# Unintended Benefits of the National Motor Vehicle Crash Causation Study: A Highway Perspective

Ana Maria Eigen
Kenneth S. Opiela

Federal Highway Administration
United States of America
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## ABSTRACT

Since its inception, the National Highway Traffic Safety Administration (NHTSA) has been concerned with providing the most complete and technologically feasible crash data collection. The collaboration with the Federal Highway Administration (FHWA) also dates back to the inception of the data sets. Funding issues and interest of primary users have limited coded infrastructure variables and attributes. In 2005, NHTSA embarked upon the congressionally-mandated National Motor Vehicle Crash Causation Study (NMVCCS) data collection. With on-scene reporting, nearly crash-time graphic data became available to end-users. In 2008, the Fatality Analysis Reporting System (FARS) published the first geographical coordinates for its cases. This eventually resulted in the re-release of data from 2001 through 2007. Although not temporally compatible, those interested in infrastructure and ***relevant elements*** would be able to complement the coded variables and attributes. The improved graphic reporting was noted in the National Automotive Sampling System (NASS) Crashworthiness Data System (CDS) pursuant to 2007 and potentially drawing from the NMVCCS model.

This paper offers an approach to mine, previously unconsulted NMVCCS data, rooted in precedent and established using FARS and NASS CDS. Using new data sources, the safety community might yield additional insights about crashes and the influence of various factors. In the narrowest sense, the findings might support the knowledge derived from crash testing and the limited extent of in-service evaluations of roadside safety elements that have been undertaken to date. As a natural by-product, this paper suggests that aggregated knowledge might populate an infrastructure dataset to aid those involved in roadway design, especially those addressing roadway departure issues, as supported by the overwhelming FARS incidence. During the feasibility study to identify the roadway elements and the value of image review, the digital image information has been enlightening. Tangentially, unlike NHTSA, FHWA may reference the unweighted data sets, as this furthers understanding of crash causation rather than underpinning rulemaking activities, thereby maximizing the use of unweighted NMVCCS data, predating the sampling plan. In the past, FWHA has consulted state-reported roadway features inventories and their resulting crashes when possible, aspiring to a macro view of roadside element description. As inconsistencies exist in the way that data has been collected, stored, and eventually processed at the state-level, this study seeks to review untapped digital images from national crash reporting, filling a void present in roadway design using a micro approach of roadside element description based upon crash scene locations. The present study seeks to address highway safety data needs by leveraging new data resources and tools.

## INTRODUCTION

NHTSA contemplated barrier data inclusion in early NASS CDS documentation. FHWA expressed the need for additional guardrail data, recognizing that barriers were involved in many fatal crashes and resulting in the development of the Longitudinal Barrier Special Study (LBSS, Ray, 2003), conducted in 1982. Under the NASS CDS architecture, LBSS was envisioned to sample and investigate 82 crashes per stratum with priority given to collisions involving breakaway cable terminal (BCT) end treatment and transition from guardrail to bridge rail. Through this effort, precedent exists for barrier data collection under the aegis of NASS CDS.

In the NASS CDS Coding Manual (NHTSA, 1979) the first harmful event could be described by an attribute known as impact attenuator. This attribute was defined as "barriers placed in front of fixed objects on the highway to absorb energy and to thus mitigate the injury effects of collisions at such sites" and examples of these barriers were found in the

Appendix C: 1979 NASS CDS Guardrail Codification. LBSS described the barrier, provided the roadside cross-section, qualified the extent of damage, reconstructed vehicle dynamics, drew the vehicle trajectory, and assessed the performance of the barrier. As suggested earlier, the investigators were provided with specific instructions regarding digital image capture designed to identify the roadside element condition, infer damage (provided the element had not been repaired,) describe the vehicle trajectory at uniform increments leading to the impact location and beyond, if redirection occurred.

From 1979 to the release of NMVCCS data in 2008, relatively little was known about the environment in which the vehicles were operated. Well-intentioned researchers recorded a number of rudimentary roadway characteristics, which disallowed any profound analysis of roadside elements or their influence on vehicle damage and occupant injury severity. The film photography, and eventually digital image capture, was based upon guidelines supporting basic occupant injury and vehicle kinematics study.

With NMVCCS, however, a complete crash scene chronicling was mandated. Further, the researcher endeavored to arrive as soon after the crash as notification time and distance permitted. In most cases, the unspoiled crash scene image was digitally captured, but occasionally under harried and sometime perilous conditions. In a hand-full of crashes, however, the roadway traffic conditions or notification window made it impossible for detailed, on-scene digital images to be recorded. In this model, NASS CDS roadway elements were better recorded from 2007, owing to the responsiveness of NHTSA, within the constraints of funding.

