APPENDIX A: METHODOLOGY FOR DETERMINING CRASH SCENARIOS

Objective and Data Source

The objective of the pre-crash developed for this study was to group collisions in national crash databases by similar pre-crash configurations. To accomplish this goal, we examined three variables available in many of the NHTSA crash test databases: pre-crash critical event, accident type, and pre-crash movement.

The databases used for this study (NASS/GES, NASS/CDS, FARS, and NMVCCS) are provided by NHTSA to the public via download (ftp://ftp.nhtsa.dot.gov/). Files are sometimes modified from their original release, to correct mistakes in the data. GES 2010 files were dated October 11, 2011 and 2011 files were dated December 9, 2012. CDS 2007 files were dated August 15, 2008, 2008 files were dated December 1, 2011, 2009 files were dated September 20, 2010, 2010 files were dated September 11, 2011, and 2011 files were dated December 18, 2012. FARS 2010 files were dated July 31, 2012 and 2011 files were dated August 14, 2012. The NMVCCS file was dated July 20, 2008.

Crash Scenario Approach

In the NHTSA databases, the critical pre-crash event, pre-crash movement, and accident type variables provide information about the configuration and driver maneuvers prior to each vehicle. Figure A1 shows the approach developed for this study to classify collisions using database variables. Example values for each variable are provided below for the striking vehicle of the rear-end crash shown above. The critical pre-crash event is the event that made the crash imminent as determined by the investigator. The databases in our study had 92 critical event categories. The accident type variable describes the configuration of the crash for the first harmful event and has approximately 100 values. Finally, the pre-crash movement describes the vehicle's activity prior to the crash, such as decelerating in lane, passing, or going straight. Together these three variables were used to assign every vehicle in each database a pre-crash scenario. Each crash was assigned a scenario based upon the actions of the two vehicles involved in the first harmful event in the crash.

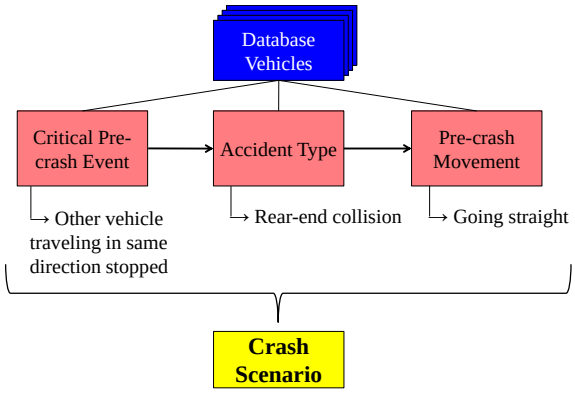

Figure A1. Approach for Determining Pre-Crash Scenario from NASS/CDS Variables.

Figure A2 shows photographs taken as part of a fatal rear-end collision involving a 2010 Ford Fusion (bottom of Figure A2) which struck a 2007 Subaru Impreza (top), which was stopped in traffic. The case was investigated as part of the CDS database (Case 2010-82-137). This case is an example of a crash that would be applicable to a forward crash avoidance system. The driver of the Impreza, a 37-year-old male, was fatally injured (brain stem transection) while a 3-year-old female in a child seat in the middle position of the back seat only suffered moderate injuries (a foot fracture and lung contusion). The driver of the Fusion was a 49-year-old male who had a 0.0 blood alcohol concentration as measured by a police administered test. The driver of the striking vehicle was seriously injured with bilateral rib fractures that required a 9-day hospitalization.

Figure A2. Photograph from NASS/CDS Investigation of a Fatal Rear-end Collision (Case 2010-82-137).

In many cases the critical pre-crash event and accident type variables indicate very similar information, such as in the example rear-end crash above. The accident type variable corresponds to the first impact in a crash whereas the critical pre-crash event describes what made the first pre-crash event unavoidable. In some scenarios this can lead to meaningful differences with regard to if an active safety system would activate. Consider NASS/CDS case 2011-41-116 whose scene diagram is shown in the left of Figure A3. Vehicle 1, a 2001 Mercedes Benz E-class departed its lane and struck vehicle 2, which was stopped. The pre-crash critical event for the striking vehicle was “this vehicle traveling over the left lane line” and the accident type was a rear-end collision. The pre-crash maneuver of the striking vehicle was going straight, not changing lanes or avoiding another critical event. For the study of active safety systems, this crash would most likely be mitigated by a Lane Departure Warning (LDW) system that could have warned the driver he was exiting his lane.

