through crash cases in Table 12. FHWA has documented these other issues in a technical brief as part of an FHWA memo (http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/policy_memo/memo052615/index.cfm) issued on May 26, 2015 and through the Agency's training effort titled "Roadside Safety Systems Inspection/Maintenance & Designers Mentoring Program" to assist highway agencies with their placement, installation, and maintenance practices of roadside safety hardware. This training has been delivered to ten States since 2010. Through the training visits to participating States, photographs of existing roadside safety hardware are taken in these States to document their design, installation, and maintenance practices.

Summary of Findings

A total of 1231 crash cases were received and 161 cases were selected for detailed review and analysis by the Task Force. Members of the Task Force identified six primary performance limitations of extruding w-beam guardrail terminals. These limitations are classified into two general categories: impact conditions and installation conditions. The impact conditions that the Task Force identified as performance limitations include side impacts, head-on/shallow-angle corner impacts, and head-on/shallow-angle high-energy impacts. The categories of installation conditions the Task Force identified as performance limitations include hardware installation/maintenance/repair, grading, and placement.

CONCLUSIONS AND RECOMMENDATIONS

This report documents a joint AASHTO and FHWA effort to examine the safety performance of extruding w-beam guardrail terminals with a focus on identifying their performance limitations. The ET-Plus w-beam guardrail terminal with a 4-inch wide feeder channel was the Task Force's primary focus, but the effort also included a review of other extruding w-beam guardrail terminals. The purpose of this effort was to determine whether there is any evidence of unique performance limitations of the ET-Plus 4-inch guardrail terminal and the degree to which any such performance limitations extend to other extruding w-beam guardrail terminals. The effort does not provide relative comparisons of the in-service safety performance of individual terminal types or an indication of the frequency of occurrence of the individual performance limitations because the collection of crash cases does not characterize a representative sample of terminals in service or a representative sample of terminals that were struck.

As background, the Task Force reviewed national safety statistics and data provided by States, which are presented in this report. Using FHWA's roadway departure definition and comparing fatalities on a national level, guardrail terminals represent a small percentage (0.2 percent) of total highway fatalities with respect to the most harmful event. These data include information on various w-beam guardrail terminals, including past designs that have no history of being crash tested under any prior performance criteria.

The Task Force determined that a detailed review of individual real-world crashes would provide the best opportunity to address the objectives of this effort. To identify potential performance limitations, the Task Force, with input from three independent expert reviewers, analyzed crash cases involving extruding w-beam guardrail terminals from 11 data sources. The crash case review process consisted of six primary components and included assessments conducted jointly by FHWA, State DOT representatives, and independent expert reviewers. Of the 1231 cases initially screened by FHWA, the Task Force and independent experts conducted a detailed analysis of 161 cases. These cases that comprised the focus of the analysis were viewed as the most likely to show potential performance limitations and represented a limited sample across five different guardrail terminal types. The data in this assessment were skewed toward severe crashes involving ET terminals; a limited sample of SKT and FLEAT cases were also captured.

Based on the analysis, the Task Force developed the following conclusions and recommendations to address the identified w-beam guardrail terminal performance limitations.

Conclusions

1. **Guardrail Terminal Crash Test Impact Conditions and Field-installed Conditions -** The review of guardrail terminal performance based upon the limited number of crashes confirms what is acknowledged in National

Cooperative Highway Research Program (NCHRP) Report 350[9] and the AASHTO Manual for Assessing Safety Hardware (MASH)[10] – there are real-world impact conditions that vary widely from the crash test matrices as related to vehicle type and sizes, first point of vehicle impact, vehicle non-tracking, and vehicle speed. Also, there are different installation and maintenance practices in place that can affect safety performance. Within the roadside safety community, it is recognized that even with the "best" practice of terminal design, with the wide variety of traffic and field conditions and applications, there will be crashes that exceed the performance expectations for the terminals. In addition, roadside features such as ditches, curbing, uneven terrain, and steep slopes in the vicinity of the terminal factor into the ability to mitigate the severity of the outcome of a guardrail terminal crash event. These terrain features can contribute to an increased likelihood of rollover during or after the impact event.

2. **Performance Limitations** – Performance limitations are factors in a real-world crash environment that can contribute to the unsuccessful performance of a roadside safety hardware device. As indicated in MASH, guardrail terminals "are generally developed and tested for selected idealized situations that are intended to encompass a large majority, but not all, of the possible in-service collisions." Satisfactory performance can typically be expected for collision conditions similar to the test conditions. However, the performance of these devices is dictated by physical laws, vehicle stability, vehicle crashworthiness, and the site conditions of these real-world crashes. The more the crash conditions differ from the test conditions, the more likely it becomes that performance will be outside of the desirable limits.

   Through its analysis, the Task Force identified several performance limitations for all types of extruding w-beam guardrail terminals reviewed in this study. The limitations fall into two general categories: 1) impact conditions, and 2) installation conditions. For impact conditions, the primary performance limitations that were identified include: 1) side impacts, 2) head-on/shallow-angle corner impacts, and 3) head-on/shallow-angle high-energy impacts. For installation conditions, the performance limitations identified include: 1) hardware installation/maintenance/repair issues, 2) grading issues, and 3) placement that does not conform to accepted guidance and practice. These installation conditions can adversely affect the safety performance of these devices, but it is unknown to what extent, since terminals are crash tested under ideal, controlled conditions.

3. **NCHRP Report 350 Crash Test Criteria** – NCHRP Report 350 crash test matrices do not specifically address the performance limitations the Task Force identified. It appears that side impacts, head-on/shallow-angle high-energy

[9] TRB's National Cooperative Highway Research Report 350 – Recommended Procedures for the Safety Performance Evaluation of Highway Features,

[10] AASHTO's Manual for Assessing Safety Hardware, 2009.

impacts, and head-on/shallow-angle corner impacts may lead to safety performance issues. However, the data analyzed did not allow for an assessment of how frequently these situations occur (i.e., they may be limited or they may appear on a regular basis) in the field. The shallow angle impact test condition is addressed in the MASH crash test criteria, but side impacts and front corner impacts are not specifically addressed in MASH. This points to the need to conduct in-service performance evaluations on roadside safety hardware including guardrail terminals; these evaluations are critical to determine whether crash-tested hardware have performance limitations that are not detected by the testing process and should be used to amend the crash test criteria in subsequent updates.

4. **Crash Testing of Extruding W-beam Guardrail Terminals** – The Task Force considered additional crash testing of all existing NCHRP 350-compliant extruding w-beam guardrail terminals but concluded that such testing would not be informative because the performance limitations identified for these terminals fall outside of the NCHRP 350 testing matrices.

Recommendations

The Task Force developed the following recommendations:

1. **Fully Implement MASH Compliance for New Installations of Guardrail Terminals** – This action is related to the roadside safety community setting a date by which new installations of guardrail terminals should be consistent with the MASH crash test criteria. MASH testing incorporates changes in the crash matrix details that will be more discerning for guardrail terminals. More specifically, MASH addresses impacts that occur at shallow angles, which is an important element in two of the performance limitations identified in this report. Each successive version of crash testing guidelines is meant to encourage manufacturers to advance the state of the practice and to develop safety devices that work with a changing vehicle fleet under a wider range of conditions. Because of the extensive development and testing required, it typically takes many years after roadside safety hardware guidelines are established for products meeting those guidelines to be widely available on the market. However, in the six years since MASH was published, there have not been a significant number of MASH-tested devices developed and brought to market. Therefore, in order to encourage the expanded development and installation of MASH-compliant devices, the Task Force supports the roadside safety design community to expeditiously transition to the MASH criteria for all new installations of guardrail terminals.

2. **Conduct In-Service Performance Evaluations of Guardrail Terminals** – The Task Force recommends that comprehensive in-service performance evaluations of guardrail terminals be conducted at the national and State levels. As previously highlighted in this report, the Task Force's assessment did not involve a complete in-service evaluation and concentrated on a limited group of mostly higher severity crashes, specifically focused on crashes with the ET-Plus terminal. The findings of this report should be considered by the National Academies' National Research

Council (NRC) committee that is conducting a project entitled "In-Service Performance of Energy-Absorbing W-beam Guardrail End Treatments." The intent of the NRC committee is to conduct exploratory work to determine what data are available, in sufficient quantity and quality, to allow for meaningful in-service evaluation studies of guardrail terminals.

3. **Expand Documentation of Guardrail Crashes** – The Task Force recommends that AASHTO and FHWA encourage public agencies to thoroughly document guardrail crashes in order to allow for conducting more comprehensive in-service evaluations. Photographic evidence of an impacted guardrail and damaged vehicle(s) involved in a crash is extremely valuable and not typically captured. In addition, the Task Force recommends that AASHTO and FHWA request that the National Highway Traffic Safety Administration (NHTSA) thoroughly document guardrail crashes in its Crash Investigation Sampling System which is being phased in over the next two years as the replacement for the NASS CDS. Also, NCHRP project 17-43, "Long-Term Roadside Crash Data Collection Program," is providing an opportunity to improve data pertaining to roadside safety hardware that helps address this recommendation.

4. **Advance Noteworthy Safety Data and Roadside Hardware Inventory Practices** – The Task Force recommends that the highway safety community and transportation agencies bring forward noteworthy practices for developing and maintaining roadside hardware inventory systems and also those that link crash data to the location and type of roadside safety devices. This linking is important and critical to obtain complete information for analyzing roadside crashes. FHWA has a noteworthy practices database established at the following web location where this information could be added in the future: (http://rspcb.safety.fhwa.dot.gov/noteworthy/default.aspx).

5. **Conduct Research on Vehicle Corner Impacts with Guardrail Terminals –** The Task Force recommends that AASHTO and FHWA conduct research to evaluate the performance of vehicle front corner impacts with guardrail terminals to gain a better understanding of these crashes and the circumstances and conditions associated with them. Greater knowledge of this crash type could potentially be used to update future crash testing criteria. As summarized by this report, there were observed performance limitations with extruding w-beam guardrail terminals when the impact occurred at or near the vehicle corner in the headlight area.

6. **Conduct Research on Vehicle Side Impacts with Guardrail Terminals -** The Task Force recommends that AASHTO and FHWA conduct research to evaluate the performance of vehicle side impacts with guardrail terminals to gain a better understanding of these crashes and the circumstances and conditions associated with them. Greater knowledge of this crash type could potentially be used to update future crash testing criteria. As summarized by this report, there were observed performance limitations with extruding w-beam guardrail terminals when the impact occurred on the side of the vehicle. The opportunity for research should be explored with NHTSA to review vehicle standards relative to the strength of the

sides of passenger vehicles and to determine if vehicle side impacts into terminals and other fixed objects can be better addressed.

7. **Promote Proper Placement, Installation, and Maintenance Practices –** The Task Force recommends that appropriate placement, installation, and maintenance practices be shared with the roadside safety community as was recently done through FHWA's May 26, 2015 memorandum. FHWA provides training and technical assistance on these practices, and the Task Force recommends that highway agencies take advantage of these resources. In addition, the Task Force recommends that AASHTO, through its Technical Committee on Roadside Safety, include additional content regarding proper placement, installation, and maintenance of guardrail terminals in the next edition of AASHTO's Roadside Design Guide.

8. **Crash Testing of Extruding W-beam Guardrail Terminals** – The Task Force does not recommend additional crash testing of existing NCHRP 350-compliant extruding w-beam guardrail terminals for two reasons. First, the performance limitations identified for these terminals fall outside of the NCHRP 350 testing matrices, nor is it expected that NCHRP 350 tested devices function under all real-world conditions beyond what is present in the crash test scenarios. Second, as discussed in recommendation #1, the Task Force recommends that the roadside design community move to full implementation of MASH for all new installations of guardrail terminals which will help address an element of some of these performance limitations. Therefore, additional NCHRP 350 crash testing of existing guardrail terminals would be irrelevant since all crash testing since January 2011 has been required under the MASH criteria.