**Film Photography and Digital Image Review - Opportunity and Precedent**

In 2008, FARS released the geographical coordinates for crashes. Recently, geographical coordinates were released for crash years 2001 through 2007. Although images for the roadway segments did not coincide with the crash date, it was noted that roadway infrastructure was generally constant and roadway elements were repaired or replaced with similar technology.

The analysis of crash scene graphic images was not new. It was rooted in precedent, as has been used in NCHRP 17-22 (Mak, et. al., 2010) and 22-15 (Eskandarian, 2004) conducted by the Midwest Roadside Safety Facility and George Washington University, respectively. Both studies relied on photographic images to better understand the crash scene, with varying degrees of cold crash scene access. This was not deemed an issue owing to the relative constancy in roadway element placement.

For the roadway safety community, crashes involving roadway departure have been of special interest. First, owing to their overwhelming contribution to fatality and injury statistics, roadway departure has merited special consideration. Its disaggregation has also been merited by the varying countermeasures required to address the roadway departure subaggregates. Additionally, many roadway departure crashes involved elements easily discernible by photographic and digital image data examination.

**Definitions**

***Relevant elements*** have been chosen to describe a subset of roadside safety elements or devices readily identifiable via digital image review. Table 1 harmonized the concept of relevant elements with attributes provided in FARS, NASS CDS, and NMVCCS.

**Table 1.**
***Relevant Element Attribute*, by Dataset**

| *Relevant Element* | FARS | CDS | NMVCCS |
|---|---|---|---|
| Impact Attenuator | x | x | x |
| Guardrail Face | x | | |
| Concrete Barrier | x | | x |
| Other Longitudinal Barrier | x | x | x |
| Guardrail End | x | | |
| Cable Barrier | x | x | |
| W-Beam Guardrail | | x | |
| **Nota Bene**: W-Beam attribute available starting in NASS CDS, 2008 | | | |

***Event disaggregation*** for ***relevant elements*** was accomplished by consulting the data, as published. For FARS and NMVCCS, the events were selected at the vehicle level. NASS CDS, however, reports events at the crash level, requiring manipulation of the data to arrive at a vehicle event level. For this reason, the chronology, established by the police accident report for FARS and the researcher determined sequencing of events for NASS CDS, was used to establish the presence of a ***relevant element*** impact. For NASS CDS, the first crash event, the most harmful, or the second most harmful vehicle event was selected. This method was sound for single vehicle crashes, however, multiple event

crashes occasionally yielded uninvestigated vehicles, which were deemed suitable for the population of the supplementary dataset but would lack in-depth vehicle and occupant data. As this study, sought to improve understanding of the roadway environment and vehicle interaction, any vehicle subject to ***relevant element*** impact was deemed to add values.

***Film photography and digital photography*** was distinguished for purposes of this study. This was meant to account for technological advances present and exploited in this study. Film photography would have been present in the preparation of LBSS, as NASS transitioned from film in 1997 to digital image capture, with the advent of the Electronic Data Collection System, supporting CDS.

***Temporal classification*** was a further classification of images resting with the time of capture. Crash-time referred to images taken on-scene, such as those taken by NMVCCS researchers. Near crash-time images referred to those taken within a specified data sampling cycling, such as those taken by NASS CDS researchers. Finally, images which were temporally non-current identified the conditions under which FARS geographical coordinates were used to extract Google Earth images. For the FARS crashes, there was no specified cycle during which the image was captured. Instead, the image provided corroboration of the crash location and possible trajectory clues, upon consulting coded elements.

## Roadway Departure Context

In 2009, the FHWA Office of Safety issued a roadway departure definition (Nicol, 2009), based upon FARS data elements, in response to the overwhelming contribution of this crash type in FARS. The data definition was coined to encourage individual states to adopt uniform reporting practices. These were concerned with first event impacts, owing to the disaggregation of vehicle events and basic crash initiation. Its extension to the NMVCCS data was considered as a context for the ***relevant element*** digital image review.

Although NMVCCS was initially identified as a substantial and untapped resource in describing the roadside environment (ESAR, 2010), its true contribution was not appreciated until FARS 2008 published geographical coordinates, with which the satellite images were used to study the crash scene and associated infrastructure, thereby enacting a digital image data extraction feasibility study. ESAR 2010 allowed for a rudimentary digital image review based upon images of infrastructure condition, within the context of vehicle damage and occupant outcome. Based upon the FARS study, supplementary issues of vehicle trajectory and multiple vehicle and event interactions were incorporated into crash understanding, as supported by the externally compiled crash scene images. Nicol (2009) provided the full FARS data definition, and its contents were used as the disaggregation for the FARS data and translated for use with NMVCCS variables and attributes. The current NMVCCS iteration yielded many unknown entries, owing to the focus and size of the sample, as well as attributes restricted by privacy concerns.