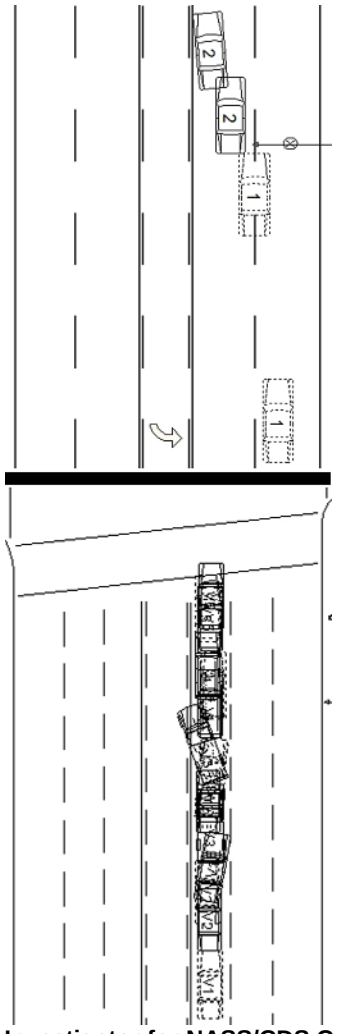

Figure A3. Scene Diagram Prepared by Investigator for NASS/CDS Cases 2011-41-116 (Left) and 2010-82-137 (Right).

Compare this rear-end crash with the one involving the Fusion and Impreza, shown in the right of Figure A3. FCAS could more likely be applicable to this crash because the struck vehicle would have been in view of the front-facing sensors in time to either deliver a warning or take action. In our approach to assign pre-crash scenarios, the pre-crash critical event was prioritized over accident type because it described the portion of the pre-crash phase where active safety systems would activate more completely.

Crash Scenarios

Figure A4 shows the single vehicle crash scenarios: single vehicle crashes with fixed objects on the roadside, control loss, animal in the road, pedestrian or cyclist in the road, object in the road, and other.

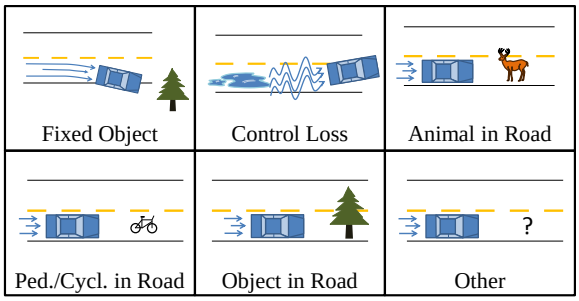

Figure A4. Single Vehicle Crash Scenario Categories.

Similarly, scenarios for multiple vehicle collision are shown in Figure A5. For target population analysis, many of these crashes can be broken down further into subgroups based on pre-crash maneuver (e.g. turning, going straight) or by object struck.

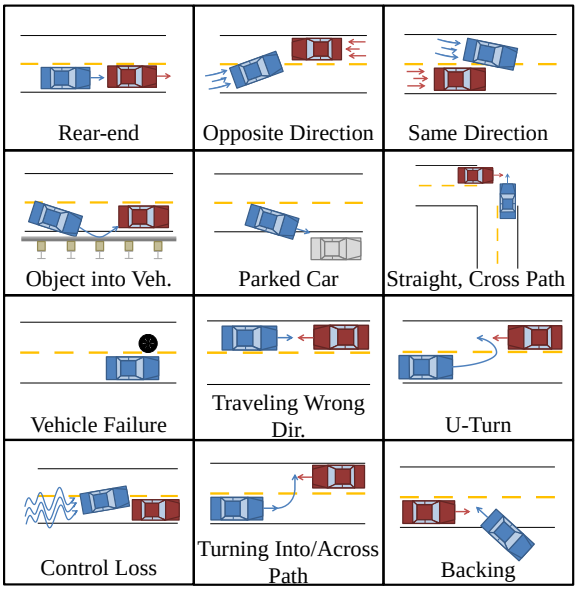

Figure A5. *Multi-Vehicle Crash Scenario Categories.*

Table A1 lists the distribution of pre-crash scenarios by the number of all severity, tow-away, and fatal crashes. Table A2 lists the distribution of pre-crash scenarios for all occupants, seriously injured occupants, and fatalities.

NHTSA uses a pre-crash envelope definition of the pre-crash that describes what caused the crash to become unavoidable. Using the general crash scenarios developed here, more detailed analysis can be performed. For example, the number of control loss crashes potentially caused by weather can be examined by tabulate the weather conditions for crashes in the control loss category.

