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Advanced Crash Avoidance Technologies (ACAT) Program – Final Report of the GM-VTTI Backing Crash Countermeasures Project

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16. Abstract

The Backing crash Countermeasures project, part of the U.S. Department of Transportation's Advanced Crash Avoidance Technologies (ACAT) program, developed a basic methodological framework and computer-based simulation model to estimate the effectiveness and potential safety benefits of various backing crash countermeasure systems. The project was led by the General Motors Corporation (GM) with support from Virginia Tech Transportation Institute (VTTI), and involved a series of tasks which included: characterizing backing crashes, assembling a research test bed for use within the project, developing a series of objective testing procedures to characterize backing crash countermeasure system performance, and developing and exercising a computer-based Safety Impacting Methodology (SIM) model used to estimate the effectiveness and potential safety benefits of the prototype backing crash countermeasure system evaluated. The SIM was designed with an emphasis on three key characteristics: accuracy and precision of estimates, modularity, and flexibility. Despite the availability of prior work and extensive data collection within the project, many limitations remain. While the SIM serves as a useful tool to bring together data from a wide array of research into a unified simulation, the limitations identified constrain its usefulness in predicting potential real world safety benefits of emerging backing crash avoidance systems. Benefit estimates from the SIM should be considered preliminary indications of backing crash countermeasure performance useful in studying the interaction of technology with driver behavior at various stages along the crash timeline.

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PREFACE

Advanced Collision Avoidance Technologies (ACAT) Research Program

The automotive industry has made significant progress in the development of advanced technologies intended to prevent crashes and their consequences. Advanced technologies that include sensing, computing, positioning, and communications may have the ability to help drivers avoid crashes or events that often lead to crashes and to reduce the severity of crashes that do occur.

However, the effectiveness of advanced technology safety systems in reducing crashes is not well understood. General Motors was one of four teams awarded an ACAT Cooperative Agreement in the Fall of 2006.

General Motors identified a prototype crash avoidance system that may help drivers to avoid backing crashes. A set of scenarios that represent backing crashes were identified using data from a variety of crash data sources. This work utilized national and state crash databases, previous empirical work, and targeted crash investigations to identify key factors and moderating variables thought to contribute to the crash problem. Under this project Safety Impact Methodology (SIM) was developed to estimate the safety benefits of the prototype technology. An estimate of effectiveness for this technology was developed using the SIM.

The ACAT program was a proof-of-concept effort that sought to determine the feasibility of developing estimates of effectiveness for specific safety technologies in the absence of data from real-world or field operational tests. This project was successful at developing and demonstrating a methodology that could be used to estimate the safety effectiveness of the particular backing crash countermeasure evaluated in this research project. In addition, the project used data that was publicly available at the time of development. Therefore data from additional backing crashes that were investigated by NHTSA after 2006 and the new Not-in-Traffic Surveillance (NiTS) data source are not included in this effort. A follow-on effort would be needed to incorporate any new data and would change the effectiveness estimates generated in this study.

Executive Summary

This project, part of the United States Department of Transportation's Advanced Crash Avoidance Technologies (ACAT) program, developed a basic methodological framework and computer-based simulation model to estimate the effectiveness and potential safety benefits of various backing crash countermeasure systems. A prototype suite of integrated backing crash countermeasures was evaluated and its performance was characterized using a set of objective test protocols. These protocols involved the application of a series of unique tests designed to assess system parameters relating to response sensitivity to stationary and moving obstacles (of varying types and sizes) under a range of backing conditions, false alarm rate performance, and driver interactions and responsiveness to system information, warnings, and interventions. These test results provided data for use in the computer-based Safety Impact Methodology (SIM) model used to estimate the effectiveness and potential safety benefits of the prototype backing crash countermeasure system evaluated.

The project was conducted cooperatively through an agreement between the National Highway Traffic Safety Administration and General Motors Corporation (GM) with support from Virginia Tech Transportation Institute (VTTI), and followed a process (the "SIM process") which involved a series of tasks: characterizing backing crashes, developing initial requirements for backing crash countermeasure systems, assembling a research test bed for use within the project, developing a series of objective testing procedures to characterize crash countermeasure system performance, and developing and exercising a model to estimate system effectiveness and potential safety benefits.

Initial work in the SIM process focused on identifying a set of scenarios to represent backing crashes and to examine the robustness of those scenarios using data on backing crashes from a variety of crash data sources. This work utilized national and state crash databases, previous empirical work, and targeted crash investigations to identify key factors and moderating variables thought to contribute to the crash problem. A small set of representative backing crash scenarios was identified to serve as a basis for generating objective tests and for assessing a range of possible countermeasures. This set consisted of 10 scenarios selected to represent backing crashes to include: six scenarios involving backing conflicts with children (pedestrians), three scenarios involving backing conflicts with vehicles, and one scenario involving a backing conflict with a fixed object. Special emphasis was placed on pedestrian crashes because of the complexity of pedestrian backover crashes. Scenarios were largely identified through a reasoned analytic process, making best use of the limited data available.

Once the backing crash scenarios were identified, a set of 15 objective tests was developed to characterize system performance and provide data for use in the SIM. The approach to objective testing integrated various backing scenarios using common underlying factors to collapse across conditions (e.g., reduce the number of necessary tests). Three types of objective tests were defined to capture different aspects or dimensions of backing crash countermeasure system performance. Grid Tests of System Response Performance measured the system's ability to respond to obstacles, including coverage and response zones for static and incurring obstacles under a range of situations. Included as part of the set of obstacles utilized were a unique set of test properties which were developed and verified for use in pedestrian conflict scenarios. Data from the Grid tests were used to define areas

behind the vehicle where an object is likely to trigger a system response (i.e., response zones). Tests of False Alarm Performance assessed the extent to which active backing countermeasures are likely to issue unhelpful alerts, warnings, or interventions (false system activations) under typical operating environments. Driver-in-the-Loop Performance tests used naïve participants to drive the vehicle and exercise the system in a context resembling a conflict scenario in order to gauge driver interactions and performance in response to the countermeasure system. Unlike the Grid tests, Driver-in-the-Loop tests do not assess the system's response performance. Rather, these tests yield measures of driver responsiveness to the information, warnings, and control assistance provided by the backing countermeasures. Thus, objective tests were designed to assess those aspects of countermeasure effectiveness involving both the vehicle and driver (e.g., how well sensors/processors cover the vehicle-obstructed areas for obstacles of interest; the propensity for false alarms in representative environments; and how driver and vehicle respond together as a system). Taken together, these objective tests were designed to provide specific inputs to the SIM model. The results of any given test cannot be used in isolation to assess system effectiveness. The SIM model is required to integrate the performance results as a whole.

The SIM model was designed with an emphasis on three key characteristics: 1) accuracy and precision of estimates; 2) modularity to allow components to be added or subtracted as needed for the situation being modeled; and 3) flexibility to accommodate countermeasures that are outside its original scope provided that sufficient data are available to characterize these technologies. The SIM model is implemented within the Matlab engineering environment using the Simulink simulation language which is embedded within Matlab. Model parameters were populated using a variety of data sources, including: national databases such as the Fatality Analysis Reporting System (FARS), the General Estimates System (GES), the Crashworthiness Data System (CDS), the Centers for Disease Control (CDC), naturalistic driving studies (e.g., Dingus, et al., 2006), nontraditional sources such as "Kids and Cars," the National Center for Health Statistics (NCHS), existing GM-sponsored empirical studies assessing backing-collision avoidance technology, as well as objective tests developed under the current project.