Table 2 provided an overview of the currently codified data, data desired but unavailable, and uncodified data but potentially available through digital image review. Although FARS, NASS CDS, and NMVCCS data allowed for greater data opportunity, the depth and breadth of supplementation was tempered by the privacy protocols and data collection mandate.

**Table 2.**
**Summary of Data, by Availability**

| Data Type | Data Elements | | |
|---|---|---|---|
| | Codified | Unavailable | Uncodified |
| Basic | Basic Vehicle Data | | |
| | Basic Occupant Demography | | |
| Crash | General Vehicle Contacts | Precise vehicle trajectory | Specific Type of Element |
| | *Geographical Location* | | Roadway, Roadside Description |

❑*Geographical Location* given for FARS, providing Google Earth Coordinates
❑NASS CDS and NMVCCS provide scene photographs

As the roadway departure issue had been defined as a substantial issue, with over half of fatalities attributable to this crash configuration, FHWA decided that this rubric required additional consideration and disaggregation. Many different countermeasures might address the crashes known, in aggregate, as roadway departure, and before 2009 defined within the NHTSA public health and safety context, for which vehicular and occupant protection countermeasures might be best defined. For FHWA, however, the data could conduct to better roadway solutions, by filtering and disaggregating by groups that might have similar countermeasures and conducting toward the NMVCCS Application of the roadway departure definition and analysis.

**NMVCCS Application**

Upon using NMVCCS for a study of valuable clues in crash causation yielded from on-site digital image capture, it was found that the condition of elements

was available and also useful. In this way, not only the greater confidence of a vehicular impact point owing to the paint transfer but also deformation characteristics, depending upon the element type and digital image detail. The yielded benefits outweighed the present disbenefits.

Most limitations relevant to this study involved the ability for the researcher to obtain meaningful crash scene digital images. This was compounded by NASS privacy protocols. Geographical coordinates were not provided owing to protocols protecting crash victim information in place for NASS. In the absence of geographical coordinates, the end-user was limited to the digital images offered by the NMVCCS researcher. Further, roadway conditions dictated the specificity of the image capture. In congested or complex roadway environments the researcher was forced to obtain capture images while driving past and slowing near the crash scene for his protection and those involved in the investigation. Researcher-determined views, vehicle kinematics, predominant crash-producing trajectory and damage driven were enumerated among strengths and weaknesses of the reporting. These disbenefits were tempered by yielded benefits.

The benefits of digital image review were found in the majority of cases reviewed for the roadway departure and selected other crashes. The images were found to provide insights on the crash scene and ***relevant elements*** involved in the impacts. These crash images went beyond mere corroboration of the elements, as was seen in the FARS study, owing to the temporal concurrence with which these images were captured. Many of the images were of strong enough quality to feed a supplementary ***relevant element*** data set.

**FARS and NASS CDS Methodology**

In contrast to the FARS methodology, in which the geographical coordinates were entered into Google Earth, yielding the requested roadway segment, the researcher captured images were the only basis for supplementary data. Occasionally, there was some guess work when assessing seemingly similar, contiguous roadway segments, as seen in Figure 3 for FARS cases. The graphic revealed the seeming guesswork involved in trajectory disentanglement. This was the sacrifice made for camera view autonomy.

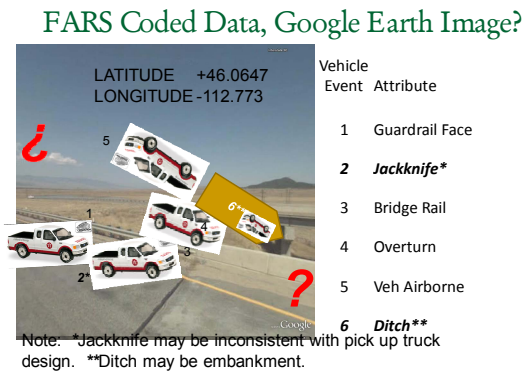



**Figure 3: FARS Supplemental Data Review using Google Earth.**

The temporally non-current digital images allowed for identification of the crash scene, ordering of vehicle events, and identification of at least one possible vehicle trajectory. Subject to image, type of ***relevant element*** might be identified, as well as its gross performance during the crash. The issue of design for planar crashes rather than rollover crashes yielded most crashes, although ending in fatality with ***relevant elements*** performing as designed. The design characteristics, however, may have been exceeded and examination of application might be warranted for specific situations. These situations included but not were not limited to: vehicle attitude, multiple impacts, and other vehicle interactions. It was also noted that cases were identified in which solutions might involve vehicle sensor and roadside hardware improvements to best mitigate the crash scenario. This would encourage the continued dialogue sustained by NHTSA and FHWA.