Table A1. Distribution of Crash Scenarios for All Severity (GES 2010-2011), Tow-Away Severity (NASS/CDS 2007-2011), and Fatal Severity (FARS 2010-2011)

	Crashes			% Crashes		
Scenario	**All Severity (GES)**	**Tow-Away (CDS)**	**Fatal (FARS)**	**All Severity (GES)**	**Tow-Away (CDS)**	**Fatal (FARS)**
No Scenario	262,843	113,458	1,703	3%	1%	3%
Sing Veh - Departure	1,246,953	1,777,338	18,041	12%	17%	32%
Sing Veh - Control Loss	767,361	1,164,234	6,293	7%	11%	11%
Sing Veh - Animal in Road	551,988	196,984	648	5%	2%	1%
Sing Veh - Ped/Cyclist in Road	173,260	9,950	6,684	2%	0%	12%
Sing Veh - Object in Road	52,144	54,127	90	1%	1%	0%
Sing Veh - Other	162,961	57,421	909	2%	1%	2%
Mult Veh - Rear-end	3,375,457	2,526,304	3,723	32%	25%	7%
Mult Veh - Opp Dir, no turning	135,545	239,757	5,549	1%	2%	10%
Mult Veh - Same Dir, no turning	692,601	253,402	849	7%	2%	1%
Mult Veh - Control Loss	165,194	272,652	1,832	2%	3%	3%
Mult Veh - Object into Vehicle	0	27,046	4	0%	0%	0%
Mult Veh - Parked Car	7,715	211,209	291	0%	2%	1%
Mult Veh - Crossing Path, Both Straight	703,792	909,727	3,971	7%	9%	7%
Mult Veh - Turning Into/Across Path	1,676,597	2,193,720	4,409	16%	21%	8%
Mult Veh - Wrong Direction	10,127	26,216	569	0%	0%	1%
Mult Veh - U-turn	76,535	68,417	226	1%	1%	0%
Mult Veh - Backing	166,700	30,525	51	2%	0%	0%
Vehicle Failure	74,029	107,784	530	1%	1%	1%
Multiple/Conflicting Scenarios	97,043	23,563	283	1%	0%	0%
No Driver	5,717	4,018	90	0%	0%	0%
Total	10,404,563	10,267,849	56,745	100%	100%	100%

Table A2. Distribution of Scenarios for All Occupants (GES 2010-2011), Seriously Injured Occupants (NASS/CDS 2007-2011), and Fatalities (FARS 2010-2011)

	Occupants (All/Injured/Fatalities)			% Occupants		
Scenario	**All Occ. (GES)**	**MAIS3+ Occ. (CDS)**	**Fatalities (FARS)**	**All Occ. (GES)**	**MAIS3+ Occ. (CDS)**	**Fatalities (FARS)**
No Scenario	2,878,851	4,315	1,885	4%	1%	3%
Sing Veh - Departure	7,150,105	109,596	19,234	10%	31%	31%
Sing Veh - Control Loss	2,834,048	50,972	6,876	4%	15%	11%
Sing Veh - Animal in Road	2,133,696	1,205	668	3%	0%	1%
Sing Veh - Ped/Cyclist in Road	1,428,773	0	6,743	2%	0%	11%
Sing Veh - Object in Road	100,626	23	97	0%	0%	0%
Sing Veh - Other	1,605,906	1,007	965	2%	0%	2%
Mult Veh - Rear-end	26,178,075	25,375	4,122	35%	7%	7%
Mult Veh - Opp Dir, no turning	1,397,609	38,897	6,712	2%	11%	11%
Mult Veh - Same Dir, no turning	7,801,025	5,748	948	10%	2%	2%
Mult Veh - Control Loss	1,214,458	18,084	2,126	2%	5%	3%
Mult Veh - Object into Vehicle	0	2,122	5	0%	1%	0%
Mult Veh - Parked Car	38,804	2,444	348	0%	1%	1%
Mult Veh - Crossing Path, Both Straight	5,357,616	27,460	4,459	7%	8%	7%
Mult Veh - Turning Into/Across Path	11,802,498	54,477	4,682	16%	16%	8%
Mult Veh - Wrong Direction	52,844	2,909	704	0%	1%	1%
Mult Veh - U-turn	594,974	1,491	239	1%	0%	0%
Mult Veh - Backing	1,228,037	177	55	2%	0%	0%
Vehicle Failure	272,519	4,023	636	0%	1%	1%
Multiple/Conflicting Scenarios	1,166,662	319	321	2%	0%	1%
No Driver	2,377	0	94	0%	0%	0%
Total	75,239,504	350,645	61,919	100%	100%	100%

Target Populations for Active Safety Systems

This section tabulates the annual number of crash that are applicable to each of the four active safety systems examined for this study. The data in these tables was used to create **Error! Reference source not found.** and **Error! Reference source not found.** in the body of this paper. Table A3 lists the number of annual number of all severity, serious injury, and fatal crashes that could be potentially mitigated by each active safety system.