An integrated suite of backing crash countermeasures was configured for evaluation in this project and incorporated into a 2008 Chevrolet Tahoe. The research test bed was comprised of four features which shared sensors and computational hardware: 1) Rear Vision which provided the "Enhanced View" function, 2) Rear Park Assist, or Park Aid which provided the "Proximity Information" function, 3) Backing Warning including audible and brake pulse cues, and 4) Automatic Braking. This feature set was developed to provide support for the driver throughout the backing crash sequence from pre-conflict through the crash phase with different backing crash countermeasures providing assistance at one or more of phases of the backing sequence. These components are fully integrated, providing a range of backing countermeasures: from increased visibility or an advisory warning to fully automated stopping of the vehicle. This capability was used to obtain a range of objective test data to exercise the computer-based SIM model.

The SIM model was exercised through the 10 different backing crash scenarios. Estimates of potential safety benefits were generated along with descriptors of the characteristics of crashes and avoidance trials for each scenario. The model also provided the ability to define which components of the countermeasure are active and the rates at which the model estimates driver-initiated braking, automatic braking, or both types of braking to be present. A number of limitations of the SIM process for predicting safety benefits of emerging crash avoidance systems were identified. More specifically, despite the availability of prior work and extensive data collection within the project, the SIM model includes a wide range of simplifying assumptions and restrictions.

Limitations identified include:

- *The SIM model's ability to accurately represent elements of "exposure ratio."* This ratio requires information about the likelihood that the conditions for a particular conflict are present. While efforts were made to draw from a plausible range of environmental characteristics and elements commonly found in backing crash environments, these are by no means exhaustive. The full range of potential situations and objects, as well as the base rate occurrences for these types of scenarios is unknown. Additional data are needed to understand and map the exposure rates for various backing crash-specific situations.

- *Missing or limited data related to the potential for unintended consequences and the influence of false alarm frequency on driver behavior during prolonged exposure in the real world.* The SIM model only represents scenarios where an actual conflict situation is present. It does not model potential unhelpful countermeasure activations in situations where no actual conflict is present.

- *Insufficient data to model the following factors as variables*: environmental conditions (e.g., weather, light); object conspicuity (e.g., size, shape, color, reflectivity, etc.); camera / display / warning characteristics; backing vehicle type and configuration (e.g., body type and size, window glazing, headrests, etc.); driver characteristics (e.g., age, height, visual ability, flexibility, etc.); driver expectancy (i.e., novel versus typical situation); and driver familiarity with and reliance on the available crash countermeasures (including trust).

- *The coarseness of the data available for different kinematic and environmental conditions.* Despite extensive data collection, objective tests' results only represent a sampling of the range of situations and conditions identified. The accuracy of the model is limited by the number of trials used to assess system response probabilities.

Benefits estimates from the SIM model should be considered preliminary, order-of-magnitude estimates bound by the available data and test conditions used to feed the model.

The ACAT program was a proof-of-concept effort that sought to determine the feasibility of developing estimates of effectiveness for specific safety technologies in the absence of data from real-world or field operational tests. This project was successful at developing and demonstrating a methodology that could be used to estimate the safety effectiveness of the particular backing crash countermeasure evaluated in this research project. In addition, the project used data that was publicly available at the time of development. Therefore data from additional backing crashes that were investigated by NHTSA after 2006 and the new Not-in-Traffic Surveillance (NiTS) data source are not included in this effort. A follow-on effort would be needed to incorporate any new data and would change the effectiveness estimates generated in this study.

1 INTRODUCTION

This project, part of the Advanced Crash Avoidance Technologies (ACAT) program, focuses on backing-related crashes where an object, vehicle, or person is struck, and addresses the following two major project objectives:

> Objective 1: Utilize a standardized Safety Impact Methodology (SIM) process to evaluate the ability of advanced technology applications in full vehicle systems to solve specific motor vehicle safety problems; in this case, mitigate backing crashes.
>
> Objective 2: Demonstrate how the results of objective tests and available data can be used by the SIM to estimate the safety impact of a real-world backing crash countermeasure system.

The ACAT program was a proof-of-concept effort that sought to determine the feasibility of developing estimates of effectiveness for specific safety technologies in the absence of data from real-world or field operational tests. This project investigated developing and demonstrating a methodology that could be used to estimate the safety effectiveness of the particular backing crash countermeasure evaluated in this research project. In addition, the project used data that was publicly available at the time of development. Therefore data from additional backing crashes that were investigated by NHTSA after 2006 and the new Not-in-Traffic Surveillance (NiTS) data source are not included in this effort. A follow-on effort would be needed to incorporate any new data and would change the effectiveness estimates generated in this study.

Five tasks were defined and implemented to support these general project goals and demonstrate proof-of-concept. These include the following:

1. Development of a preliminary SIM,
2. Determination of the Safety Area to be Addressed and the Advanced Technology to Address it,
3. Development of Objective Tests to Support the Estimation of Safety Benefits,
4. Conduct of Objective Tests, and
5. Development of Safety Benefits Using the SIM.

Task 1 was designed to lead to the development of a standardized and adaptable SIM - an objective computational tool that provides a framework for estimating safety benefits based on the results of objective tests of full-vehicle systems. The SIM was developed and exercised by applying data related to a prototype backing crash countermeasure system which provided assistance functions ranging from warnings to automated control intervention.

Task 2 defines and characterizes the safety problem (defines crash scenarios and sequences associated with the backing problem) and identifies relevant advanced countermeasure technologies. This task increases understanding of the backing crash problem using data from a range of available sources, including traditional sources (e.g., the Fatality Analysis Reporting System [FARS], the General Estimates

System [GES], State crash databases, the National Electronic Injury Surveillance System(NEISS), naturalistic research) and non-traditional sources (e.g., the Centers for Disease Control [CDC], "Kids and Cars," National Highway Traffic Safety Administration's [NHTSA] Special Crash Investigations [SCI] Unit) to further define the crash problem and identify crash scenarios. Activities under this task also support the specification of advanced technologies and countermeasures by delineating how the technology assists in improving safety for defined crash scenarios.

In Task 3, objective tests are defined and developed to characterize and assess countermeasure system performance. These performance-based tests are intended to characterize various aspects or dimensions of backing crash countermeasures and provide data to the SIM for estimating the effectiveness and potential safety benefits of the backing crash countermeasure systems.

Task 4 provides the opportunity gather objective test data on a set of backing crash countermeasures using the objective test protocols developed under Task 3. Data representing system performance will serve as input to the SIM in evaluating the effectiveness of these advanced backing crash countermeasure technologies.

Task 5 provides an estimation of potential safety benefits by utilizing the SIM. Data from Task 4 and other relevant data sources are input into the model and used to provide safety benefit estimates for the backing crash countermeasures. This task essentially exercises the SIM computer-based model.