With near crash time data collection present in NASS CDS, although sacrificing specific location, increased confidence in the crash location and the elements captured in the images. Scene diagrams and crash summaries allowed for more accurate disaggregation of the crash into the constituent events, through the objects contacted, as seen in Figure 4.

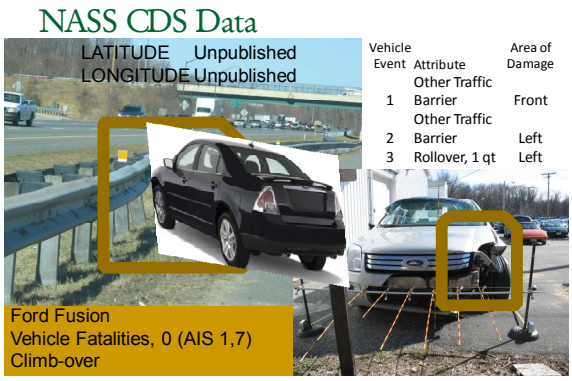



**Figure 4: NASS CDS Digital Image Data Review.**

As of 2007, crashes in which interaction with a ***relevant element*** occurred might have been appreciated through vehicle approach and detailed digital capture of the element. Although obscured by the sample image overlay in Figure 4, the guardrail deformation corresponding to the vehicle damage shown was matched to the post-crash vehicle image, to the left of Figure 4. The deformation corresponded to the vehicle hitting the guardrail and corroborated by the vehicle digital image. Additionally, further review might have been required to determine whether the planar capacity was within the bounds of retention in the travel direction, or whether the barrier contributed to the change in vehicle attitude, as suggested by the climb-over rollover type. In this case, however, vehicle technologies provided occupant protection. In the absence of any element of occupant retention, the outcome might have varied.

**Limitation of FARS and NASS CDS**

As seen in Figure 3, the overlay provided one possible representation of the vehicle events. Owing to the difference in timing between crash occurrence and digital image capture, important clues might have been lost or uncaptured. Further, Figure 3 suggested the identification of a classic problem: an inadequate connection of the stiffened guardrail transition elements to the bridge rail itself, but the evidence of an induced roll suggested that something upstream yielded too much allowing the vehicle to mount the barrier. With the limitations in coding and the non-temporal concurrence of the image, this was one of the theories that might accompany the proposed progression of events. In Figure 4, however, the timeline might have been such to capture damaged elements; however, the lack of scaling plagued most image review. The images might have been deemed for a qualitative review of the crash scene and the damaged elements but lack the detail or on-scene quality needed to assess barrier performance and vehicle interaction.

As with NASS CDS, NMVCCS provided valuable pictographic data with respect to type of hardware, interaction point with vehicle, damaged components, and complexity of damage. This information was envisioned to provide a micro view of the ***relevant elements*** populating the crash scene. With varied state reporting of roadway element inventories, providing a macro view of the overall roadway inventory, it has been difficult to understand the national roadway system, in terms of the placement and type of concrete barriers, guardrails, and impact attenuators. These, however, were better identified, predicated on digital image quality, as seen in Figure 5. For crash locations with the vehicle still at final rest, the ability to backtrack through the vehicle events has been facilitated. Not only has hardware been clearly identified but the condition of both the vehicle and hardware was better matched. Coded data and vehicle summaries provided the remaining interpretation clues necessary for translating most digital image data. Although some mystery still existed in these crashes, it transcended all understanding previously yielded through the near crash time or temporally non-current image data sets.

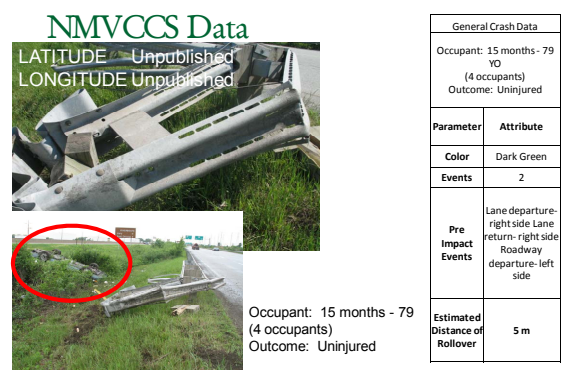



**Figure 5: NMVCCS Digital Image Data Review.**

The red circle in Figure 5 delineated the vehicle final rest, pursuant to a rollover crash involving a guardrail. The two-events, involved a planar interaction and a subsequent rollover crash. The digital image suggested a slotted kinking end terminal (SKT), designed to collapse. The rollover, however, might have been attributed to tire deflation or crash moment, as the vehicle moved toward the barrier. Although occupants were uninjured, it should be noted that not all occupant outcomes match this one. In fact, Figures 4 and 5 were selected owing to the clarity of the ***relevant elements*** rather than the vehicle damage and occupant outcomes. This was

done to highlight the digital image data codification possibilities when assessing planar design capacity and rollover exigencies beyond envisioned design parameters.