Table A3. Annual Number of All Severity, Serious Injury, and Fatal Crashes Applicable to Active Safety Systems

Category	Group	FCW	PCAS	LDW	V2V/V2I	Combined
Pre-Crash Scenario	All Crashes	1,583,155	48,077	713,433	1,031,811	3,376,476
	MAIS3+ Crashes	3,921	0†	23,822	14,208	41,951
	Fatal Crashes	1,833	3,051	12,357	4,422	21,662
	% Distraction Critical Reason (NMVCCS)	53%	53%‡	24%	51%	34%
Adjusted for Distraction	All Crashes	838,387	25,460	167,855	338,939	1,155,258
	MAIS3+ Crashes	2,076	0†	5,605	4,667	14,353
	Fatal Crashes	970	1,615	2,907	1,453	7,412

†NASS/CDS does not include crashes with pedestrians and cyclists
‡NMVCCS also does not contain pedestrian crashes. For this study we assumed the proportion of distracted drivers in PCAS crashes would be the same as that for FCW applicable crashes.

APPENDIX B: CATEGORIES OF CRITICAL REASON IN NMVCCS

The critical reason for a crash in NMVCCS could have a possible 67 levels, which are grouped by similar critical reason to get 11 primary categories, summarized in Table B1.

Table B1. Examples of Critical Reasons Categories from NMVCCS Coded Critical Reason

Derived Category	Example (critical reason from NMVCCS)
Non-Performance Error	Sleeping
	Heart attack or other physical impairment
	Other Critical Non-performance
Distraction	Inattention (i.e. daydreaming)
	Internal Distraction
	External Distraction
	Inadequate Surveillance
Speed Related	Too fast for conditions
	Too fast to respond
	Too fast for curve/turn
Judgment Error	Misjudged gap or other's speed
	Following too Closely
	False Assumption of Other's Actions
Illegal Maneuver	e.g. Illegal Passing, turned from wrong lane
Aggressive Acts	Rapid/Frequent Lane Change, Rapid Accelerating, Obscene Gestures
Inadequate Evasive Maneuver	Inadequate Action (e.g. braking only)
	Incorrect Action
Performance Error	Panic/Freeze
	Overcompensation
	Poor Direction Control
Vehicle Failure	Brakes Failed
	Tires/Wheels Failed
	Steering Failed
	Transmission/Engine Failure
	Cargo Shifted
Highway Conditions	Signs/Signals Missing
	View Obstructed by Road Design
	Maintenance Problems
	Slick Roads
Environmental Conditions	Rain, snow
	Fog
	Glare
	Blowing Debris

APPENDIX C: SAS SOURCE CODE FOR DETERMINATION OF PRE-CRASH SCENARIOS

This appendix contains the source code for determining pre-crash scenarios used in this paper. Code is presented for NASS/CDS. To run the code, the user must download the NASS/CDS case year 2011 files from ftp://ftp.nhtsa.dot.gov/. The user should change both "libname" statements in File 1 to the location of the NASS/CDS SAS files. NASS/GES, FARS, and NMVCCS pre-crash scenarios can be found in similar fashion. This source code is also available for download online at http://www.kriskusano.com/precrash

At the end of the process, the distribution of crash scenarios should match Table B1 (note the data is unweighted).

Table C1. Crash Scenarios for NASS/CDS 2011

Scenario (crash_scen)	Frequency (unweighted)
Mult Veh - Turning Into/Across Path	934
Sing Veh - Departure	922
Mult Veh - Rear-end	788
Mult Veh - Crossing Path, Both Straight	497
Sing Veh - Control Loss	400
Mult Veh - Opp Dir, no turning	173
Mult Veh - Same Dir, no turning	118
Mult Veh - Control Loss	112
Mult Veh - Parked Car	87
No Scenario	55
Mult Veh - U-turn	46
Sing Veh - Animal in Road	46
Mult Veh - Object into Vehicle	26
Vehicle Failure	26
Sing Veh - Object in Road	14
Mult Veh - Wrong Direction	13
Mult Veh - Backing	8
Multiple/Conflicting Scenarios	6
Sing Veh - Other	6
Sing Veh - Ped/Cyclist in Road	1
Total	4278