Figure 1 illustrates the general approach and task interrelationships adopted under this ACAT backing crash countermeasure project.

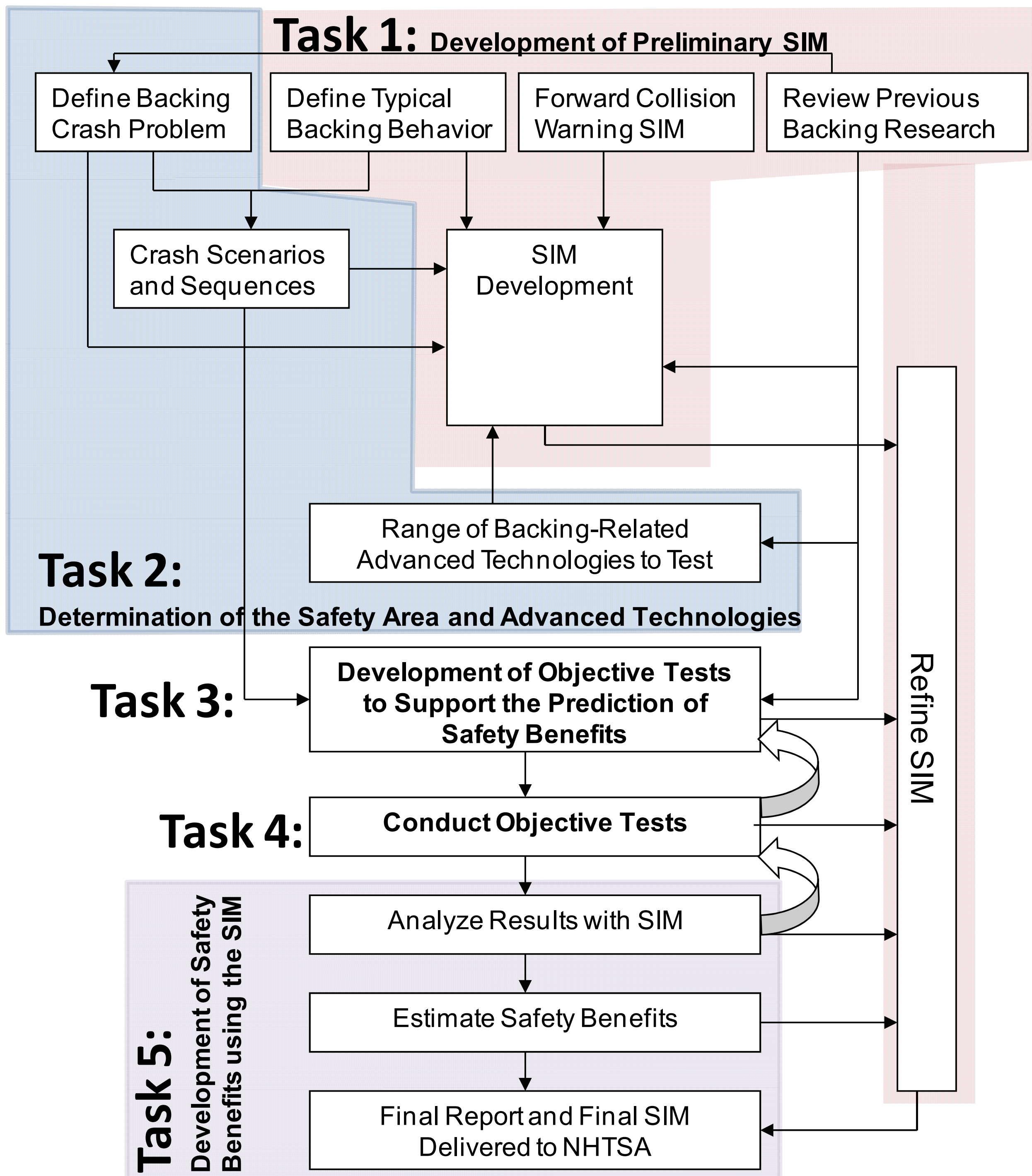


Figure 1. Project Overview.

2 SAFETY AREA AND COUNTERMEASURE DESCRIPTION

2.1 Overview

The safety area upon which this project focused was that of ***backing crashes***. This area encompassed backing crashes of all types (e.g., backing crashes with pedestrians, fixed objects, and vehicles), but an emphasis was placed on understanding the most complex of these to address with technology (i.e., child pedestrian backover crashes). As part of an effort to develop a SIM, the project began by examining, understanding, and characterizing backing crashes, then proceeded with the development of initial requirements for countermeasure systems that could be used to address these crashes and identified a prototype backing crash countermeasure system that could be evaluated within the project using the SIM. The Safety Area (backing crashes) and the prototype backing crash countermeasure system (a set of emerging advanced crash avoidance technologies which were configured within a prototype system for use as a test bed for the project) are described in this chapter.

In interpreting the figures of crash problem magnitude used in this document, note that they represent the best information available to the project team at the time. While an effort was made to update the numbers as new figures became available, it is expected that better and more complete sources of information about the backing crash problem will continue to become available. Therefore, future users of the SIM model should assess whether better estimates are available and incorporate them in their SIM executions when appropriate.

2.2 Safety Area

2.2.1 Overall Magnitude/Size of Area

The U.S. Department of Transportation (DOT) estimates that the number of backing collisions in the United States could be as high as 500,000 per year, resulting in 50,000 injuries and 390 fatalities (NHTSA, 1997). To understand these estimates more thoroughly, searches of existing crash databases were initially conducted to estimate the number of backing crashes (based on Police Accident Reports) in the United States and the stability of this number over time. Using 1992 GES data, Eberhard et al. (1994) estimated the magnitude of backing crashes (and also developed a categorization of backing crash types, which is discussed later). Using 2005 data, this analysis was repeated; however, some of the coding practices changed over that time period. According to GES 2005 data, there were approximately 222,000 backing-related crashes (about 3.6 percent of all crashes), where a backing crash was defined as a vehicle striking or being struck by an obstacle or other vehicle while moving backwards. The percentage of backing crashes appears to have remained relatively stable between 1992 (when it was about 3.8 percent of all crashes) and 2005 (when it was about 3.6 percent of all crashes).

It should be noted that GES data include almost exclusively crashes on public roads. As such, crashes on private property such as driveways are not accounted for by these data. Therefore, state databases were examined to determine if crashes in private driveways, alleyways, and parking lots were entered into the crash record somewhere. State data from Kentucky and Nebraska yielded estimates indicating that approximately 37% and 41% (respectively) of backing crashes occurred on property that was not a traffic way (e.g., private driveways and parking lots). Because there are inconsistencies between states in the definition and coding of non-traffic ways, a broad-based estimate across multiple states for the number of backing crashes occurring in non-traffic ways was not possible. Nonetheless, the proportions in Nebraska and Kentucky suggest that perhaps an additional 130,000 – 155,00 backing crashes may occur nationally each year beyond those that are captured in GES as occurring on public roadways.