Unlike the FARS and NASS CDS, the on-scene condition of the barrier yielded complementary coded elements and researcher enterprise in relating hidden information unaccommodated in the coded elements, as seen in Figure 6.

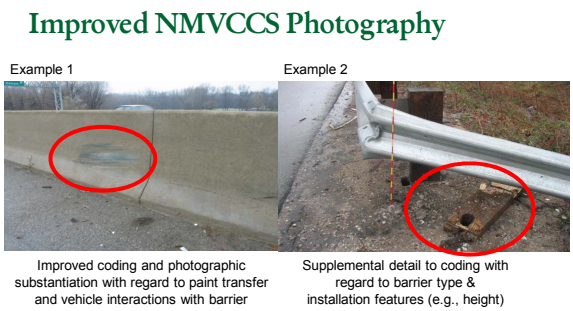



**Figure 6: NMVCCS Available Digital Image Data.**

Vehicle color reporting has been useful in reconstructing vehicle trajectory and understanding roadway element influence on vehicle damage and occupant outcome, as seen in Example 1. Although outside of the crash reporting norms, the vertical placement of vehicle damage measurement rod provided valuable information regarding guardrail height and damage location. The presence of measurement rods might be the only opportunity to obtain quantitative measurements of roadside hardware contained in the digital images, as related to the crash scene. True barrier height has become an area of interest, with variations pursuant to maintenance or roadside erosion. Another issue, absent from previous photographic and digital image capture and data collection, has been the constituent components of the ***relevant element***. The digital image capture yielded damaged components, whose shape and moisture seemed to be consistent with the digitally-captured crash scene.

## NMVCCS Digital Image Data, Specific Examples and Improvements – Crash-Time versus Near Crash-Time and Non-Temporally Consecutive Data

Through the FARS feasibility study, relevant codified variables were identified. Additionally, variables of interest, but unavailable via forensic analysis were identified. As noted in Table 2, perfect information will never be available from data sets designed to address issues of public health and vehicle design, however, it has been shown that the data sets might be repurposed to yield valuable data to the roadside design community, unavailable to date.

Many but not all ***relevant element*** crashes were able to be identified as roadway departure crashes. It should be recalled that the roadway departure definition was prepared using FARS variables and adapted to the working roadway departure definition applied by FHWA, Office of Safety. To that end, the roadway departure definition was retained as an additional descriptor; however, the ***relevant element*** crashes were eligible from any rubric. The subsequent examples provided major ***relevant elements*** types identified in NMVCCS and yielded proposed variables and attributes readily extractable pursuant to digital image review of qualified crashes.

**Example 1: Concrete Barrier**

Figure 7 yielded information relevant to a single vehicle and single event crash, with possible injury as most serious injury reported for this vehicle per KABCO rating. The vehicle stayed on the roadway but left the original travel lane with concrete barrier impact. The path to final rest provides clues regarding its trajectory, toward the top of the image. The vehicle impact point was corroborated by light blue paint transfers, coded as the vehicle color. This was classified as a roadway departure, with fixed object. Although designed as temporary measures, concrete barriers have been retained tacitly as long-term roadway design elements, meriting additional consideration.

**Figure 7: NMVCCS Trajectory and Impact Point, Concrete Barrier.**

A FARS case would have relied on the geographical coordinates to identify the specific concrete barrier section. Further, an observational injury rating might have been obtained. The information relevant to path and trajectory, which might have been used to interpret the digital image, would have been very basic and not enjoyed the possibility of the vehicle final rest in the image. The limitations would have

existed in the reconstruction of the crash events and the interpretation of crash scene digital image.

**Example 2: Cable Barrier**

Figure 8 yielded information relevant to a single vehicle and multiple event crash, with no reported injuries for this vehicle, per KABCO rating. The vehicle stayed in the original travel lane, as the cable barrier was contiguous to the roadway. The path to final rest provided clues regarding its trajectory, which were confounded owing to the presence of an object falling from a vehicle, precipitating the motion causing two subsequent barrier impacts. The barrier retained the vehicle in the travel direction, although rotating it to face traffic. Ultimately, the barrier impeded the departure on to the opposing roadway. The barrier was deemed to have performed as designed with the added benefit of no occupant injury and minimal vehicle damage. Again in this case, the paint transfer did not come into consideration. Instead, the depth of detail of the vehicle impact, with damaged guardrail support toward the top right of the image provided clues relevant to barrier durability, while performing as designed. This was classified as a roadway departure, with fixed object.