Appendix A – Glossary

Anchor: The mechanism that fixes the ends of a run of guardrail to the ground, providing rail tension in the event of a LON impact.

Channel, Feeder Channels: The portion of the extruder head that aligns the device with the w-beam rail. (The ET-plus terminal head was made with feeder channels that were 5 inches wide or 4 inches wide.)

Clear Zone, Clear Roadside: Flat, traversable terrain next to the traveled way that is available for an errant vehicle to slow, stop, or return to the roadway without encountering roadside hazards.

Crashworthy: Refers to a roadside safety device that has passed the appropriate crash tests, typically in accordance with NCHRP Report 350 or the AASHTO Manual for Assessing Safety Hardware.

Energy-Absorbing Terminal: A category of guardrail terminals that is designed to slow or stop an impacting vehicle through the use of energy-dissipating mechanisms such as bending, kinking, crushing, or otherwise deforming the w-beam rail.

Errant Vehicle: A vehicle that leaves the traveled way, typically at speed, and encroaches onto the roadside.

Extruding Terminal, Extruding Guardrail Terminal: A specific type of energy-absorbing guardrail terminal where the extruder head is designed to be pushed down the w-beam rail when impacted head-on, deforming the rail and directing it away from the vehicle. Examples of extruding terminals are the ET-2000, ET-Plus, SKT, and FLEAT.

Gate, Gating: The ability of a guardrail terminal to yield and bend out of the way when impacted at an angle, allowing an errant vehicle to proceed behind the rail. Most guardrail terminals, including all extruding terminals, gate when a vehicle impacts at an angle in the vicinity of the first three posts.

Guardrail, W-beam Guardrail: A semi-rigid post-and-steel-beam barrier designed to smoothly redirect a vehicle impacting the face of the barrier at some angle. Guardrail absorbs the energy of a crash through deformation and deflection of the w-beam rail, deformation of the guardrail posts, and rotation of the posts through the soil.

Guardrail End: The leading or trailing limit of w-beam guardrail. It may or may not have a crashworthy guardrail terminal. Non-crashworthy terminals include the blunt-end, turn-down terminal, Breakaway Cable Terminal (BCT), and Modified Eccentric Loader Terminal (MELT).

Guardrail Face, Guardrail Run: The length-of-need portion of a guardrail installation.

Guardrail Terminal, Guardrail End Terminal, Guardrail End Treatment, Crashworthy Terminal, and Terminal: A device designed to anchor the leading end of a w-beam guardrail while reducing the likelihood of spearing, vaulting, or rolling a vehicle during head-on or angled impacts. Guardrail terminals examined in this study included the ET-2000, ET-Plus, Sequential Kinking Terminal (SKT), and Flared Energy Absorbing Terminal (FLEAT).

Head, Extruder Head, Impact Head: The portion of an extruding terminal that rests on the end of the w-beam rail. The head deforms the w-beam as it is pushed down the rail by the vehicle.

Head-on Impact: Frontal impact into a guardrail terminal where the travel direction of the vehicle is in-line with or parallel to the run of guardrail. This impact is also referred to as a zero-degree impact.

High-Energy Impact: Crash involving a vehicle that exceeds the 4400-pound mass of the ¾-ton pickup truck specified for crash testing of guardrail terminals and/or a crash where the impact speed was greater than 62 mph. (These conditions are beyond the NCHRP Report 350 Test Level 3 impact conditions.)

Length of Need (LON): The middle portion of a guardrail installation, located away from the ends, or the length of guardrail needed in advance of a roadside feature to

adequately shield it for a theoretical vehicle leaving the road along a calculated or presumed path.

Non-Tracking: A vehicle skidding or sliding in a direction other than where its axis is pointing. This type of crash can result in a side impact or rollover.

Occupant Compartment Deformation: Event that occurs when the force of a guardrail impact deforms the interior structure of a vehicle's passenger area. Injuries can result from occupant contact with the intruding structure.

Occupant Compartment Penetration: Event that involves a portion of the guardrail entering or penetrating into the passenger area of the vehicle. Injuries can result from occupant contact with the penetrating rail.

Performance Limitations: Performance limitations are factors in a real-world crash environment that can contribute to the unsuccessful performance of a roadside safety hardware device. Crashworthy guardrail terminals and other safety hardware performance may be affected when in-service crashes are outside the limits of the ideal crash tested conditions. The performance of these devices is dictated by physical laws, vehicle stability, vehicle crashworthiness, and the site conditions of these real-world crashes.

Rolling, Rollover: Crash scenario where an errant vehicle rolls onto its side during a crash event. It may continue to roll onto its roof and stop, or roll multiple times. Rollovers have a high incidence of occupant ejection from the vehicle or head trauma from flail within the vehicle.

Shallow-Angle Impact: Frontal impact into a guardrail terminal where the travel direction of the vehicle is nearly parallel (approximately ten degrees or less) to the run of guardrail.

Side Impact: Crash where the initial point of vehicle contact is the passenger side or driver side rather than the front or rear plane of the vehicle. Side impacts are typically non-tracking events where the vehicle may be sliding at an angle or yawing.

Snagging: The undesirable interaction of vehicle components with a barrier face or posts during impact due to deflection and/or surface irregularities in the barrier. Parts of the vehicle may be sheared off, or the vehicle may decelerate abruptly, spinout, or rollover. Severe snagging during impact with a w-beam barrier or terminal may lead to rail separation and failure of the barrier to contain the vehicle.

Spearing: Guardrail penetrating the exterior of an impacting vehicle and potentially penetrating into the occupant compartment.

Sudden Deceleration: This event involves forces exerted when a vehicle is slowed down abruptly or brought to a sudden stop through contact with the guardrail, potentially resulting in injuries to passengers.

Tracking: A vehicle traveling in the same direction as its wheels are pointing. A tracking vehicle is not sliding or skidding sideways.

Vaulting: Launching of a vehicle into the air upon impact with a roadside feature.

Yaw, Yawing: The rotation of an out-of-control vehicle skidding on the pavement or roadside.

Appendix B – Summary of State Responses

This appendix represents a summary of States' responses to the October 10, 2014 FHWA memo requesting information from State DOTs regarding the performance of the ET-Plus in the field (http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/memo_eplus_wbeam101014.cfm).

Number of States That Responded

All 50 States plus Puerto Rico; Pacific Territories; U.S. Virgin Islands; Washington, DC; and the Illinois Toll Authority

Summary of Responses

States that responded without any information given on guardrail face and terminal crashes (including ET-Plus)

Alabama, Colorado, Georgia, Idaho, Indiana, Kansas, Kentucky, Louisiana, Maryland, Montana, New Mexico, New Jersey, South Dakota, Texas, Utah, Vermont, West Virginia, and Wisconsin

States that are monitoring the situation and may have additional information in the future

Alabama, Arizona, California, Florida, Georgia, Idaho, Illinois, Indiana, Kentucky, Maryland, Massachusetts, Mississippi, Montana, New Mexico, Oregon, Rhode Island, South Dakota, Tennessee, Texas, Utah, Vermont, Virginia, Washington, and Wisconsin

States/Territories that do not use ET-Plus

Puerto Rico (with the exception of one private toll road), American Samoa, Wyoming

States that reported general crash statistics on guardrail faces (i.e., along the guardrail)

Iowa, Minnesota, Oklahoma, North Carolina, South Carolina, and Virginia

States that reported general crash statistics on guardrail terminals

Hawaii, Iowa, Illinois (provided a comparison of different terminals), Indiana, Maine, Massachusetts, Minnesota, Missouri (provided a comparison of different terminals), Nebraska, Nevada, North Carolina, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, and Virginia

States that reported anecdotal or general information on guardrail terminals

Arkansas, California, and New York

States that reported anecdotal or general information regarding Trinity's ET-Plus terminal

Alaska, Arkansas, Arizona, Connecticut, Delaware, Illinois Toll Authority, Michigan, Mississippi, North Dakota, Ohio, Rhode Island, Tennessee (two lawsuits involving guardrail spearing fatalities alleging the guardrail failed to perform), Texas, U.S. Virgin Islands, and Washington, DC.

States that reported crash statistics on Trinity's ET-Plus terminal

Connecticut, Illinois, Indiana, Iowa, Massachusetts, Missouri, New Hampshire (one crash), North Carolina (one crash), Pennsylvania, and Texas

Appendix C – Narrative Summary of 231 Crash Cases from Harman Data Source

This summary presents FHWA's observations of the crash cases contained in the spreadsheet and supporting documentation provided by the source. FHWA received a spreadsheet summarizing crash cases from 231 locations, by State, in which the source indicated a 4-inch ET-Plus guardrail terminal failed to operate as intended. These cases included photographs of damaged terminals, photographs of damaged vehicles involved in crashes, and additional documentation such as crash reports, new articles, and legal documents. FHWA reviewed each crash case using the documentation provided by the source to independently assess whether an ET-Plus 4-inch device was involved.

Of the 231 crash cases, FHWA's assessment is that 156 involved an ET-Plus 4-inch device. In addition, FHWA identified 29 initial crash cases of significant interest for further analysis that involved severe injuries, vehicle compartment intrusion, vehicle occupant compartment penetration, spearing, rollover, snagging of rail, or otherwise appeared to be unusual or extreme.

The tables in this Appendix provide frequency totals comparing the spreadsheet of the 231 crash cases and FHWA's analysis of those cases; a review of the 156 identified and confirmed ET-Plus 4-inch crash cases; and a review of the 29 crash cases for further analysis. The tables summarize whether an ET-Plus 4-inch device was involved in the crash; whether the result of the crash involved a fatality, injury or was unknown; and what supporting documentation was provided for each crash case to include media information, crash reports, legal documentation, photographs of the damaged device, photographs of the damaged vehicles, and photographs of new or replacement devices following a crash.

Table 1 summarizes the distribution of crash cases by State. Of the 231 crash cases, 70 percent (161) are from three States: Tennessee, Texas, and Virginia.

TABLE 1 – Number of Crash Cases by State

STATE	# OF CASES	% OF TOTAL		STATE	# OF CASES	% OF TOTAL
Alabama	4	1.7%		New York	1	0.4%
Arkansas	3	1.3%		North	5	2.2%
California	5	2.2%		Ohio	3	1.3%
Colorado	1	0.4%		Oklahoma	4	1.7%
Delaware	1	0.4%		Oregon	1	0.4%
Florida	2	0.9%		Pennsylvani	5	2.2%
Georgia	3	1.3%		Rhode Island	1	0.4%
Illinois	5	2.2%		South	3	1.3%
Kentucky	1	0.4%		**Tennessee**	**75**	**32.5%**
Maryland	7	3.0%		**Texas**	**47**	**20.3%**
Massachusetts	2	0.9%		Vermont	1	0.4%
Minnesota	1	0.4%		**Virginia**	**39**	**16.9%**
Missouri	5	2.2%		West	2	0.9%
New	3	1.3%				
New Jersey	1	0.4%		Total	231	100.0%

Table 2 summarizes the results of FHWA's independent review of the crash cases contained in the spreadsheet. FHWA reviewed the photographs for each crash case to determine whether the device had a 4-inch channel width and the head was visible. Photographs that clearly displayed a 4-inch channel width and visible head were confirmed by FHWA to be an ET-Plus 4-inch device. Conversely, photographs that clearly confirmed that the device was not an ET-Plus 4-inch (i.e., ET-Plus 5-inch or SKT) were classified as not being an ET-Plus 4-inch device. Photographs that did not clearly display the channel width or head were classified as unknown since FHWA was unable to make a determination regarding whether the device was an ET-Plus 4-inch. In addition, any crash cases that did not include photographs were also classified as unknown.