Therefore, the project concluded that U.S. DOT estimates continue to be the best and most comprehensive estimates characterizing the **overall** magnitude of the backing crash safety area: 500,000 per year, resulting in 50,000 injuries and 390 fatalities (NHTSA, 1997). For purposes of SIM development, a decomposition of overall numbers into those for each backing crash scenario was required – and that is described in Chapter 3.

2.2.1.1 Schema for Identifying Types of Backing Crashes

A categorization of backing crashes was developed by Eberhard et al. (1994). It was used with 1992 GES data to estimate the percentage of backing crashes falling within each type of backing crash identified by Eberhard et al. within their schema. This analysis was updated in this project, using 2005 GES data, and results are shown in Figure 2 and Table 1. These 2005 GES data were the most recent that were publicly available and the findings from them were used for project purposes to help characterize backing crashes in the United States.

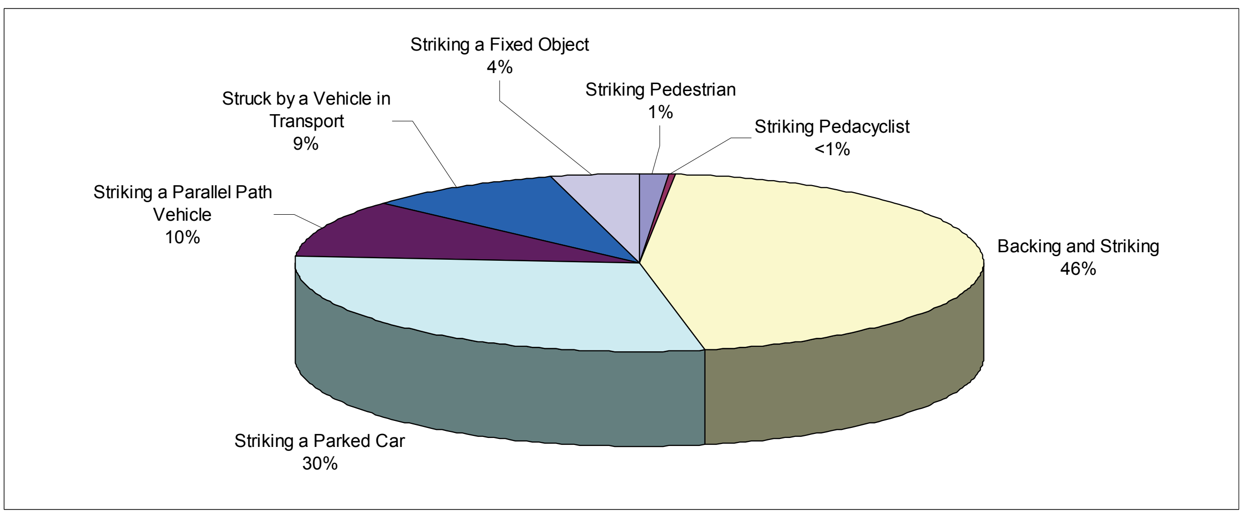


Figure 2. Backing crash percentages based on the schema of Eberhard et al. (1994), but derived from 2005 GES data.

Table 1. Backing Crashes, 2005 GES Data.

Estimated Number	Crash Type
2798	Striking Pedestrian
794	Striking Pedalcyclist
100,738	Backing and Striking a Motor Vehicle in Transport
64,703	Striking a Parked Car
23,297	Striking a Parallel Path Vehicle
20,311	Struck by a Vehicle in Transport
9,253	Striking a Fixed Object

In addition to the categorization scheme of Eberhard et al. (1994), another important crash classification schema that includes backing crashes has been derived by Najm, Smith, and Yanagisawa (2007); it is known as "*37 Crashes*." According to *37 Crashes*, backing crashes make up approximately 3.3 percent of total crashes, which is consistent with the percentages previously cited. The Najm et al. (2007) schema includes the following two types of backing crashes and associated descriptions. (This is thus a different categorization of backing crash types than the one put forth by Eberhard et al.)

Backing Up into Another Vehicle (2.2 percent of crashes)

Typical Scenario is one in which the vehicle is backing up in an urban area, in daylight, under clear weather, at a driveway/alley location, with a posted speed limit of 25 mph; and then collides with another vehicle.
Factors Over-Represented are daylight conditions, driveway/alley and intersection-related locations, low-speed roads, vision obscured, inattention, and younger drivers (based on a simple comparison of percentages).
Dynamic Variations include vehicle is leaving a parked position and backs into another vehicle.

Road Edge Departure while Backing Up (1.11 percent of all crashes)

Typical Scenario is one in which the vehicle is backing up in an urban area, in daylight, under clear weather, with a posted speed limit of 25 mph; and then departs the road edge on the shoulder/parking lane in a driveway/alley location.
Factors Over-Represented are driveway/alley locations, low-speed roads, alcohol, inattention, and younger drivers (based on a simple comparison of percentages).
Dynamic Variations include vehicle is leaving/entering a parked position while backing up and departs the edge of the road. Najm, Smith, and Yanagisawa (2007) note, however, that there is significant pedestrian involvement in this scenario.

2.2.2 Factors Which Are Relevant Across Most Backing crash Types

Several factors were important to examine across all backing crashes: speed of travel, roadway profile/grade, vehicle type, time of day, driver age, driver gender, and role of driver distraction. These are first described, and then illustrated in figures below.

2.2.2.1 Speed of Travel

Not surprisingly, the overwhelming majority of backing crashes occurred at speeds of 5 mph or slower. This can be seen in Figure 3.

2.2.2.2 Roadway Profile/Grade

By far, most backing crashes occurred on level roadways, but a notable proportion also occurred on graded roadways (see Figure 4).

2.2.2.3 Vehicle Type

Whether the struck object is a pedestrian, another vehicle, or a fixed object, pickup trucks were more likely to be involved in a backing crash than other passenger vehicle types, when controlling for the number of registered vehicles on the road (Figure 5), based on GES 2004.

2.2.2.4 Time of Day

Figure 6 shows the pattern of backing crashes across the hours of the day. Pedestrian and vehicle strikes had modal values at around 1:00 or 2:00 p.m., whereas fixed object strikes were more dispersed with a predominance of strikes occurring between 5:00 p.m. and midnight. This overrepresentation of pedestrian crashes from 1:00 to 2:00 p.m. is somewhat surprising. It might be hypothesized that drivers would be most likely to strike a pedestrian at the beginning of a trip. Yet the largest number of trip-beginnings might be expected to occur at the beginning of the workday and at the end of the workday. Therefore, the pattern in the GES 2005 data might suggest that factors other than just driving patterns are involved in pedestrian backover crashes – such as times of day when young children are active (rather than sleeping, eating, attending class, or napping) – or days of the week when families are active at non-work times (e.g., weekends). Alternatively, this overrepresentation may be an artifact of GES crash-reporting criteria (the vast majority of the GES backover cases are on the public roadways and may differ in some way from those that occur on non-public driveways, parking lots, and other areas).

2.2.2.5 Driver Age

The proportion of backing crashes involving pedestrians increased monotonically from the youngest drivers up to those in the group aged 41 to 50. Then, for each age group over 40, striking a pedestrian in a backing crash was more likely than striking another vehicle or fixed object (Figure 7).