**Figure 8: NMVCCS Trajectory and Impact Point, Cable Barrier.**

FARS coders generally have categorized concrete barriers effectively, however, for barrier permutation; discernment varies by police officer and, ultimately, coder. The burden was somewhat eased by release of geographical coordinates. Until 2008, the engagement of the vehicle with a cable barrier would have been lost within an aggregated NASS CDS ***relevant element*** attribute, other barrier including guardrail, and possibly recounted in a crash summary. As there was no template for information included in the NASS CDS crash summary, this merely formed part of the universe of remote inclusion possibilities. This NMVCCS image allowed final rest point to retroactively reconstruct the crash events using objects contacted, and trajectories, compared with the digital image, yielding vehicle retention and damage information.

**Example 3: W-Beam Guardrail**

Figure 9 yielded information relevant to a single vehicle and multiple event crash, with no reported injuries for this vehicle, per KABCO rating. The vehicle departed the roadway, mounted the guardrail, dislodged and impacted a speed limit sign. Although a concept of the trajectory was available, it was evident that the addition of even one event introduced ambiguity, with regard to the influence of the ***relevant element***. This was tempered by the extreme improvement over roadside crash assessment, now available through the NMVCCS crash reporting. In this case, paint transfers were not visible, owing to the aspects offered through the digital image capture, obfuscated by the timing of vehicle removal and investigation conduct. This was classified as a roadway departure, with fixed object. The digital image suggested that a weak post system was in place owing to the accompanying guardrail deflection. The absence of reported injuries, also supported this contention, as the strong post and fixed guardrails were generally associated with higher injury severities (Ray, 2003). Additionally, it was surmised that insufficient entry speed was present, thereby retarding vehicle rollover.

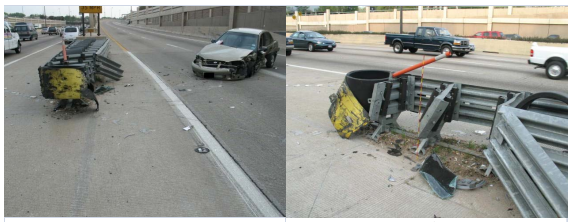
**Figure 9: NMVCCS Trajectory and Impact Point, W-Beam Guardrail.**

Of interest in Figure 9 would be the orientation, generally absent from coding found in FARS. NASS CDS crash summary and scene diagram might have effectively conveyed this condition. Its role in the crash versus mitigation might have been lost within coded details. Digital image review was considered the only true means of gaining a qualitative understanding of this crash.

**Example 4: Impact Attenuator**

Figure 10 yielded information relevant to a multiple vehicle and multiple event crash, resulting in a non-incapacitating injury reported as most serious for the vehicle per KABCO rating. The vehicle departed the roadway. As in Figure 9, potential vehicle trajectories were available. Uncertainty was added with the presence of another vehicle. Owing to the severe deformation of the guardrail, paint transfers

were not visible. The type of supports and their condition were readily evident in digital images other than those seen in final impact point image. Also, additional detailed digital images were provided in the case file, potentially supplementing the data shown in Figure 10. This was classified as crash type other or unknown, potentially owing to the limitation of translation of the FARS roadway departure data definition applied to NMVCCS variables .and attributes. The image suggested that the barrier performed as designed with the rails sliding back and managing energy by collapsing plastic cells and posts, as shown.



Vehicle Path to Final Rest | Vehicle Point of Final Impact

**Figure 10: NMVCCS Trajectory and Impact Point, Impact Attenuator.**

Even with detailed on-scene crash information, the presence of multiple vehicles and their subsidiary crash events, the crash scene was very complex. The digital images provided a plausible ordering for the coded elements, as well as chronicled the damage caused during this crash. This added level of detail would have been impossible to discern from FARS or NASS CDS, owing to the near crash or non-temporally concurrent data collection.

## Discussion

Figures 7 through 10 illustrated the range of roadside data that might be identified by querying NMVCCS for ***relevant elements***. Through the feasibility study, a data set concept has been conceived. Additionally, the contribution to the roadway departure problem and the role of the ***relevant element*** in the crash might be better understood.

Through the FARS feasibility study, the ***relevant elements*** were identified through Google Earth image. These shaped the filter applied to NMVCCS data. All NMVCCS ***relevant element*** cases yielded acceptable digital images. This was understandable owing to the fresh crash scene and detailed digital image capture. This was in contrast to FARS with nearly 30 percent of unusable ***relevant element*** crash images. The digital image capture did vary in quality owing to the prevailing roadway traffic and investigation conditions.