TABLE 2 – FHWA Review and Identification of ET-Plus 4-Inch Devices

FHWA OBSERVATIONS	FREQUENCY	% OF TOTAL
Confirmed ET-Plus 4-inch device	**156***	67.5%
Non-ET-Plus 4-inch device (i.e., ET-Plus 5-inch or	6	2.6%
Unknown device	69	29.9%
Total	231	100.0%

**Note: More information about the 156 crash cases confirmed to be the ET-Plus 4-inch devices is provided in Tables 7 and 8.*

- For 156 (67.5%) of the cases, FHWA concurred with the identification that the crash cases involved an ET-Plus 4-inch device.
- For 6 (2.6%) of the 231 crash cases, FHWA identified a device other than the ET-Plus 4-inch (i.e., ET-Plus 5-inch or SKT).

Tables 3 and 4 summarize the severity of the 231 crash cases. In the source documents, the crash cases were categorized in the spreadsheet as a fatality/injury (fatalities and injuries were grouped together), no fatality/injury, or unknown. FHWA was able to further classify the cases as fatality or injury or unknown based on the documentation provided. In cases where there was no supporting documentation regarding the severity of the crash, FHWA identified those crashes as unknown. Table 3 shows the source's identification of the crash cases in the spreadsheet compared to FHWA's analysis identifying crash severity, and Table 4 shows a comparison of the crash cases.

TABLE 3 – Source Identification of Crash Severity

CRASH SEVERITY	Source OBSERVATIONS (Spreadsheet)	% OF TOTAL	FHWA OBSERVATIONS	% OF TOTAL
Fatality	52	22.5%	19	8.2%
Injury			20	8.7%
No Fatality/Injury	1	0.4%	0	0.0%
Unknown	178	77.1%	192	83.1%
Total	231	100.0%	231	100.0%

- The spreadsheet classified 52 (23%) of the 231 crash cases as fatality/injury and 178 (77%) as unknown.
- FHWA classified 19 (8%) of the 231 crash cases as fatality, 20 (9%) as injury, and192 (83%) as unknown.

TABLE 4 – Comparison of Crash Severity

SOURCE (Spreadsheet) OBSERVATION	FHWA OBSERVATION	FREQUENCY	% OF TOTAL
Fatality/Injury	Fatality	18	7.8%
	Injury	20	8.7%
Fatality/Injury	Unknown	14	6.1%
No Fatality/Injury	Unknown	1	0.4%
Unknown	Fatality	1	0.4%
Unknown	Unknown	177	76.6%
Total		231	100.0%

- The source documents and FHWA both identified that 38 (17%) of the crash cases involved a fatality or injury. However, only 10 of these cases include a crash report and FHWA used other sources (news article, obituary, lawsuit information) to identify injury severity. For those cases without a crash report, confirmation of injury severity would require contacting respective State officials to obtain an official report.

Table 5 provides a summary of the types of documentation provided. FHWA reviewed all of the crash cases to identify the documentation that was provided for each case.

TABLE 5 – FHWA Review of Supporting Documentation

FHWA Observation	Media Information	Crash Report	Legal Documents	Photo of Damaged Device	Photo of Vehicle	Photo of New or Replacement Installation
Included in case files	23 (10.0%)	10 (4.3%)	6 (2.6%)	211 (91.3%)	35 (15.2%)	2 (0.9%)
Not included in case files	208 (90.0%)	221 (95.7%)	225 (97.4%)	20 (8.7%)	196 (84.8%)	229 (99.1%)
Total	231	231	231	231	231	231

- 211 (91%) of the 231 crash cases include photographs of the damaged device, 35 (15%) include photographs of the damaged vehicle, 10 (4%) include crash reports, 23 (10%) include media information, and 6 (3%) included legal documentation.
- 177 (77%) of the 231 cases include only photographs of the damaged device with no other information provided, and 8 cases include no documentation at all.

Confirmed ET-Plus 4-Inch Crash Cases

FHWA confirmed a total of 156 crash cases to involve an ET-Plus 4-inch device summarized below using the same criteria as in Tables 1, 3, 4 and 5.

TABLE 6 – Number of Crashes by State of Confirmed ET-Plus 4-Inch Crash Cases from Source Document

STATE	# OF CASES	% OF TOTAL		STATE	# OF CASES	% OF TOTAL
Alabama	3	1.9%		New York	1	0.6%
Arkansas	2	1.3%		North	2	1.3%
California	1	0.6%		Ohio	2	1.3%
Colorado	0	0.0%		Oklahoma	3	1.9%
Delaware	1	0.6%		Oregon	0	0.0%
Florida	1	0.6%		Pennsylvania	4	2.6%
Georgia	3	1.9%		Rhode Island	1	0.6%
Illinois	3	1.9%		South	2	1.3%
Kentucky	0	0.0%		**Tennessee**	**62**	**39.7%**
Maryland	6	3.9%		**Texas**	**24**	**15.6%**
Massachusetts	1	0.6%		Vermont	0	0.0%
Minnesota	0	0.0%		**Virginia**	**28**	**18.2%**
Missouri	3	1.9%		West	1	0.6%
New Hampshire	2	1.3%				
New Jersey	0	0.0%		Total	156	100.0%

- Of the 156 confirmed ET-Plus 4-inch devices involved in crashes, 73 percent (114) occurred in three States: 40% in Tennessee, 18% in Virginia, and 16% in Texas.

TABLE 7 – FHWA Identification of Crash Severity of Confirmed ET-Plus 4-Inch Crash Cases

CRASH SEVERITY	SOURCE OBSERVATIONS (Spreadsheet)	% OF TOTAL	FHWA OBSERVATIONS	% OF TOTAL
Fatality	13	8.3%	5	3.2%
Injury			4	2.6%
Unknown	143	91.7%	147	94.2%
Total	156	100.0%	156	100.0%

- The source document classified 13 (8%) of the 156 confirmed ET-Plus 4-inch crash cases as fatality/injury and 143 (92%) as unknown.
- FHWA classified 5 (3%) of the 156 confirmed ET-Plus 4-inch crash cases as fatality, 4 (3%) as injury, 147 (94%) as unknown.

TABLE 8 – Comparison of Crash Severity of Confirmed ET-Plus 4-Inch Crash Cases

SPREADSHEET OBSERVATION	FHWA OBSERVATION	FREQUENCY	% OF TOTAL
Fatality/Injury	Fatality	5	3.2%
	Injury	4	2.6%
Fatality/Injury	Unknown	4	2.6%
Unknown	Unknown	143	91.7%
Total		156	100.0%

- The spreadsheet and FHWA both identified that nine (6%) of the crash cases involved the ET-Pus 4-inch device resulted in a fatality or injury. However, only two cases include a crash report, and FHWA used other sources (news article, obituary, lawsuit information) to identify injury severity for the other three cases. For those cases without a crash report, confirmation of injury severity would require contacting respective State officials to get an official report.
- The spreadsheet and FHWA both identified 143 (92%) of the crash cases involving the 4-inch device with unknown fatality or injury severity.

TABLE 9 – Supporting Documentation for Confirmed ET-Plus 4-Inch Crash Cases

FHWA Observation	Media Information	Crash Report	Legal Documents	Photo of Damaged Device	Photo of Vehicle	Photo of New or Replacement Installation
# Included in case files	4 (2.6%)	2 (1.3%)	1 (0.6%)	153 (98.1%)	9 (5.8%)	2 (1.3%)
# Not included in case files	152 (97.4%)	154 (98.7%)	155 (99.4%)	3 (1.9%)	147 (94.2%)	154 (98.7%)
Total	156	156	156	156	156	156

- Of the 156 confirmed ET-Plus 4-inch crash cases, 153 (91%) include photographs of the damaged device, 9 (6%) include photographs of the damaged vehicle, 2 (1%) include crash reports, 4 (3%) include media information, and 1 includes legal documentation.

29 Crash Cases Analyzed Further

Tables 10 through 14 present information regarding the 29 crash cases from the source, which the Task Force analyzed to attempt to assess the performance of the 4-inch ET-Plus. They represent cases of interest involving fatal or severe injury, vehicle occupant compartment intrusion, vehicle occupant compartment penetration, rollover, snagging of rail, or otherwise appeared to be unusual or extreme. These cases are summarized below using the same criteria that was used in Tables 1, 3, 4 and 5.

TABLE 10 – Number of Cases by States for the 29 Initial Crash Cases of Interest

STATE	# OF CASES	% OF TOTAL
California	**2**	**6.9%**
Florida	**1**	**3.4%**
Illinois	**2**	**6.9%**
Massachusetts	**1**	**3.4%**
Minnesota	**1**	**3.4%**
Missouri	**1**	**3.4%**
New Hampshire	**1**	**3.4%**
North Carolina	**4**	**13.8%**
Ohio	**1**	**3.4%**
Oklahoma	**1**	**3.4%**
Oregon	**1**	**3.4%**
Pennsylvania	**4**	**13.8%**
South Carolina	**1**	**3.4%**
Tennessee	**4**	**13.8%**
Texas	**2**	**6.9%**
Virginia	**2**	**6.9%**
Total	**29**	**100.0%**

- Of the 29 cases identified for further analysis, 42% occurred in three States: 14% in Tennessee, 14% in North Carolina, and 14% in Pennsylvania.

TABLE 11 – FHWA Review and Identification of the ET-Plus 4-Inch for 29 Cases

FHWA OBSERVATIONS	FREQUENCY	% OF TOTAL
Confirmed ET-Plus 4-inch device	13	44.8%
ET-Plus 4-inch or 5-inch device	1	3.4%
Unknown device	15	51.7%
Total	29	100.0%

- 13 (45%) of the crash cases were confirmed by FHWA to involve the ET-Plus 4-inch device.

TABLE 12 – Independent Observations of Crash Severity for the 29 Crash Cases of Interest

OBSERVATIONS	SOURCE DOCUMENT (Spreadsheet)	% OF TOTAL	FHWA	% OF TOTAL
Fatality	22	82.8%	7	24.1%
Injury			14	48.3%
No Fatality/Injury	1	3.4%	0	0.0%
Unknown	4	13.8%	8	27.6%
Total	29	100.0%	29	100.0%

- The source document classified 22 crash cases as fatality/injury and 4 as unknown.
- FHWA classified 7 crash cases as fatality, 14 as injury, and 8 as unknown.

Table 13 – Comparison of Crash Severity for the 29 Crash Cases of Interest

SOURCE DOCUMENT (Spreadsheet) OBSERVATON	FHWA OBSERVATION	FREQUENCY	% OF TOTAL
Fatality/Injury	Fatality	7	24.1%
	Injury	14	48.3%
Fatality/Injury	Unknown	3	10.3%
No Fatality/Injury	Unknown	1	3.4%
Unknown	Unknown	4	13.8%
Total		29	100.0%

- The source document and FHWA's observations concurred that 21 (70%) out of the 29 crash cases involved a fatality or injury.

Table 14 - FHWA Observations of Supporting Documentation for the 29 Crash Cases of Interest

FHWA Observation	Media Information	Crash Report	Legal Documents	Photo of Damaged Device	Photo of Vehicle	Photo of New or Replacement Installation
# Included in case files	11 (37.9%)	5 (17.2%)	3 (10.3%)	23 (79.3%)	16 (55.2%)	0 (0.0%)
# Not included in case files	18 (62.1%)	24 (82.8%)	26 (89.7%)	6 (20.7%)	13 (44.8%)	29 (100.0%)
Total	29	29	29	29	29	29

- 23 (79%) include photographs of the damaged device, 16 (60%) include photographs of the damaged vehicle, 5 (17%) include crash reports, 11 (38%) include media information, and 3 (10%) include documentation of a lawsuit.

Summary

The majority of the 231 cases (177 cases or 77%) provided in the source document include only photos of a damaged device, the date the photos were taken, and the route location of where the damage occurred.

Due to the lack of complete information, FHWA could only confirm that the ET-Plus 4-inch device was involved in 156 cases (or 68% of the cases) with the greatest number of cases in Tennessee (62 or 40%). Based on FHWA's observations, 5 fatal crashes and 4 injury crashes (out of the 156 cases) were confirmed involving an ET-Plus 4-inch device.