2.2.2.6 Driver Gender

For each backing crash type, males far exceed females (Figure 8), even though there are an approximately equal number of male and female licensed drivers in the Unites States (Federal Highway Administration, 2005). Males have been shown to drive more miles (for example, based upon the 2001 National Household Travel Survey, men drove 1,410,985 [in millions] of miles of travel while women drove 863,784 [in millions] of vehicle miles of travel). On the other hand, according to this same source, women take slightly more trips (51.3 percent) than men (48.7 percent). It could be argued that for backing-related crashes, the number of trips might be a better metric than miles driven for how likely drivers were to be involved in a backing-related incident (and might thus lead to a hypothesis of slightly higher female driver involvement. However, the GES 2005 data depicted below do not show that. They instead indicate that males are overly represented in this crash type. (This interpretation assumes that men and women are somewhat equally likely to perform a backing maneuver during a trip.)

2.2.2.7 Role of Driver Distraction

Pedestrian and fixed-object strikes were not predominantly associated with distraction, whereas distraction did seem to play a much greater role in vehicle strikes (Figure 9). Of course, in many instances, the degree and nature of distraction in any particular crash may simply be unknown or go unreported. Another way to look at these data is to consider that approximately 10 percent of the crashes in which a pedestrian was struck, and a nearly similar percentage in which an object was struck, did include distraction – so distraction was involved in a backing crash between approximately 10 to 30 percent of the time (across all backing crash types).

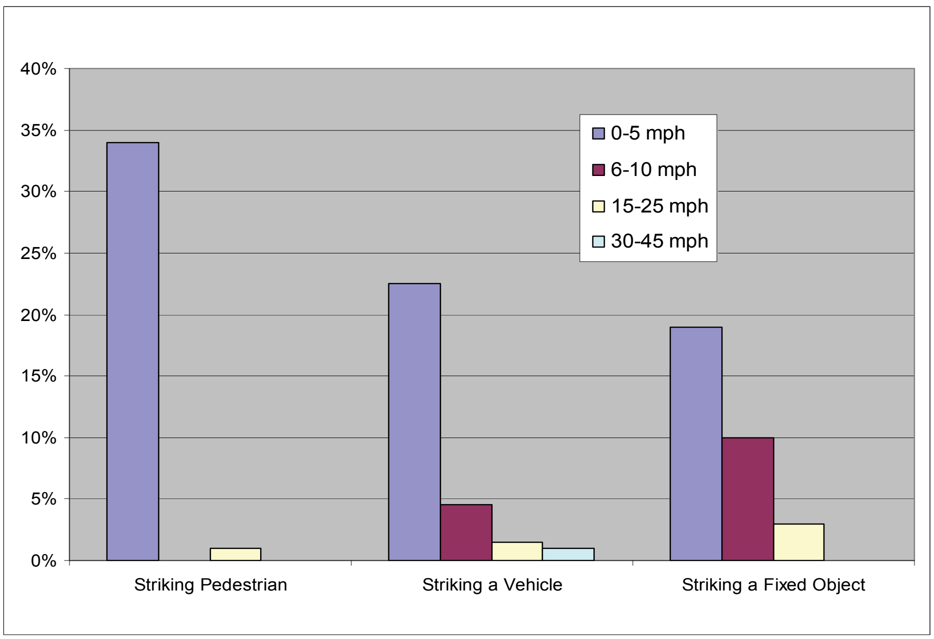


Figure 3. Backing crashes by vehicle speed, GES 2005.

(Note: Only documented speeds used therefore percentages can't total 100%.)

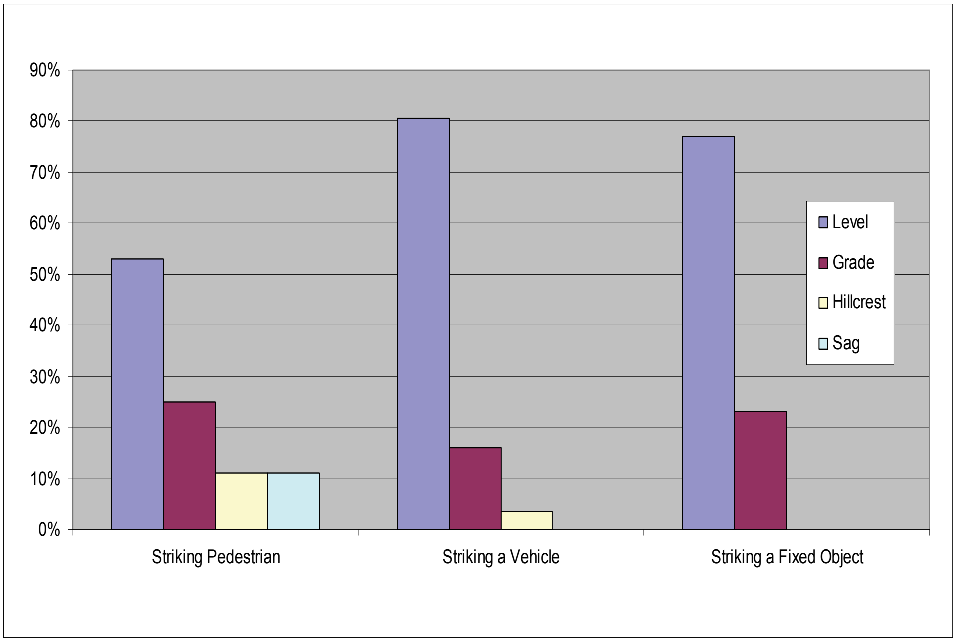


Figure 4. Backing crash type by roadway profile, GES 2005.

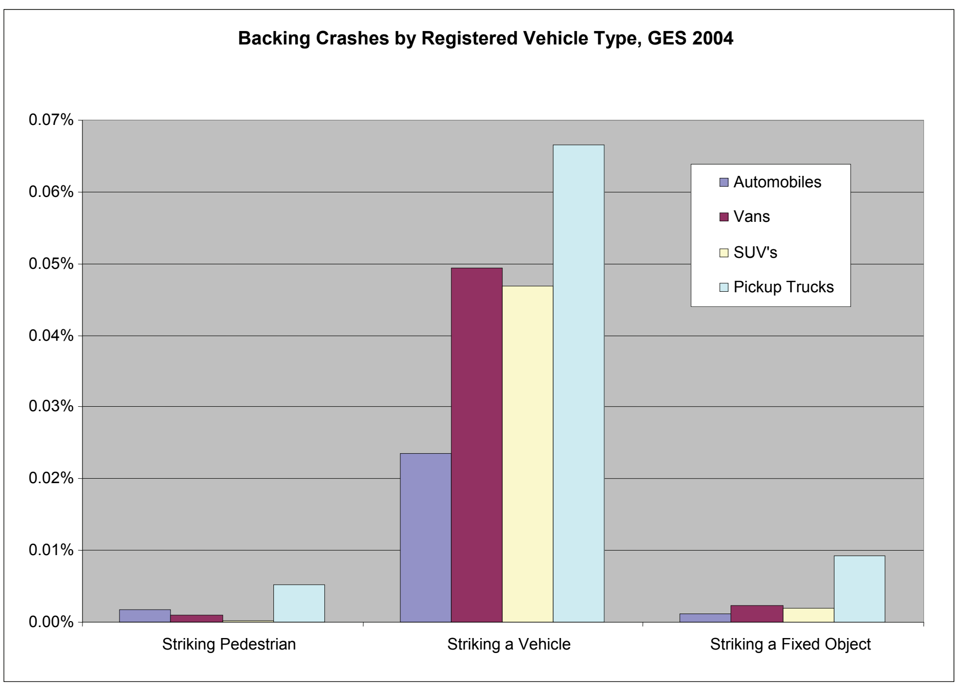


Figure 5. Backing crash type by registered vehicle type – percentage rate per number of registered vehicles, GES 2004.