With the feasibility study, the range of variables and attributes possible for collection have been identified. For clear and detailed images, the type of ***relevant element*** might be described. Further, the contact points might be described, coincident to the vehicle impacts. The role of the element might be identified as causal to the outcome or serving in designed capacity. In some cases, exceeded design parameters might be identified. This might be extended to the role of vehicle attitude in the performance of the ***relevant element***. Condition of the element might also be identified. In one case sample seen in the feasibility study, a measurement rod provided valuable information regarding guardrail placement. Some data might be readily coded from all crashes, while other attributes might be reserved for capture from the best images. A baseline of data capture does exist, as seen in the Figures 7 through 10.

The degree of detail might have been dependent upon prevailing roadway conditions, which precipitated digital image capture as the vehicle moved past the crash scene. This might not have yielded the most intricate clues but served to better define the ***relevant element*** type.

With codification parameters established through the FARS feasibility study, Google Earth images governed the non-temporally consecutive digital images, however, the stability in ***relevant element*** choice allowed for review to provide additional facets to roadway study. This was applied to NASS CDS and NMVCCS, in the absence of roadway location but benefiting from the descriptive image capture. As seen in the examples, additional micro information might supplement the findings from those states with roadway element inventories of comparable detail for a balanced macro view. In the absence of standardized state roadway inventories, the micro view will provide valid insights into damage-producing crashes.

Data available from digital image capture to determine ***relevant element*** effectiveness might be inadequate. With regard to the micro inventory approach inventory, the possibility of populating a detailed inventory of ***relevant elements*** and their crash parameter exists. These include but would not be limited to damage measurements, influence of speed, and description of model and type of selected roadway elements.

## Opportunities

A thorough data mining of all the barrier impact cases in NMVCCS, and to a lesser extent, FARS and NASS CDS, using available data resources has been envisioned. This might yield several hundred cases that when stratified by type of barrier would potentially offer the safety community some new insights about such crashes and the influence of various factors. At minimum, the findings should support the knowledge yielded from crash testing and the limited extent of in-service roadway safety element evaluations that have been undertaken to date. This effort might be likened to one-time data capture of LBSS; however, any effort to review information might be suited to a searchable resource for future researchers. In light of the inconsistencies in state inventories and their associated crash experience, this micro approach has been suggested as a complement and a deepening of understanding beyond the macro state compilations. Although a mix of coded data and video logs has been employed, the micro repository might provide some nexus to the state offerings. Although efforts are underway to standardize state data inventories with the Model Inventory of Roadway Elements effort, the micro approach will provide data that is currently available and house results of immediate interest to the safety community.

**Case Pool and Repository**

The feasibility component has been completed for FARS crash years 2006 through 2009. In adherence to the roadway departure definition, application to crash years 2004 and 2005 will be undertaken, however, geographical location data has been made available for 2001 through 2003, also. NASS CDS digital image protocols seemed to improve in concurrence with the close of NMVCCS, in 2007. For that reason, 2007 through 2009 will be considered. Finally, all qualifying crashes will be included in the feasibility study. To date, the NMVCCS roadway departure classified crashes have been qualified for codification and work has started to qualify those crashes classified as other or unknown. A summary of the population from which the supplemental data set might be drawn is shown in Table 3.

It is noted that the film and digital crash images are not without limitations. This information does fill a void of identification and qualitative condition data. Refinements might be possible with respect to raw image files but limitations are outweighed by the wealth of previously unavailable data available for extraction from the images.

**Table 3.**
**Data Sets, by *Relevant Element* Vehicle Impact Event and Attitude**

| Potential Crashes for Review | | | | |
|---|---|---|---|---|
| Dataset | Years | Relevant Vehicles | Rollover among Relevant Cases | Relevant Vehicles to Total |
| NMVCCS | 2005-2007 | 126,384 (439) | 26% (20%) | 3.1% |
| NASS CDS | 2005-2009 | 1,542,633 (848) | 16% (20%) | 7.6% |
| FARS | 2001-2009 | 794 | 45% | 0.2% |

Upon completion of the feasibility study, identifying candidate cases for digital image codification, data identified in the discussion will be codified to form a supplementary ***relevant element*** data set, as set forth in Appendix A, Figure A1, with possible augmentation in areas such as ***relevant element*** deflection. This would become the repository for data collected and described above. Such an inventory might be useful to State Departments of Transportation to identify successful applications, determine replacements, and design safer solutions.

**Next Steps**

The feasibility study was limited to impacts, easily discernible in digital images and relevant to the roadway departure community. Upon completion of this phase, the extension to review all roadside features, using digital image capture supplementation, was suggested. Further, extension of the study to review ***relevant element*** impacts occurring during any event during the crash rather than first event might be considered. Although the complication of multiple event crashes was noted in the NMVCCS Specific Examples, it was suggested that the condition of the guardrail, if captured would provide useful insight from an environmental condition rather than a vehicle damage perspective.