Of the 231 cases, FHWA analyzed the 29 cases as presented in Tables 10 through 14. These crashes were identified for further analysis because they involved severe injury, vehicle compartment intrusion, spearing of the vehicle, vehicle occupant compartment penetration, rollover, snagging of rail, or otherwise appeared to be unusual or extreme conditions. FHWA's assessment was that 13 of these cases (4 fatal crashes, 4 injury crashes, and 5 of unknown severity) involved the ET-Plus 4-inch.

Appendix D–Listing of Crash Cases

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
1A	NMVCCS	1				6A #2				SKT
1A	NMVCCS	2					X			SRT
1A	NMVCCS	3	Yes							ET-Plus
1A	NMVCCS	4	Yes							ET-Plus 5"
1A	NMVCCS	5					X			SRT
1A	NMVCCS	6							X	
1A	NMVCCS	7					X			SRT
1A	NMVCCS	8			X					SKT
1A	NMVCCS	9					X			Blunt End
1A	NMVCCS	10	Yes							ET 2000
1A	NMVCCS	11	Yes							ET-Plus
1A	NMVCCS	12					X			Crash Cushion
1A	NMVCCS	13					X			SRT
1A	NMVCCS	14		X						
1A	NMVCCS	15		X						
1A	NMVCCS	16	Yes							ET-2000
1A	NMVCCS	17					X			Blunt End
1A	NMVCCS	18					X			Crash Cushion
1A	NMVCCS	19					X			Turned-Down
1A	NMVCCS	20							X	
1A	NMVCCS	21					X			Blunt End

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
1A	NMVCCS	22		X						
1A	NMVCCS	23							X	
1A	NMVCCS	24	Yes							ET-Plus
1A	NMVCCS	25					X			Blunt End
1A	NMVCCS	26	Yes							ET Plus
1A	NMVCCS	27					X			Blunt End
1A	NMVCCS	28					X			Blunt End
1A	NMVCCS	29		X						
1A	NMVCCS	30					X			CAT-350
1A	NMVCCS	31					X			BCT
1A	NMVCCS	32					X			MELT
1A	NMVCCS	33	Yes							ET-Plus
1A	NMVCCS	34		X						
1A	NMVCCS	35	Yes							ET-Plus 5-inch
1A	NMVCCS	36	Yes							ET-Plus
1A	NMVCCS	37		X						ET-Plus
1A	NMVCCS	38	Yes							ET-Plus
1A	NMVCCS	39	Yes							ET-Plus
1A	NMVCCS	40					X			Blunt End
1A	NMVCCS	41					X			Turned-Down
1A	NMVCCS	42		X						
1A	NMVCCS	43					X			CASS
1A	NMVCCS	44							X	

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
1A	NMVCCS	45					X			Crash Cushion
1A	NMVCCS	46					X			MELT?
1A	NMVCCS	47					X			BCT or MELT
1A	NMVCCS	48					X			Blunt End
1A	NMVCCS	49							X	
1A	NMVCCS	50	Yes							ET-2000
1A	NMVCCS	51							X	
1A	NMVCCS	52					X			SRT
1A	NMVCCS	53							X	
1A	NMVCCS	54					X			Crash Cushion
1A	NMVCCS	55							X	
1A	NMVCCS	56		X						
1A	NMVCCS	57							X	
1A	NMVCCS	58		X						
1A	NMVCCS	59							X	
1A	NMVCCS	60		X						ET (SRT anchor)
1A	NMVCCS	61							X	
1A	NMVCCS	62				6A #1				SKT
1A	NMVCCS	63					X			Crash Cushion
1A	NMVCCS	64					X			Crash Cushion
1A	NMVCCS	65							X	
1A	NMVCCS	66	Yes							ET-2000
1A	NMVCCS	67					X			Crash Cushion

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
1A	NMVCCS	68							X	
1A	NMVCCS	69							X	
1A	NMVCCS	70				6A #3				SKT
1A	NMVCCS	71							X	
1A	NMVCCS	72							X	
1A	NMVCCS	73					X			BCT
1A	NMVCCS	74							X	
1A	NMVCCS	75					X			BCT?
1A	NMVCCS	76							X	
1A	NMVCCS	77							X	
1A	NMVCCS	78					X			REACT
2A	Harman	1		X						ET-Plus 4"
2A	Harman	2		X						ET-Plus 4"
2A	Harman	3						X		
2A	Harman	4		X						ET-Plus 4"
2A	Harman	5						X		
2A	Harman	6		X						ET-Plus 4"
2A	Harman	7		X						ET-Plus 4"
2A	Harman	8		X						ET-Plus 4"
2A	Harman	9						X		
2A	Harman	10						X		
2A	Harman	11						X		
2A	Harman	12						X		

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
2A	Harman	13						X		
2A	Harman	14		X						ET-Plus 4"
2A	Harman	15	Yes							ET-Plus 4"
2A	Harman	16						X		
2A	Harman	17		X						ET-Plus 4"
2A	Harman	18		X						ET-Plus 4"
2A	Harman	19		X						ET-Plus 4"
2A	Harman	20		X						ET-Plus 4"
2A	Harman	21		X						ET-Plus 4"
2A	Harman	22		X						ET-Plus 4"
2A	Harman	23						X		
2A	Harman	24						X		
2A	Harman	25		X						
2A	Harman	26		X						ET-Plus 4"
2A	Harman	27		X						ET-Plus 4"
2A	Harman	28		X						ET-Plus 4"
2A	Harman	29						X		
2A	Harman	30		X						ET-Plus 4"
2A	Harman	31		X						ET-Plus 4"
2A	Harman	32		X						ET-Plus 4"
2A	Harman	33		X						ET-Plus 4"
2A	Harman	34						X		
2A	Harman	35						X		

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
2A	Harman	36				2B #10				ET-Plus 4"
2A	Harman	37		X						ET-Plus 4"
2A	Harman	38		X						ET-Plus 4"
2A	Harman	39						X		
2A	Harman	40		X						
2A	Harman	41		X						ET-Plus 4"
2A	Harman	42		X						ET-Plus 4"
2A	Harman	43						X		
2A	Harman	44						X		
2A	Harman	45		X						ET-Plus 4"
2A	Harman	46						X		
2A	Harman	47		X						
2A	Harman	48	Yes							ET-Plus 4"
2A	Harman	49	Yes							ET-Plus 4"
2A	Harman	50	Yes							ET-Plus
2A	Harman	51						X		ET-Plus 4"
2A	Harman	52		X						ET-Plus 4"
2A	Harman	53	Yes							ET-Plus 4"
2A	Harman	54						X		
2A	Harman	55		X						ET-Plus 4"
2A	Harman	56		X						ET-Plus 4"
2A	Harman	57	Yes							ET-Plus 4"
2A	Harman	58						X		

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
2A	Harman	59		X						ET-Plus 4"
2A	Harman	60	Yes							ET-Plus 4"
2A	Harman	61	Yes							ET-Plus 4"
2A	Harman	62						X		
2A	Harman	63	Yes							ET-Plus 4"
2A	Harman	64		X						ET-Plus 4"
2A	Harman	65		X						ET-Plus 4"
2A	Harman	66		X						ET-Plus 4"
2A	Harman	67		X						
2A	Harman	68		X						ET-Plus 4"
2A	Harman	69		X						ET-Plus 4"
2A	Harman	70		X						ET-Plus 4"
2A	Harman	71		X						ET-Plus 4"
2A	Harman	72		X						ET-Plus 4"
2A	Harman	73		X						ET-Plus 4"
2A	Harman	74		X						ET-Plus 4"
2A	Harman	75						X		
2A	Harman	76						X		
2A	Harman	77		X						ET-Plus 4"
2A	Harman	78		X						ET-Plus 4"
2A	Harman	79		X						ET-Plus 4"
2A	Harman	80		X						ET-Plus 4"
2A	Harman	81		X						ET-Plus 4"

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
2A	Harman	82		X						ET-Plus 4"
2A	Harman	83		X						ET-Plus 4"
2A	Harman	84		X						ET-Plus 4"
2A	Harman	85		X						ET-Plus 4"
2A	Harman	86		X						ET-Plus 4"
2A	Harman	87		X						ET-Plus 4"
2A	Harman	88	Yes							ET-Plus 4"
2A	Harman	89		X						ET-Plus 4"
2A	Harman	90		X						ET-Plus 4"
2A	Harman	91		X						ET-Plus 4"
2A	Harman	92		X						ET-Plus 4"
2A	Harman	93		X						ET-Plus 4"
2A	Harman	94		X						ET-Plus 4"
2A	Harman	95		X						ET-Plus 4"
2A	Harman	96		X						ET-Plus 4"
2A	Harman	97		X						ET-Plus 4"
2A	Harman	98		X						ET-Plus 4"
2A	Harman	99		X						ET-Plus 4"
2A	Harman	100		X						ET-Plus 4"
2A	Harman	101		X						ET-Plus 4"
2A	Harman	102						X		
2A	Harman	103						X		
2A	Harman	104		X						ET-Plus 4"

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
2A	Harman	105		X						ET-Plus 4"
2A	Harman	106		X						ET-Plus 4"
2A	Harman	107		X						ET-Plus 4"
2A	Harman	108		X						ET-Plus 4"
2A	Harman	109		X						ET-Plus 4"
2A	Harman	110		X						ET-Plus 4"
2A	Harman	111		X						ET-Plus 4"
2A	Harman	112		X						ET-Plus 4"
2A	Harman	113		X						ET-Plus 4"
2A	Harman	114		X						ET-Plus 4"
2A	Harman	115						X		
2A	Harman	116		X						ET-Plus 4"
2A	Harman	117		X						ET-Plus 4"
2A	Harman	118		X						ET-Plus 4"
2A	Harman	119		X						ET-Plus 4"
2A	Harman	120		X						ET-Plus 4"
2A	Harman	121		X						ET-Plus 4"
2A	Harman	122						X		
2A	Harman	123		X						ET-Plus 4"
2A	Harman	124		X						ET-Plus 4"
2A	Harman	125		X						ET-Plus 4"
2A	Harman	126		X						ET-Plus 4"
2A	Harman	127		X						ET-Plus 4"

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
2A	Harman	128		X						ET-Plus 4"
2A	Harman	129		X						ET-Plus 4"
2A	Harman	130						X		
2A	Harman	131		X						ET-Plus 5"
2A	Harman	132						X		
2A	Harman	133		X						ET-Plus 4"
2A	Harman	134						X		
2A	Harman	135	Yes							ET-Plus 4"
2A	Harman	136		X						ET-Plus 4"
2A	Harman	137		X						ET-Plus 4"
2A	Harman	138						X		
2A	Harman	139		X						ET-Plus 4"
2A	Harman	140		X						
2A	Harman	141		X						ET-Plus 4"
2A	Harman	142						X		
2A	Harman	143		X						ET-Plus 4"
2A	Harman	144		X						ET-Plus 4"
2A	Harman	145		X						ET-Plus 4"
2A	Harman	146		X						ET-Plus 4"
2A	Harman	147		X						
2A	Harman	148	Yes							ET-Plus 4"
2A	Harman	149		X						ET-Plus 4"
2A	Harman	150		X						ET-Plus 4"

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
2A	Harman	151		X						ET-Plus 4"
2A	Harman	152		X						ET-Plus 4"
2A	Harman	153		X						ET-Plus 4"
2A	Harman	154		X						ET-Plus 4"
2A	Harman	155		X						ET-Plus 4"
2A	Harman	156		X						ET-Plus 4"
2A	Harman	157		X						ET-Plus 5"
2A	Harman	158		X						ET-Plus 4"
2A	Harman	159		X						ET-Plus 4"
2A	Harman	160		X						ET-Plus 4"
2A	Harman	161		X						ET-Plus 4"
2A	Harman	162						X		
2A	Harman	163		X						ET-Plus 4"
2A	Harman	164		X						
2A	Harman	165		X						
2A	Harman	166		X						ET-Plus 4"
2A	Harman	167						X		
2A	Harman	168						X		
2A	Harman	169		X						
2A	Harman	170		X						ET-Plus 4"
2A	Harman	171		X						
2A	Harman	172		X						
2A	Harman	173		X						ET-Plus 4"