(Note: Not all crash types shown.)

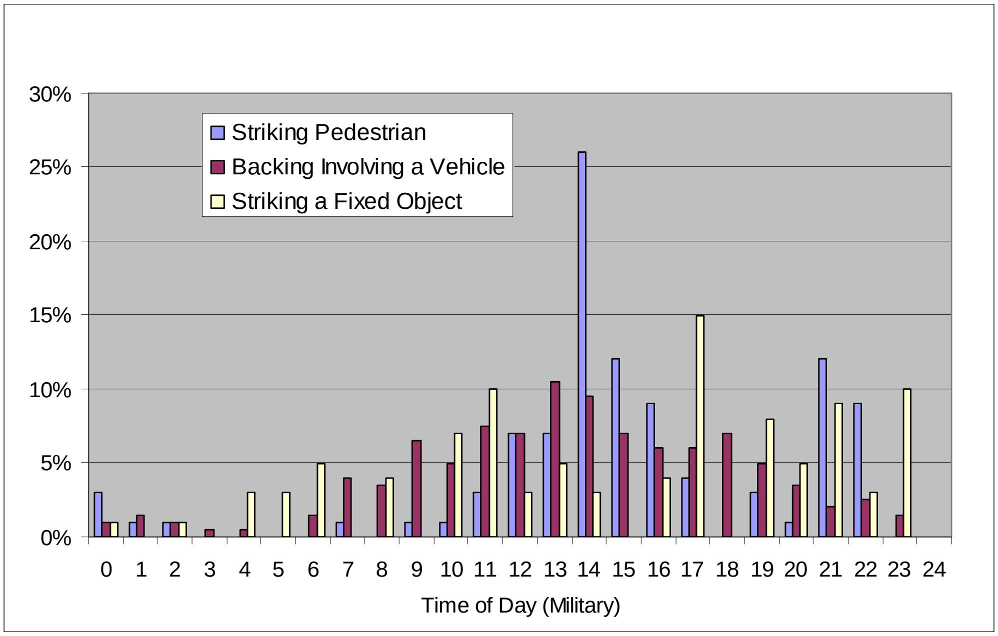


Figure 6. Backing crashes by time of day, GES 2005.

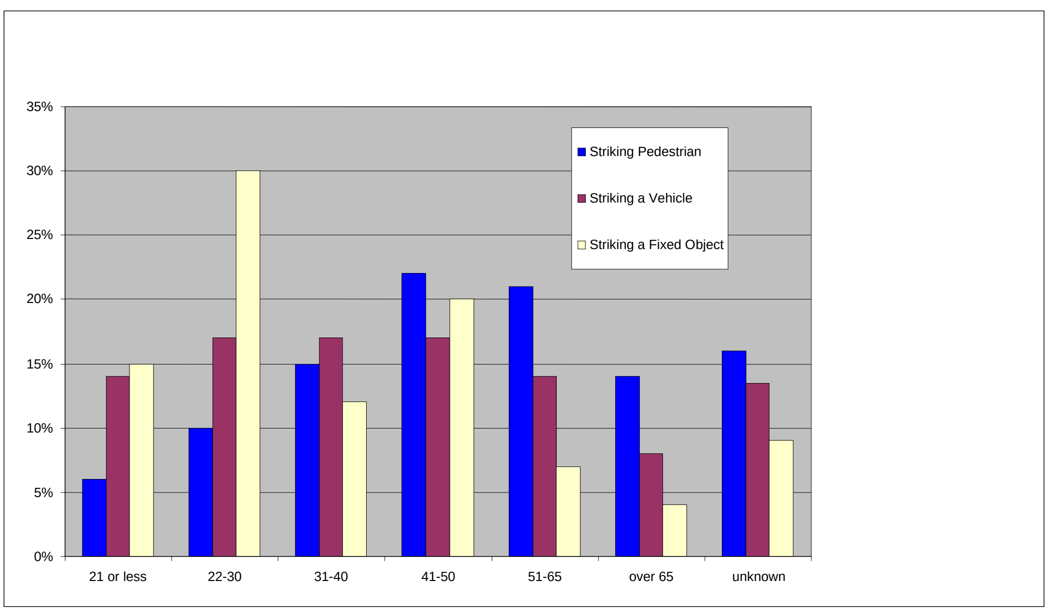


Figure 7. Backing crash type by driver age, GES 2005.

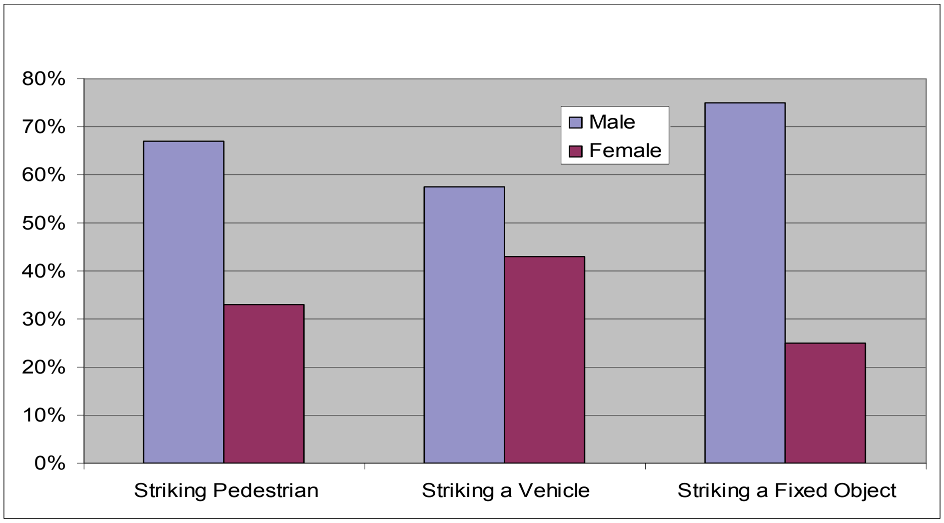


Figure 8. Backing crash type by gender, GES 2005.