## Potential Benefits to Safety Community

Ultimately, the data is envisioned to be made available to anyone interested in roadside safety. The dataset might also yield better understanding of crashes by vehicle attitude and crash mode. This is also foreseen to better explain the roadway departure definition by supplementing extracted graphic data. Each year, increased codified data drawn from compilation precedent will form a dataset from which answers might be drawn. Finally, synergies drawn from continued interagency cooperation will yield desired results by continuing to support the effort of

the FHWA Roadside Departure Team and the safety community at-large.

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## DISCLAIMER


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# Appendix A: Proposed Data Synthesis

| Dataset | Years | Rationale | Basic Image Review | Composite Image Review | Anatomy of Data Synthesis |
|---|---|---|---|---|---|
| Fatality Analysis Reporting System | 2004-2009 | Original Application of Roadway Departure Definition | FARS Coded Data, Google Earth Image<br>LATITUDE +46.0647<br>LONGITUDE -112.773<br>Vehicle Event Attribute<br>1 Guardrail Face<br>2 *Jackknife**<br>3 Bridge Rail<br>4 Overturn<br>5 Veh Airborne<br>6 *Ditch***<br>Note: *Jackknife may be inconsistent with pick up truck design. **Ditch may be embankment. | unavailable owing to non-temporal concurrence, image to crash | Query for relevant elements.<br>Extract geographical coordinate and vehicle events<br>Input geographical coordinates into Google Earth<br>Scan yielded image(s) and place event(s)<br>Develop trajectory scenario(s) |
| National Crashworthiness Sampling System Crashworthiness Data System | 2007-2009 | Photographic improvements made pursuant to NMVCCS data collection | NASS CDS Data<br>LATITUDE Unpublished<br>LONGITUDE Unpublished<br>Vehicle Event Attribute Area of Damage<br>1 Other Traffic Barrier Front<br>2 Other Traffic Barrier Left<br>3 Rollover, 1 qt Left<br>Ford Fusion<br>Vehicle Fatalities, 0 (AIS 1,7)<br>Climb-over | unavailable owing to non-temporal concurrence, image to crash | Query for relevant elements.<br>Scan image(s) and place event(s)<br>Review images for researcher or police markings on elements.<br>Review researcher crash summary.<br>Develop trajectory scenario(s). |
| National Motor Vehicle Crash Causation Study | 2005-2007 | Dataset span owing to the on-scene data collection | Improved NMVCCS Photography<br>Example 1<br>Example 2<br>Improved coding and photographic substantiation with regard to paint transfer and vehicle interactions with barrier<br>Supplemental detail to coding with regard to barrier type & installation features (e.g., height) | Vehicle Path to Final Rest<br>Vehicle Point of Final Impact<br>Vehicle Path to Final Rest<br>Vehicle Point of Final Impact<br>Vehicle Path to Final Rest<br>Vehicle Point of Impact<br>Vehicle Path to Final Rest<br>Vehicle Point of Final Impact | Query for relevant elements.<br>Scan image(s) and place event(s)<br>Review images for researcher or police markings on elements.<br>Review vehicle final rest images, when available.<br>Review researcher crash summary.<br>Develop trajectory scenario starting with vehicle final rest.<br>Assemble images supporting final rest path and relevant impact. |
| Proposed Supplementary Dataset Variables and Attributes | 2004-2009 | Based upon review of FARS, NASS CDS, and NMVCCS photographs | Variables | Element / Perform, / Causal / Damage / Paint / Not required Element / Height, Element / Width, Element / Depth, Element / Attribute, Element | Concatenate findings for all data sets. |
| | | | *Attributes, for proposed Variables* | *Type* / *per Design* / *Damage* / *Type* / *Transfer* / *rod measure* / *with units* / *with units* / *with units* / *guardrail base* | Note the data set and case number. |
| | | | | *concrete barrier, specify* / *redirect, planar* / *yes* / *scuff* / *yes, color* / *other, specify* / / / / *damage height* | Provide information, as data set and image permits. |
| | | | | *cable median barrier* / *exceeded design, planar* / *no* / *scrape* / *no* / / / / / *guardrail top* | |
| | | | | *W-beam barrier* / *exceeded design, rollover* / / *paint transfer* / / / / / / *debris, specify* | |
| | | | | *??* / / / *displace* / / / / / / | |
| | | | | / / / *dislodge* / / / / / / | |
| | | | | / / / *deform* / / / / / / | |

**Figure A1: Proposed Dataset Extraction Schema, for Relevant FARS, NASS CDS, and NMVCCS Crashes**