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
2A	Harman	174		X						
2A	Harman	175						X		
2A	Harman	176						X		
2A	Harman	177						X		
2A	Harman	178		X						ET-Plus 4"
2A	Harman	179						X		
2A	Harman	180						X		
2A	Harman	181		X						
2A	Harman	182						X		
2A	Harman	183						X		
2A	Harman	184		X						
2A	Harman	185						X		
2A	Harman	186		X						
2A	Harman	187						X		
2A	Harman	188						X		
2A	Harman	189						X		
2A	Harman	190		X						SKT
2A	Harman	191		X						ET-Plus 4"
2A	Harman	192						X		
2A	Harman	193						X		
2A	Harman	194		X						ET-Plus 4"
2A	Harman	195		X						ET-Plus 4"
2A	Harman	196		X						ET-Plus 4"

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
2A	Harman	197		X						ET-Plus 4"
2A	Harman	198						X		
2A	Harman	199		X						ET-Plus 4"
2A	Harman	200		X						ET-Plus 4"
2A	Harman	201		X						ET-Plus 4"
2A	Harman	202		X						ET-Plus 4"
2A	Harman	203		X						ET-Plus 4"
2A	Harman	204		X						ET-Plus 4"
2A	Harman	205		X						ET-Plus 4"
2A	Harman	206		X						ET-Plus 4"
2A	Harman	207						X		
2A	Harman	208		X						ET-Plus 4"
2A	Harman	209		X						ET-Plus 4"
2A	Harman	210		X						ET-Plus 4"
2A	Harman	211		X						ET-Plus 4"
2A	Harman	212		X						ET-Plus 5"
2A	Harman	213		X						ET-Plus 4"
2A	Harman	214		X						ET-Plus 4"
2A	Harman	215		X						ET-Plus 4"
2A	Harman	216		X						ET-Plus 4"
2A	Harman	217		X						ET-Plus 4"
2A	Harman	218		X						ET-Plus 4"
2A	Harman	219		X						ET-Plus 4"

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
2A	Harman	220						X		
2A	Harman	221						X		
2A	Harman	222	Yes							ET-Plus 4"
2A	Harman	223				2A #221				
2A	Harman	224						X		
2A	Harman	225		X						ET-Plus 4"
2A	Harman	226		X						ET-Plus 4"
2A	Harman	227						X		
2A	Harman	228	Yes							ET-Plus 4"
2A	Harman	229						X		
2A	Harman	230		X						ET-Plus 4"
2A	Harman	231							X	
2B	Missouri	1		X						ET-Plus 5"
2B	Missouri	2		X						ET-2000
2B	Missouri	3	Yes							ET-Plus 4"
2B	Missouri	4	Yes							ET-Plus
2B	Missouri	5	Yes							ET-Plus
2B	Missouri	6	Yes							ET-Plus
2B	Missouri	7	Yes							ET-Plus 4"
2B	Missouri	8	Yes							ET-Plus
2B	Missouri	9	Yes							ET-Plus 4"
2B	Missouri	10	Yes							ET-Plus 4"
2B	Missouri	11	Yes							ET-Plus 4"

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
2B	Missouri	12		X						ET-2000
2B	Missouri	13					X			Turned-Down
2B	Missouri	14					X			None
2B	Missouri	15					X			BCT
2B	Missouri	16							X	
2B	Missouri	17							X	
2B	Missouri	18					X			Turned-Down
2B	Missouri	19							X	
2B	Missouri	20						X		
2B	Missouri	21					X			Turned-Down
2B	Missouri	22					X			Blunt End
2B	Missouri	23					X			Blunt End
2B	Missouri	24					X			Blunt End
2B	Missouri	25						X		
2B	Missouri	26					X			Concrete
2B	Missouri	27						X		
2B	Missouri	28					X			Blunt End
2B	Missouri	29					X			Bridge Rail
2B	Missouri	30							X	
2B	Missouri	31					X			
2B	Missouri	32							X	
2B	Missouri	33	Yes							ET-Plus 4”
2B	Missouri	34	Yes							ET-Plus 4”

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
3A	NASS CDS	1					X			Turn Down
3A	NASS CDS	2					X			Blunt End
3A	NASS CDS	3						X		
3A	NASS CDS	4					X			SRT
3A	NASS CDS	5					X			Blunt End
3A	NASS CDS	6			X					FLEAT
3A	NASS CDS	7					X			SRT
3A	NASS CDS	8	Yes							ET-Plus 5”
3A	NASS CDS	9					X			Blunt End
3A	NASS CDS	10						X		
3A	NASS CDS	11					X			Turn Down
3A	NASS CDS	12					X			Blunt End
3A	NASS CDS	13	Yes							ET-Plus 5” & Cable Barrier Terminal
3A	NASS CDS	14	Yes							ET-Plus
3A	NASS CDS	15	Yes							ET-Plus 5”
3A	NASS CDS	16	Yes							ET-Plus
3A	NASS CDS	17				6A #4				FLEAT
3A	NASS CDS	18		X						
3A	NASS CDS	19	Yes							ET-Plus 4”
3A	NASS CDS	20	Yes							ET-Plus 4”
3A	NASS CDS	21					X			CAT-350
3A	NASS CDS	22	Yes							ET-Plus 4”

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
3A	NASS CDS	23					X			Blunt End
3A	NASS CDS	24	Yes							ET-Plus
3A	NASS CDS	25					X			SRT
3A	NASS CDS	26			X					SKT
3A	NASS CDS	27					X			Turndown
3A	NASS CDS	28					X			Impact Attenuator
3A	NASS CDS	29					X			Trailing End
3A	NASS CDS	30					X			Blunt End
3A	NASS CDS	31					X			Blunt End
3A	NASS CDS	32	Yes							ET-Plus
3A	NASS CDS	33		X						
3A	NASS CDS	34					X			MELT
3A	NASS CDS	35					X			SRT
3A	NASS CDS	36						X		
3A	NASS CDS	37						X		
3A	NASS CDS	38						X		
3A	NASS CDS	39						X		
3A	NASS CDS	40						X		
3A	NASS CDS	41						X		
3A	NASS CDS	42						X		
3A	NASS CDS	43						X		
3A	NASS CDS	44						X		
3A	NASS CDS	45						X		

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
3A	NASS CDS	46						X		
3A	NASS CDS	47						X		
3A	NASS CDS	48						X		
3A	NASS CDS	49						X		
3A	NASS CDS	50						X		
3A	NASS CDS	51						X		
3A	NASS CDS	52						X		
3A	NASS CDS	53						X		
3A	NASS CDS	54						X		
3A	NASS CDS	55						X		
3A	NASS CDS	56						X		
3B	Missouri	1	Yes							ET-Plus 4"
3B	Missouri	2	Yes							ET-Plus 4"
3B	Missouri	3	Yes							ET-2000
3B	Missouri	4	Yes							ET-Plus 4"
3B	Missouri	5	Yes							ET-Plus 4"
3B	Missouri	6	Yes							ET-Plus 4"
3B	Missouri	7	Yes							ET-Plus 4"
3B	Missouri	8	Yes							ET-Plus 4"
3B	Missouri	9	Yes							ET-Plus 4"
3B	Missouri	10	Yes							ET-Plus 4"
3B	Missouri	11	Yes							ET-Plus 4"
3B	Missouri	12	Yes							ET-Plus 4"

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
3B	Missouri	13	Yes							ET-Plus 4"
3B	Missouri	14	Yes							ET-Plus 4"
3B	Missouri	15	Yes							ET-Plus 4"
3B	Missouri	16	Yes							ET-Plus 4"
3B	Missouri	17	Yes							ET-Plus 4"
3B	Missouri	18						X		
3B	Missouri	19							X	
3B	Missouri	20	Yes							ET-Plus 4"
3B	Missouri	21	Yes							ET-Plus 4"
3B	Missouri	22	Yes							ET-Plus 4"
3B	Missouri	23				6A #5				SKT
3B	Missouri	24	Yes							ET-Plus
3B	Missouri	25	Yes							ET-Plus 4"
3B	Missouri	26	Yes							ET-Plus
3B	Missouri	27	Yes							ET-Plus 4"
3B	Missouri	28	Yes							ET-Plus 4"
3B	Missouri	29	Yes							ET-Plus
3B	Missouri	30	Yes							ET-Plus 5"
3B	Missouri	31	Yes							ET-Plus 4"
3B	Missouri	32						X		
3B	Missouri	33	Yes							ET-2000
3B	Missouri	34	Yes							ET-Plus
3B	Missouri	35	Yes							ET-2000

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
3B	Missouri	36	Yes							ET-Plus 4"
3B	Missouri	37		X						
3B	Missouri	38		X						
4A	Delaware	1	Yes							ET-Plus 4"
4A	Delaware	2	Yes							ET-Plus 4"
4A	Delaware	3	Yes							ET-Plus 4"
4A	Delaware	4	Yes							ET-Plus 4"
4A	Delaware	5	Yes							ET-Plus 4"
4A	Delaware	6	Yes							ET-Plus 4"
4A	Delaware	7	Yes							ET-Plus 4"
4A	Delaware	8		X						
4A	Delaware	9		X						
4A	Delaware	10		X						
4A	Delaware	11	Yes							ET-Plus 4"
4A	Delaware	12		X						
4B	Connecticut	1	Yes							ET-Plus
4B	Connecticut	2	Yes							ET-Plus 4"
4B	Connecticut	3	Yes							Unknown
4B	Connecticut	4	Yes							Unknown
4B	Connecticut	5	Yes							Unknown
4B	Connecticut	6	Yes							ET-Plus 4"
4C	Washington	1	Yes							ET-2000
4C	Washington	2			X					ET-31

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4C	Washington	3	Yes							ET-31
4C	Washington	4			X					ET-31
4C	Washington	5	Yes							ET-31
4C	Washington	6	Yes							ET-31
4C	Washington	7			X					ET-31
4C	Washington	8	Yes							ET-31
4C	Washington	9			X					ET-31
4C	Washington	10	Yes							ET-31
4C	Washington	11	Yes							ET-31
4C	Washington	12			X					ET-Plus
4C	Washington	13		X						ET-Plus
4C	Washington	14	Yes							ET-Plus
4C	Washington	15	Yes							ET-Plus
4C	Washington	16			X					ET-Plus
4C	Washington	17	Yes							ET-Plus
4C	Washington	18			X					ET-Plus
4C	Washington	19	Yes							ET-Plus
4C	Washington	20	Yes							ET-Plus
4C	Washington	21	Yes							ET-Plus
4C	Washington	22			X					ET-Plus
4C	Washington	23			X					ET-Plus
4C	Washington	24	Yes							ET-Plus
4C	Washington	25	Yes							ET-Plus

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4C	Washington	26	Yes							ET-Plus
4C	Washington	27			X					ET-Plus
4C	Washington	28	Yes							ET-Plus
4C	Washington	29	Yes							ET-Plus
4C	Washington	30	Yes							ET-Plus
4C	Washington	31			X					ET-Plus
4C	Washington	32			X					ET-Plus
4C	Washington	33			X					ET-Plus
4C	Washington	34			X					ET-Plus
4C	Washington	35	Yes							ET-Plus
4C	Washington	36			X					ET-Plus
4C	Washington	37		X						FLEAT
4C	Washington	38							X	
4C	Washington	39		X						FLEAT
4C	Washington	40		X						SKT
4C	Washington	41				6A #6				SKT
4C	Washington	42				6A #7				SKT
4C	Washington	43		X						SKT
4C	Washington	44				6A #8				SKT
4C	Washington	45				6A #9				SKT
4C	Washington	46				6A #10				SKT
4C	Washington	47		X						SKT
4C	Washington	48		X						ET-2000