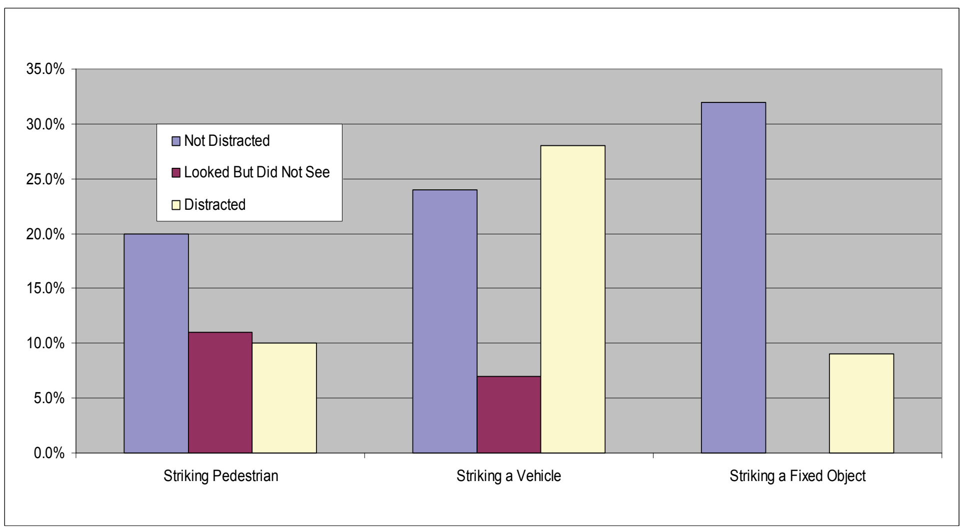


Figure 9. Backing crash type by driver distraction, GES 2005.

(Note: Figure only uses reported driver states. The unreported state is not included in figure.)

2.2.3 Factors Which Help Distinguish Between Types of Backing Crashes

At a high level, backing crashes can be characterized in terms of Crash Types, Pre-Event Maneuvers, and Critical Events – dimensions identified by Najm et al. (2007) as important in the definition of pre-crash scenarios. These dimensions indeed proved useful in characterizing backing crashes – and help distinguish one type of backing crash from another.

2.2.4 Crash Types within Backing Crashes

Within backing crashes, three basic types were distinguished, based on the type of obstacle that is struck:

- Backing vehicle strikes pedestrian
- Backing vehicle strikes another vehicle
- Backing vehicle strikes a fixed object

Descriptive information about each of these is provided below.

2.2.4.1 Backing vehicle strikes pedestrian (backover crashes)

Even though backover crashes involving pedestrians or pedacyclists are in the minority relative to all backing crashes (based on GES data), they are thought to be an under-counted source of auto-pedestrian injuries and fatalities (Fenton, Scaife, Meyers, Hansen, and Firth, 2005; Nadler, Anita, Courcoulas, Gardner, and Ford, 2001). Factors contributing to such incidents may include the driver's inability to see the pedestrian, inattention/distraction, or unexpected circumstances, among others.

It is difficult to gain a true perspective of the magnitude of this crash type because, as currently implemented, national databases (i.e., FARS and GES) store only *traffic-related* crashes. In both FARS and GES a backover crash is defined as a vehicle striking a pedestrian or pedacyclist with the rear of the vehicle when a driver was present in the vehicle. Since these databases compile only traffic-related crashes, those crashes that occur in or near driveways or parking lots are often excluded. This poses a serious challenge for estimating the number of backover crashes, as many of them appear to happen in these excluded situations. Beyond FARS and GES, relevant data are available from hospital emergency departments and death certificates, as well as through various media sources (e.g., *Kids in Cars* and *Kids and Cars*™ advocacy groups). These sources have several limitations of their own. For example, hospital records include only a small subset of the population and typically lack the detail needed to fully understand the crash scenario; death certificates also lack the detail needed to recreate the crash incident; and newspaper sources do not present a statistically valid sample. Also, not all newspaper crash reports are recorded in available databases (e.g., LexisNexis). As a result, various sources report different numbers of fatalities and injuries due to backover incidents (NHTSA, 2006). It is commonly agreed (for the reasons described above) that pedestrian crashes are underreported. NHTSA (2006) combined different sources of this information to estimate that approximately 183 fatalities and between 6,700 and 7,419 injuries per year occur as a result of a pedestrian being struck by a backing vehicle in the United States.

2.2.4.2 Pedestrian Characteristics in Backover Crashes

Children under the age of 5 are at the highest risk for a backover incident (NHTSA, 2006). Children experience a disproportion of the severe and fatal pedestrian injuries (USDOT, 1999; Winn, Agran, and Castillo, 1991). An epidemiological investigation was conducted on the incidence of driveway backover events during the years 1998 to 2003 in the State of Utah (Pinkney, Smith, Mann, Mower, Davis, and Dean, 2006). These researchers attempted to quantify the risk of backover injuries to children and found that 7.09 per 100,000 (<10 years old) would be involved in a driveway backover related injury.

Table 2 includes data from the CDC report (2005) on the estimated annual number of nonfatal motor-vehicle-related backover injuries treated in emergency departments among children aged 1-14 years from 2001 to 2003 (weighted estimates were based on 168 cases during the 3-year period). As shown, those 1 to 4 years of age are involved in half of all cases. Across all ages, females and males are struck approximately equally in backover crashes. It should be noted that these findings only include injuries that were treated in hospital emergency departments, not those treated in physicians' offices or clinics.

Table 2. Estimated annual number, percentage, and rate of nonfatal motor-vehicle-related backover injuries treated in emergency departments among children aged 1-14 years, by age and gender – United States, 2001-2003 (CDC, 2005).

Characteristic	Estimated #	%	Rate per 100,000 population	95% Confidence Interval
Age Group				
1 – 4	1246	50.0	-	-
5 – 9	603	24.2	3.02	1.69 - 4.35
10 – 14	642	25.8	3.05	1.14 - 4.68
Gender				
Male	1220	49	4.21	2.62 - 5.80
Female	1271	51	4.6	2.23 - 6.98

From the 183-backover fatalities gleaned from FARS and death certificates in 1998: 38 percent (69) were children under 5 years old, 42 percent (76) were children under 15 years old, and 27 percent (49) were over 70 years of age. Comparing these numbers to each group's contribution to the overall population, the prevalence of backover injuries becomes most apparent in those younger than 5 years and older than 70 years. Figure 10 demonstrates the normalized backover crash risk by age group according to death certificate records and FARs in the year 1998 (NHTSA, 2006).

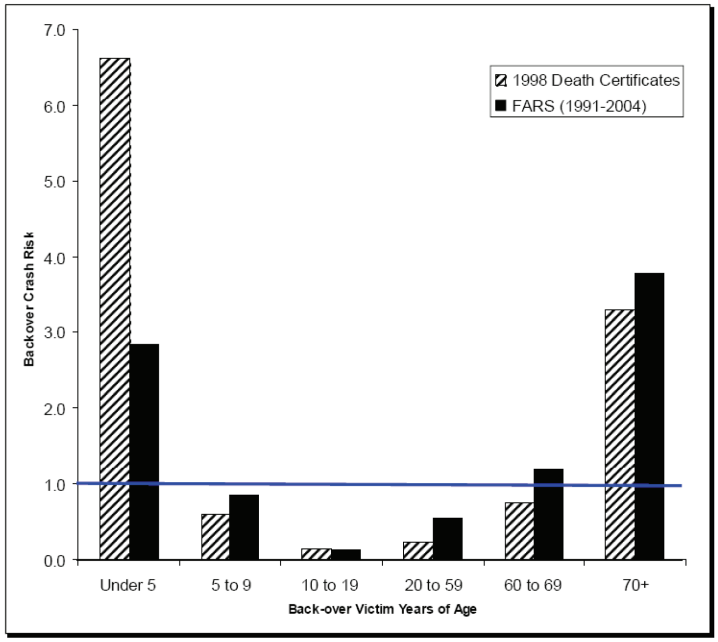


Figure 10. Ratio of normalized backover crashes/normalized United States population by age group (from NHTSA, 2006). The horizontal blue line at 1.0 represents the theoretical number of struck pedestrians expected for each age group based on its proportion of the overall population.