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4C	Washington	49		X						ET-2000
4C	Washington	50			X					ET-31
4C	Washington	51			X					ET-31
4C	Washington	52		X						ET-31
4C	Washington	53			X					ET-31
4C	Washington	54			X					ET-31
4C	Washington	55			X					ET-31
4C	Washington	56			X					ET-31
4C	Washington	57			X					ET-31
4C	Washington	58		X						ET-31
4C	Washington	59		X						ET-31
4C	Washington	60			X					ET-31
4C	Washington	61		X						ET-31
4C	Washington	62			X					ET-31
4C	Washington	63		X						ET-31
4C	Washington	64		X						ET-31
4C	Washington	65			X					ET-31
4C	Washington	66		X						ET-31
4C	Washington	67			X					ET-31
4C	Washington	68		X						ET-31
4C	Washington	69		X						ET-31
4C	Washington	70			X					ET-31
4C	Washington	71			X					ET-31

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4C	Washington	72				4C-66				ET-31
4C	Washington	73			X					ET-Plus
4C	Washington	74			X					ET-Plus
4C	Washington	75		X						ET-Plus
4C	Washington	76			X					ET-Plus
4C	Washington	77			X					ET-Plus
4C	Washington	78			X					ET-Plus
4C	Washington	79		X						ET-Plus
4C	Washington	80			X					ET-Plus
4C	Washington	81			X					ET-Plus
4C	Washington	82			X					ET-Plus
4C	Washington	83		X						ET-Plus
4C	Washington	84		X						ET-Plus
4C	Washington	85			X					ET-Plus
4C	Washington	86			X					ET-Plus
4C	Washington	87			X					ET-Plus
4C	Washington	88			X					ET-Plus
4C	Washington	89			X					ET-Plus
4C	Washington	90		X						ET-Plus
4C	Washington	91			X					ET-Plus
4C	Washington	92			X					ET-Plus
4C	Washington	93		X						ET-Plus
4C	Washington	94		X						ET-Plus

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4C	Washington	95			X					ET-Plus
4C	Washington	96		X						ET-Plus
4C	Washington	97			X					ET-Plus
4C	Washington	98			X					ET-Plus
4C	Washington	99			X					ET-Plus
4C	Washington	100		X						ET-Plus
4C	Washington	101			X					ET-Plus
4C	Washington	102			X					ET-Plus
4C	Washington	103			X					ET-Plus
4C	Washington	104		X						ET-Plus
4C	Washington	105		X						ET-Plus
4C	Washington	106		X						ET-Plus
4C	Washington	107		X						ET-Plus
4C	Washington	108			X					ET-Plus
4C	Washington	109			X					ET-Plus
4C	Washington	110			X					ET-Plus
4C	Washington	111			X					ET-Plus
4C	Washington	112			X					ET-Plus
4C	Washington	113		X						ET-Plus
4C	Washington	114		X						ET-Plus
4C	Washington	115			X					ET-Plus
4C	Washington	116			X					ET-Plus
4C	Washington	117		X						ET-Plus

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4C	Washington	118		X						ET-Plus
4C	Washington	119		X						ET-Plus
4C	Washington	120		X						ET-Plus
4C	Washington	121		X						ET-Plus
4C	Washington	122				4C-76				ET-Plus
4C	Washington	123		X						ET-Plus
4C	Washington	124		X						FLEAT
4C	Washington	125		X						FLEAT
4C	Washington	126			X					FLEAT
4C	Washington	127			X					FLEAT
4C	Washington	128		X						FLEAT
4C	Washington	129			X					FLEAT
4C	Washington	130		X						FLEAT
4C	Washington	131		X						FLEAT
4C	Washington	132		X						FLEAT
4C	Washington	133			X					SKT
4C	Washington	134			X					SKT
4C	Washington	135		X						SKT
4C	Washington	136			X					SKT
4C	Washington	137			X					SKT
4C	Washington	138			X					SKT
4C	Washington	139			X					SKT
4C	Washington	140			X					SKT

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4C	Washington	141			X					SKT
4C	Washington	142		X						SKT
4C	Washington	143			X					SKT
4C	Washington	144			X					SKT
4C	Washington	145			X					SKT
4C	Washington	146		X						SKT
4C	Washington	147			X					SKT
4C	Washington	148			X					SKT
4C	Washington	149			X					SKT
4C	Washington	150			X					SKT
4C	Washington	151			X					SKT
4C	Washington	152		X						SKT
4C	Washington	153		X						SKT
4C	Washington	154		X						SKT
4C	Washington	155			X					SKT
4C	Washington	156			X					SKT
4C	Washington	157		X						SKT
4C	Washington	158			X					SKT
4C	Washington	159		X						SKT
4C	Washington	160		X						SKT
4C	Washington	161		X						SKT
4C	Washington	162		X						SKT
4D	Massachusetts	1			X					

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	2		X						
4D	Massachusetts	3		X						
4D	Massachusetts	4		X						
4D	Massachusetts	5		X						
4D	Massachusetts	6		X						
4D	Massachusetts	7		X						
4D	Massachusetts	8		X						
4D	Massachusetts	9		X						
4D	Massachusetts	10			X					
4D	Massachusetts	11		X						
4D	Massachusetts	12		X						
4D	Massachusetts	13			X					
4D	Massachusetts	14			X					
4D	Massachusetts	15		X						
4D	Massachusetts	16		X						
4D	Massachusetts	17		X						
4D	Massachusetts	18		X						
4D	Massachusetts	19			X					
4D	Massachusetts	20		X						
4D	Massachusetts	21		X						
4D	Massachusetts	22		X						
4D	Massachusetts	23			X					
4D	Massachusetts	24			X					

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	25		X						
4D	Massachusetts	26		X						
4D	Massachusetts	27		X						
4D	Massachusetts	28			X					
4D	Massachusetts	29		X						
4D	Massachusetts	30			X					
4D	Massachusetts	31		X						
4D	Massachusetts	32		X						
4D	Massachusetts	33		X						
4D	Massachusetts	34			X					
4D	Massachusetts	35		X						
4D	Massachusetts	36		X						
4D	Massachusetts	37			X					
4D	Massachusetts	38			X					
4D	Massachusetts	39		X						
4D	Massachusetts	40				4D-30				
4D	Massachusetts	41		X						
4D	Massachusetts	42			X					
4D	Massachusetts	43		X						
4D	Massachusetts	44			X					
4D	Massachusetts	45		X						
4D	Massachusetts	46			X					
4D	Massachusetts	47		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	48		X						
4D	Massachusetts	49		X						
4D	Massachusetts	50		X						
4D	Massachusetts	51		X						
4D	Massachusetts	52		X						
4D	Massachusetts	53		X						
4D	Massachusetts	54		X						
4D	Massachusetts	55		X						
4D	Massachusetts	56			X					
4D	Massachusetts	57			X					
4D	Massachusetts	58		X						
4D	Massachusetts	59			X					
4D	Massachusetts	60		X						
4D	Massachusetts	61			X					
4D	Massachusetts	62		X						
4D	Massachusetts	63		X						
4D	Massachusetts	64		X						
4D	Massachusetts	65		X						
4D	Massachusetts	66			X					
4D	Massachusetts	67			X					
4D	Massachusetts	68		X						
4D	Massachusetts	69		X						
4D	Massachusetts	70			X					

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	71		X						
4D	Massachusetts	72		X						
4D	Massachusetts	73		X						
4D	Massachusetts	74			X					
4D	Massachusetts	75			X					
4D	Massachusetts	76			X					
4D	Massachusetts	77			X					
4D	Massachusetts	78			X					
4D	Massachusetts	79		X						
4D	Massachusetts	80		X						
4D	Massachusetts	81		X						
4D	Massachusetts	82			X					
4D	Massachusetts	83		X						
4D	Massachusetts	84			X					
4D	Massachusetts	85		X						
4D	Massachusetts	86			X					
4D	Massachusetts	87			X					
4D	Massachusetts	88			X					
4D	Massachusetts	89		X						
4D	Massachusetts	90		X						
4D	Massachusetts	91			X					
4D	Massachusetts	92			X					
4D	Massachusetts	93			X					

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	94		X						
4D	Massachusetts	95		X						
4D	Massachusetts	96		X						
4D	Massachusetts	97			X					
4D	Massachusetts	98		X						
4D	Massachusetts	99			X					
4D	Massachusetts	100		X						
4D	Massachusetts	101		X						
4D	Massachusetts	102		X						
4D	Massachusetts	103		X						
4D	Massachusetts	104		X						
4D	Massachusetts	105			X					
4D	Massachusetts	106		X						
4D	Massachusetts	107		X						
4D	Massachusetts	108			X					
4D	Massachusetts	109		X						
4D	Massachusetts	110		X						
4D	Massachusetts	111			X					
4D	Massachusetts	112		X						
4D	Massachusetts	113			X					
4D	Massachusetts	114		X						
4D	Massachusetts	115		X						
4D	Massachusetts	116			X					

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	117			X					
4D	Massachusetts	118			X					
4D	Massachusetts	119		X						
4D	Massachusetts	120		X						
4D	Massachusetts	121			X					
4D	Massachusetts	122			X					
4D	Massachusetts	123		X						
4D	Massachusetts	124			X					
4D	Massachusetts	125			X					
4D	Massachusetts	126		X						
4D	Massachusetts	127		X						
4D	Massachusetts	128		X						
4D	Massachusetts	129			X					
4D	Massachusetts	130		X						
4D	Massachusetts	131			X					
4D	Massachusetts	132		X						
4D	Massachusetts	133		X						
4D	Massachusetts	134			X					
4D	Massachusetts	135		X						
4D	Massachusetts	136			X					
4D	Massachusetts	137			X					
4D	Massachusetts	138			X					
4D	Massachusetts	139		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	140		X						
4D	Massachusetts	141		X						
4D	Massachusetts	142		X						
4D	Massachusetts	143		X						
4D	Massachusetts	144		X						
4D	Massachusetts	145		X						
4D	Massachusetts	146		X						
4D	Massachusetts	147		X						
4D	Massachusetts	148			X					
4D	Massachusetts	149		X						
4D	Massachusetts	150			X					
4D	Massachusetts	151		X						
4D	Massachusetts	152		X						
4D	Massachusetts	153		X						
4D	Massachusetts	154		X						
4D	Massachusetts	155			X					
4D	Massachusetts	156			X					
4D	Massachusetts	157		X						
4D	Massachusetts	158			X					
4D	Massachusetts	159		X						
4D	Massachusetts	160		X						
4D	Massachusetts	161		X						
4D	Massachusetts	162		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	163		X						
4D	Massachusetts	164		X						
4D	Massachusetts	165		X						
4D	Massachusetts	166			X					
4D	Massachusetts	167			X					
4D	Massachusetts	168		X						
4D	Massachusetts	169		X						
4D	Massachusetts	170		X						
4D	Massachusetts	171			X					
4D	Massachusetts	172		X						
4D	Massachusetts	173		X						
4D	Massachusetts	174		X						
4D	Massachusetts	175			X					
4D	Massachusetts	176			X					
4D	Massachusetts	177		X						
4D	Massachusetts	178			X					
4D	Massachusetts	179		X						
4D	Massachusetts	180			X					
4D	Massachusetts	181		X						
4D	Massachusetts	182		X						
4D	Massachusetts	183		X						
4D	Massachusetts	184		X						
4D	Massachusetts	185		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	186		X						
4D	Massachusetts	187			X					
4D	Massachusetts	188		X						
4D	Massachusetts	189		X						
4D	Massachusetts	190		X						
4D	Massachusetts	191			X					
4D	Massachusetts	192		X						
4D	Massachusetts	193		X						
4D	Massachusetts	194		X						
4D	Massachusetts	195		X						
4D	Massachusetts	196		X						
4D	Massachusetts	197		X						
4D	Massachusetts	198		X						
4D	Massachusetts	199		X						
4D	Massachusetts	200		X						
4D	Massachusetts	201			X					
4D	Massachusetts	202		X						
4D	Massachusetts	203		X						
4D	Massachusetts	204		X						
4D	Massachusetts	205		X						
4D	Massachusetts	206			X					
4D	Massachusetts	207		X						
4D	Massachusetts	208		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	209		X						
4D	Massachusetts	210		X						
4D	Massachusetts	211		X						
4D	Massachusetts	212			X					
4D	Massachusetts	213			X					
4D	Massachusetts	214			X					
4D	Massachusetts	215		X						
4D	Massachusetts	216		X						
4D	Massachusetts	217		X						
4D	Massachusetts	218			X					
4D	Massachusetts	219			X					
4D	Massachusetts	220		X						
4D	Massachusetts	221		X						
4D	Massachusetts	222			X					
4D	Massachusetts	223		X						
4D	Massachusetts	224		X						
4D	Massachusetts	225			X					
4D	Massachusetts	226		X						
4D	Massachusetts	227		X						
4D	Massachusetts	228		X						
4D	Massachusetts	229			X					
4D	Massachusetts	230		X						
4D	Massachusetts	231		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	232		X						
4D	Massachusetts	233			X					
4D	Massachusetts	234		X						
4D	Massachusetts	235		X						
4D	Massachusetts	236		X						
4D	Massachusetts	237			X					
4D	Massachusetts	238		X						
4D	Massachusetts	239			X					
4D	Massachusetts	240		X						
4D	Massachusetts	241		X						
4D	Massachusetts	242		X						
4D	Massachusetts	243		X						
4D	Massachusetts	244			X					
4D	Massachusetts	245		X						
4D	Massachusetts	246		X						
4D	Massachusetts	247		X						
4D	Massachusetts	248		X						
4D	Massachusetts	249		X						
4D	Massachusetts	250		X						
4D	Massachusetts	251			X					
4D	Massachusetts	252		X						
4D	Massachusetts	253		X						
4D	Massachusetts	254			X					

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	255			X					
4D	Massachusetts	256			X					
4D	Massachusetts	257		X						
4D	Massachusetts	258		X						
4D	Massachusetts	259		X						
4D	Massachusetts	260			X					
4D	Massachusetts	261			X					
4D	Massachusetts	262			X					
4D	Massachusetts	263		X						
4D	Massachusetts	264		X						
4D	Massachusetts	265		X						
4D	Massachusetts	266		X						
4D	Massachusetts	267		X						
4D	Massachusetts	268		X						
4D	Massachusetts	269		X						
4D	Massachusetts	270		X						
4D	Massachusetts	271		X						
4D	Massachusetts	272		X						
4D	Massachusetts	273		X						
4D	Massachusetts	274		X						
4D	Massachusetts	275		X						
4D	Massachusetts	276			X					
4D	Massachusetts	277		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	278			X					
4D	Massachusetts	279		X						
4D	Massachusetts	280		X						
4D	Massachusetts	281			X					
4D	Massachusetts	282			X					
4D	Massachusetts	283		X						
4D	Massachusetts	284			X					
4D	Massachusetts	285		X						
4D	Massachusetts	286		X						
4D	Massachusetts	287			X					
4D	Massachusetts	288		X						
4D	Massachusetts	289			X					
4D	Massachusetts	290			X					
4D	Massachusetts	291		X						
4D	Massachusetts	292		X						
4D	Massachusetts	293		X						
4D	Massachusetts	294		X						
4D	Massachusetts	295			X					
4D	Massachusetts	296		X						
4D	Massachusetts	297			X					
4D	Massachusetts	298		X						
4D	Massachusetts	299			X					
4D	Massachusetts	300		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	301		X						
4D	Massachusetts	302		X						
4D	Massachusetts	303		X						
4D	Massachusetts	304		X						
4D	Massachusetts	305		X						
4D	Massachusetts	306		X						
4D	Massachusetts	307		X						
4D	Massachusetts	308		X						
4D	Massachusetts	309		X						
4D	Massachusetts	310		X						
4D	Massachusetts	311			X					
4D	Massachusetts	312		X						
4D	Massachusetts	313		X						
4D	Massachusetts	314	Yes							ET-Plus
4D	Massachusetts	315			X					
4D	Massachusetts	316		X						
4D	Massachusetts	317		X						
4D	Massachusetts	318			X					
4D	Massachusetts	319		X						
4D	Massachusetts	320		X						
4D	Massachusetts	321		X						
4D	Massachusetts	322		X						
4D	Massachusetts	323			X					

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	324			X					
4D	Massachusetts	325		X						
4D	Massachusetts	326			X					
4D	Massachusetts	327		X						
4D	Massachusetts	328			X					
4D	Massachusetts	329	Yes							ET-Plus
4D	Massachusetts	330		X						
4D	Massachusetts	331							X	
4D	Massachusetts	332		X						
4D	Massachusetts	333		X						
4D	Massachusetts	334	Yes							Unknown
4D	Massachusetts	335		X						
4D	Massachusetts	336		X						
4D	Massachusetts	337		X						
4D	Massachusetts	338		X						
4D	Massachusetts	339			X					
4D	Massachusetts	340		X						
4D	Massachusetts	341		X						
4D	Massachusetts	342			X					
4D	Massachusetts	343			X					
4D	Massachusetts	344			X					
4D	Massachusetts	345		X						
4D	Massachusetts	346		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	347		X						
4D	Massachusetts	348		X						
4D	Massachusetts	349		X						
4D	Massachusetts	350			X					
4D	Massachusetts	351	Yes							ET-Plus
4D	Massachusetts	352		X						
4D	Massachusetts	353		X						
4D	Massachusetts	354		X						
4D	Massachusetts	355			X					
4D	Massachusetts	356			X					
4D	Massachusetts	357			X					
4D	Massachusetts	358			X					
4D	Massachusetts	359		X						
4D	Massachusetts	360		X						
4D	Massachusetts	361			X					
4D	Massachusetts	362		X						
4D	Massachusetts	363		X						
4D	Massachusetts	364		X						
4D	Massachusetts	365			X					
4D	Massachusetts	366		X						
4D	Massachusetts	367			X					
4D	Massachusetts	368		X						
4D	Massachusetts	369			X					

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	370	Yes							Unknown
4D	Massachusetts	371		X						
4D	Massachusetts	372	Yes							ET-Plus
4D	Massachusetts	373			X					
4D	Massachusetts	374			X					
4D	Massachusetts	375		X						
4D	Massachusetts	376		X						
4D	Massachusetts	377		X						
4D	Massachusetts	378			X					
4D	Massachusetts	379			X					
4D	Massachusetts	380			X					
4D	Massachusetts	381		X						
4D	Massachusetts	382		X						
4D	Massachusetts	383			X					
4D	Massachusetts	384		X						
4D	Massachusetts	385		X						
4D	Massachusetts	386		X						
4D	Massachusetts	387		X						
4D	Massachusetts	388		X						
4D	Massachusetts	389			X					
4D	Massachusetts	390			X					
4D	Massachusetts	391			X					
4D	Massachusetts	392			X					

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	393		X						
4D	Massachusetts	394		X						
4D	Massachusetts	395			X					
4D	Massachusetts	396		X						
4D	Massachusetts	397	Yes							ET-Plus
4D	Massachusetts	398		X						
4D	Massachusetts	399			X					
4D	Massachusetts	400			X					
4D	Massachusetts	401			X					
4D	Massachusetts	402		X						
4D	Massachusetts	403			X					
4D	Massachusetts	404			X					
4D	Massachusetts	405			X					
4D	Massachusetts	406			X					
4D	Massachusetts	407		X						
4D	Massachusetts	408	Yes							ET-Plus
4D	Massachusetts	409	Yes							Unknown
4D	Massachusetts	410			X					
4D	Massachusetts	411		X						
4D	Massachusetts	412			X					
4D	Massachusetts	413			X					
4D	Massachusetts	414			X					
4D	Massachusetts	415		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	416			X					
4D	Massachusetts	417			X					
4D	Massachusetts	418		X						
4D	Massachusetts	419		X						
4D	Massachusetts	420		X						
4D	Massachusetts	421		X						
4D	Massachusetts	422			X					
4D	Massachusetts	423	Yes							ET-Plus
4D	Massachusetts	424			X					
4D	Massachusetts	425			X					
4D	Massachusetts	426		X						
4D	Massachusetts	427			X					
4D	Massachusetts	428	Yes							N/A
4D	Massachusetts	429		X						
4D	Massachusetts	430			X					
4D	Massachusetts	431		X						
4D	Massachusetts	432			X					
4D	Massachusetts	433			X					
4D	Massachusetts	434			X					
4D	Massachusetts	435		X						
4D	Massachusetts	436			X					
4D	Massachusetts	437		X						
4D	Massachusetts	438		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	439			X					
4D	Massachusetts	440		X						
4D	Massachusetts	441			X					
4D	Massachusetts	442		X						
4D	Massachusetts	443			X					
4D	Massachusetts	444		X						
4D	Massachusetts	445			X					
4D	Massachusetts	446	Yes							ET-Plus
4D	Massachusetts	447			X					
4D	Massachusetts	448			X					
4D	Massachusetts	449		X						
4D	Massachusetts	450			X					
4D	Massachusetts	451		X						
4D	Massachusetts	452		X						
4D	Massachusetts	453			X					
4D	Massachusetts	454			X					
4D	Massachusetts	455			X					
4D	Massachusetts	456		X						
4D	Massachusetts	457		X						
4D	Massachusetts	458		X						
4D	Massachusetts	459		X						
4D	Massachusetts	460			X					
4D	Massachusetts	461		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	462			X					
4D	Massachusetts	463			X					
4D	Massachusetts	464		X						
4D	Massachusetts	465			X					
4D	Massachusetts	466			X					
4D	Massachusetts	467		X						
4D	Massachusetts	468			X					
4D	Massachusetts	469		X						
4D	Massachusetts	470			X					
4D	Massachusetts	471			X					
4D	Massachusetts	472			X					
4D	Massachusetts	473			X					
4D	Massachusetts	474			X					
4D	Massachusetts	475			X					
4D	Massachusetts	476			X					
4D	Massachusetts	477			X					
4D	Massachusetts	478		X						
4D	Massachusetts	479	Yes							ET-Plus
4D	Massachusetts	480			X					
4D	Massachusetts	481		X						
4D	Massachusetts	482		X						
4D	Massachusetts	483			X					
4D	Massachusetts	484			X					

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	485			X					
4D	Massachusetts	486			X					
4D	Massachusetts	487		X						
4D	Massachusetts	488		X						
4D	Massachusetts	489			X					
4D	Massachusetts	490		X						
4D	Massachusetts	491		X						
4D	Massachusetts	492			X					
4D	Massachusetts	493			X					
4D	Massachusetts	494			X					
4D	Massachusetts	495		X						
4D	Massachusetts	496			X					
4D	Massachusetts	497	Yes							ET-Plus
4D	Massachusetts	498			X					
4D	Massachusetts	499		X						
4D	Massachusetts	500			X					
4D	Massachusetts	501			X					
4D	Massachusetts	502			X					
4D	Massachusetts	503			X					
4D	Massachusetts	504			X					
4D	Massachusetts	505			X					
4D	Massachusetts	506			X					
4D	Massachusetts	507			X					

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	508	Yes							ET-Plus
4D	Massachusetts	509	Yes							ET-Plus
4D	Massachusetts	510			X					
4D	Massachusetts	511			X					
4D	Massachusetts	512			X					
4D	Massachusetts	513			X					
4D	Massachusetts	514			X					
4D	Massachusetts	515			X					
4D	Massachusetts	516			X					
4D	Massachusetts	517			X					
4D	Massachusetts	518		X						
4D	Massachusetts	519			X					
4D	Massachusetts	520			X					
4D	Massachusetts	521	Yes							ET-Plus
4D	Massachusetts	522		X						
4D	Massachusetts	523		X						
4D	Massachusetts	524			X					
4D	Massachusetts	525			X					
4D	Massachusetts	526			X					
4D	Massachusetts	527		X						
4D	Massachusetts	528		X						
4D	Massachusetts	529		X						
4D	Massachusetts	530		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	531	Yes							ET-Plus
4D	Massachusetts	532			X					
4D	Massachusetts	533		X						
4D	Massachusetts	534		X						
4D	Massachusetts	535		X						
4D	Massachusetts	536		X						
4D	Massachusetts	537		X						
4D	Massachusetts	538		X						
4D	Massachusetts	539	Yes							ET-Plus
4D	Massachusetts	540		X						
4D	Massachusetts	541			X					
4D	Massachusetts	542			X					
4D	Massachusetts	543		X						
4D	Massachusetts	544			X					
4D	Massachusetts	545			X					
4D	Massachusetts	546			X					
4D	Massachusetts	547			X					
4D	Massachusetts	548			X					
4D	Massachusetts	549		X						
4D	Massachusetts	550			X					
4D	Massachusetts	551		X						
4D	Massachusetts	552	Yes							Unknown
4D	Massachusetts	553		X						

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
4D	Massachusetts	554		X						
4D	Massachusetts	555			X					
4D	Massachusetts	556		X						
4D	Massachusetts	557		X						
4D	Massachusetts	558			X					
4D	Massachusetts	559		X						
4D	Massachusetts	560		X						
5A	The Safety Institute	1	Yes							ET-Plus 5"
5A	The Safety Institute	2	Yes			2B #9				ET-Plus 4”
5A	The Safety Institute	3	Yes							ET-Plus 5"
5A	The Safety Institute	4				2A #63				ET-Plus
5A	The Safety Institute	5	Yes							ET-Plus
5A	The Safety Institute	6	Yes							ET-Plus 4"
5A	The Safety Institute	7	Yes							Unknown
5A	The Safety Institute	8	Yes							ET-Plus 4"
5A	The Safety Institute	9	Yes							Unknown

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
5A	The Safety Institute	10	Yes							ET-Plus
5A	The Safety Institute	11	Yes							ET-Plus 4"
5A	The Safety Institute	12		X						ET-Plus
5A	The Safety Institute	13				2A #24				
5A	The Safety Institute	14				2A #34				
5A	The Safety Institute	15				2A #40				
5A	The Safety Institute	16				2B #10				
5A	The Safety Institute	17				2A #48				
5A	The Safety Institute	18				2A #49				
5A	The Safety Institute	19				2A #43				
5A	The Safety Institute	20				2A #44				
5A	The Safety Institute	21		X						ET-Plus
5A	The Safety Institute	22				2A #62				

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
5A	The Safety Institute	23				2A #65				
5A	The Safety Institute	24				2A #135				
5A	The Safety Institute	25				2A #117				
5A	The Safety Institute	26				2A #172				
5A	The Safety Institute	27				2A #182				
5A	The Safety Institute	28				2A #184				
5A	The Safety Institute	29				2A #179				
5A	The Safety Institute	30				2A #189				
5A	The Safety Institute	31				2A #175				
5A	The Safety Institute	32		X						ET-Plus
5A	The Safety Institute	33				2A #50				
5A	The Safety Institute	34				2A #10				
5A	The Safety Institute	35		X						ET-Plus

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
5A	The Safety Institute	36		X						ET-Plus
5A	The Safety Institute	37				2A #187				
5A	The Safety Institute	38				2A #150				
5A	The Safety Institute	39		X						ET-Plus
5B	FHWA Division Office	1		X						ET-Plus 5"
5B	Media	2	Yes							ET-Plus 4"
5B	Media	3		X						
5B	Media	4		X						
5B	FHWA Division Office	5		X						ET-2000 or ET-Plus
5B	FHWA Division Office	6	Yes							ET-Plus
5B	FHWA Division Office	7					X			
5B	FHWA Division Office	8		X						
5B	FHWA Division Office	9				6A #19				FLEAT
5B	Media	10						X		
5B	Media	11	Yes							ET-Plus 4"

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
5B	Media	12	Yes							ET-Plus
5B	FHWA Division Office	13				6A #20				SKT
5B	FHWA Division Office	14						X		
5B	FHWA Division Office	15		X						
6A	NMVCCS	1	Yes							SKT
6A	NMVCCS	2	Yes							SKT
6A	NMVCCS	3	Yes							FLEAT
6A	NASS CDS	4	Yes							FLEAT
6A	Missouri	5	Yes							SKT
6A	Washington	6	Yes							SKT
6A	Washington	7	Yes							SKT
6A	Washington	8	Yes							SKT
6A	Washington	9	Yes							SKT
6A	Washington	10	Yes							SKT
6A	NASS CDS	11				3A #6				FLEAT
6A	NASS CDS	12				3A #26				SKT
6A	Washington	13				4C #37				FLEAT
6A	Washington	14				4C #38				FLEAT
6A	Washington	15				4C #39				FLEAT
6A	Washington	16				4C #40				SKT
6A	Washington	17				4C #43				SKT

Phase	Data Source	#	Reviewed by Task Force?	Reason for Not Sending Forward to Task Force for Review						Terminal Type (See Endnote 3)
				Insufficient Information (See Endnote 1)	Did Not Involve a Potentially Harmful Occurrence (See Endnote 2)	Duplicate of Another Case	Did Not Involve an Extruding W-Beam Guardrail Terminal	Type of Impacted Terminal Unknown or Unidentifiable	No Terminal Impacted	
6A	Washington	18				4C #47				SKT
6A	Mississippi	19	Yes							FLEAT
6A	Texas	20	Yes							SKT

Appendix D Endnotes

1. Insufficient Information: An “X” in this column denotes the assessment that there was insufficient information to evaluate the type of terminal involved in the crash, the role the terminal played in the crash, and/or the performance of the terminal during the crash. Refer to the discussion of the types of information needed for such evaluations in the main body of this report under the heading Task Force Methodology/Crash Case Review Process/Component 1: Initial Screening of All Crash Case Data by FHWA.

2. Did Not Involve a Potentially Harmful Occurrence: An “X” in this column denotes that the available information on this case does not provide evidence of any of the potentially hazardous occurrences identified in the main body of the report under the heading Task Force Findings/Crash Cases Exhibiting Performance Limitations: Impact Conditions, i.e., sudden deceleration, rollover, occupant compartment deformation, and penetration.

3. Terminal Type: The following acronyms and abbreviations are used:

BCT: Breakaway cable terminal
CASS: Cable safety system
CAT-350: Crash cushion attenuating terminal
ET-Plus: an ET-Plus for which the channel width could not be determined from the available information.
ET-31: ET-Plus with 31-inch w-beam guardrail (term used by Washington State DOT)
FLEAT: Flared energy absorbing terminal
MELT: Modified eccentric loader terminal
N/A: Not applicable, i.e., the crash did not involve a guardrail terminal
REACT: Trade name only
SKT: Sequential kinking terminal
SRT: Slotted rail terminal

Appendix E – Examples of Crash Cases Not Forwarded for Review by Task Force

Phase: 2A
Case # 13

Based on the information provided, it was not possible to identify the terminal, the speed of the vehicle, the orientation of the vehicle upon impact, condition of the terminal prior to impact, etc. This case was not forwarded to the Task Force.

Phase: 2A
Case # 25

The police report described this crash as a side impact. The file contained no information or photographs of the guardrail or terminal. This case was not forwarded to the Task Force.

Phase: 2A
Case # 93

This case consisted of 43 photographs of a damaged guardrail system. There was no information on the driver, the vehicle, or severity of crash. This case was not forwarded to the Task Force.

Phase: 2A
Case # 125

This case consisted of 27 photographs of a damaged guardrail system. There was no information on the driver, the vehicle, or the severity of the crash. This case was not forwarded to the Task Force.

Phase: 2A
Case # 68

This case consisted of 22 photographs of a damaged guardrail system. There was no information on the driver, the vehicle, or the severity of the crash. This case was not forwarded to the Task Force.

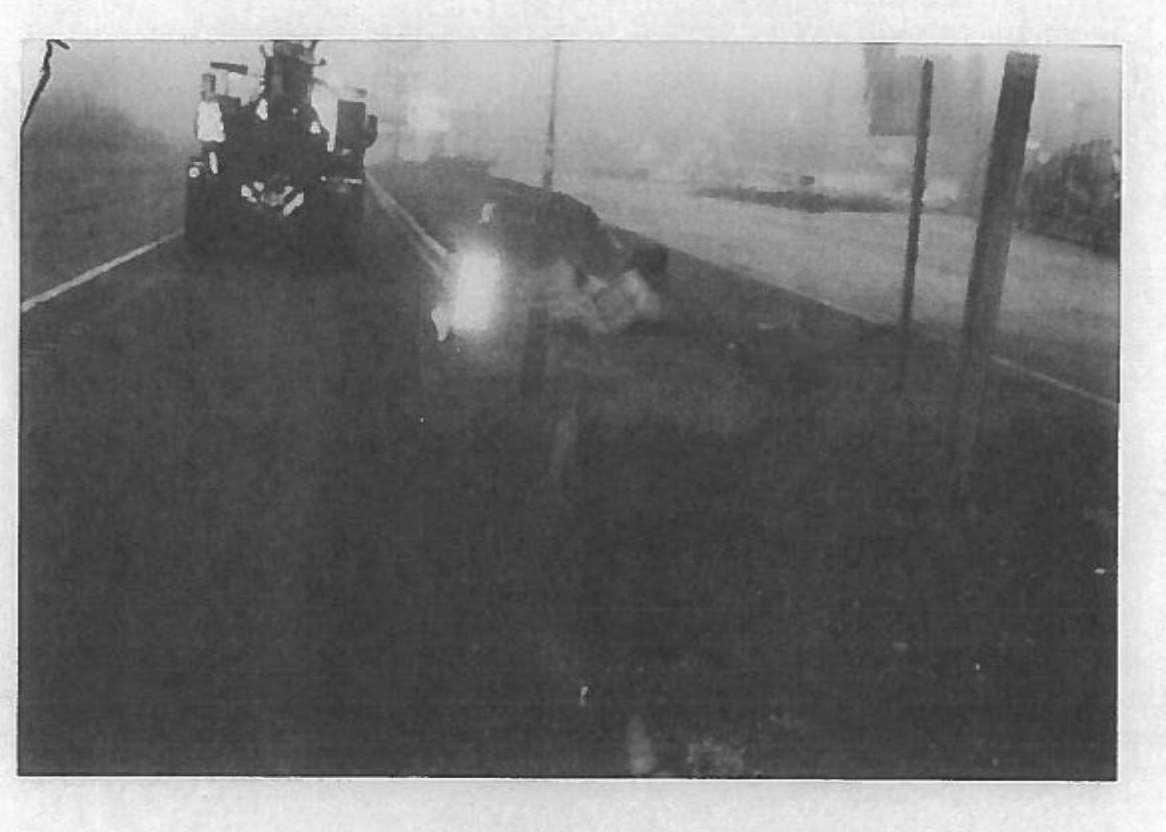
Phase: 3A
Case # 25

This case was not forwarded to the Task Force because it did not involve an energy-absorbing guardrail terminal.

Phase: 4D
Case # 10

The terminal could not be identified in the limited number of photographs for this crash, and the information provided was insufficient to evaluate the terminal's performance. This crash was not forwarded to the Task Force.

Phase: 4D
Case # 103



The photographs did not permit the type of terminal to be identified, and there was insufficient information to evaluate the terminal's performance. This crash was not forwarded to the Task Force.