Backover crashes pose a significant risk for injury and mortality (Nadler et al., 2001; Silen, Kokosak, & Fendya, 1999; Patrick, Bensard, Moore, Partington, & Darrer, 1998). Nadler et al. (2001) attempted to characterize the patterns and outcomes of driveway motor vehicle collisions. The researchers investigated 13 years of data at the Children's Hospital of Pittsburgh and found 44 patients (all children) who sustained injuries as a result of having been struck by a motor vehicle in a driveway – 85 percent of these were backing crashes. The mean age of these 44 patients was 2.0 years, with 93 percent of the patients aged 5 years or younger. Ninety-three percent were under the age of 5, with an average weight of 26 lbs. Gender distribution was nearly equal. The most commonly reported injuries were to the musculoskeletal system followed by head and chest trauma. This study showed that children under the age of 2 and less than 26.5 lbs are more severely injured in driveway-related crashes. The findings of Nadler et al. (2001) are similar to those found by Patrick et al. (1998), which show the mean age to be 3.4 years, with children under the age of 5 accounting for 41 of the 51 driveway-related backover accidents. Moreover, research from Agran, Winn, and Castillo (1991) indicates that the heights of children involved in these types of incidents range from 2.2 to 3.4 ft, with a median height of 2.8 ft.

Patrick et al. (1998) found that of the 51 driveway-related backover incidents they studied, 19 were pedestrians struck by a backing vehicle as a result of a child knocking the car out of gear. Of the remaining 32 incidents, the children were struck by the vehicle under the following circumstances:

- 19 playing under or behind a parked vehicle
- 10 were walking behind a moving vehicle
- 3 standing behind a parked vehicle

Patrick et al. (1998) pointed out that the age of the child has some influence on the type of backing crash that may occur. Children under 5 are likely to be a victim in backing crashes involving a slow-moving vehicle. Older children are more likely to dart into traffic and be struck by a more rapidly moving vehicle.

2.2.5 Driver Characteristics in Backover Crashes

Data from 2000 to 2001 reported by the CDC and the Kids and Cars™ organization indicated that the driver of the vehicle striking a child (includes accidents beyond just backovers) was a parent of the victim 57 percent of the time (CDC, 2002; http://kidsandcars.org/). In 77 percent of the cases the driver is a male (FARS, 1991-2004). Brison et al. (1988) found that a family member or a visiting family friend was involved in 71 percent of the fatalities. The family member was most often the father of the child. Similarly, Pinkney et al. (2006) studied children under the age of 10, and found that a family member was directly at fault in 48 percent of the backover cases while 24 percent involved a neighbor. Figure 11 illustrates backover crash risk relative to driver age. As shown, those 20 to 39 years of age and those 70 years and older are disproportionately at risk relative to the rest of U.S. licensed driver population (NHTSA, 2006).

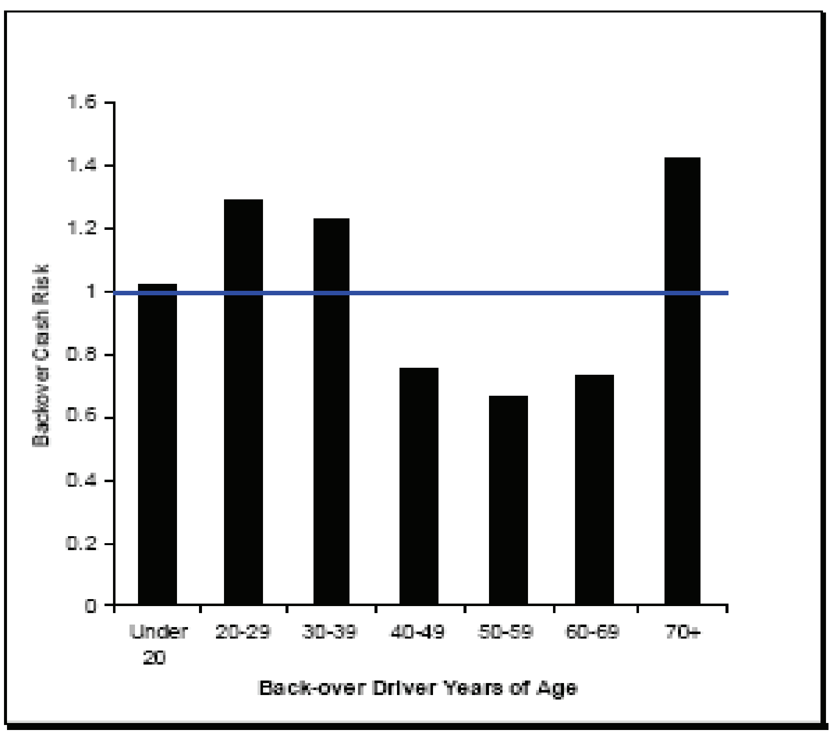


Figure 11. Driver age by backover crash risk (Source: NHTSA, 2006).

2.2.6 Vehicle Characteristics in Backover Crashes

Vehicles with poor rearward visibility may increase the likelihood of a backover incident. Rearward visibility can be affected by several factors such as: head restraints, driver's seating position (i.e., seated height), head-neck-torso flexibility, vehicle length and height, rear window dimensions and glazing, and outside rearview mirror types and positions. All these components contribute to a vehicle's "blind zone" (i.e., the 3-dimensional space behind a vehicle where the driver is unable to see). With the increase in numbers of higher-profile vehicles (e.g., sport utility vehicles [SUVs] and minivans) one might expect a proportional increase in the number of backover incidents. In 2004, the U.S. Census Bureau reported that from 1997 to 2002, the number of registered SUVs increased by 55.8 percent, and the number of minivans increased by 24.1 percent (see Figure 12). However, it has not yet been definitively demonstrated that there is a similar increasing trend in backing crashes in the United States (NHTSA, 2006). In fact, a comparison of backover crashes between 1993 and 2005 (as captured by GES) remained fairly stable. In 1993, crashes classified as "striking a pedestrian" were 1.35 percent of all crashes, and in 2005, they were 1.26 percent. While GES numbers are thought to be an underestimate, the extent of under-estimation should be similar across years. So the stability of the crash data suggests that while rearward visibility may play a part in backover crashes, there may be other important variables as well. Nearly all vehicles (including sedans and coupes) have rear blind zones as well.

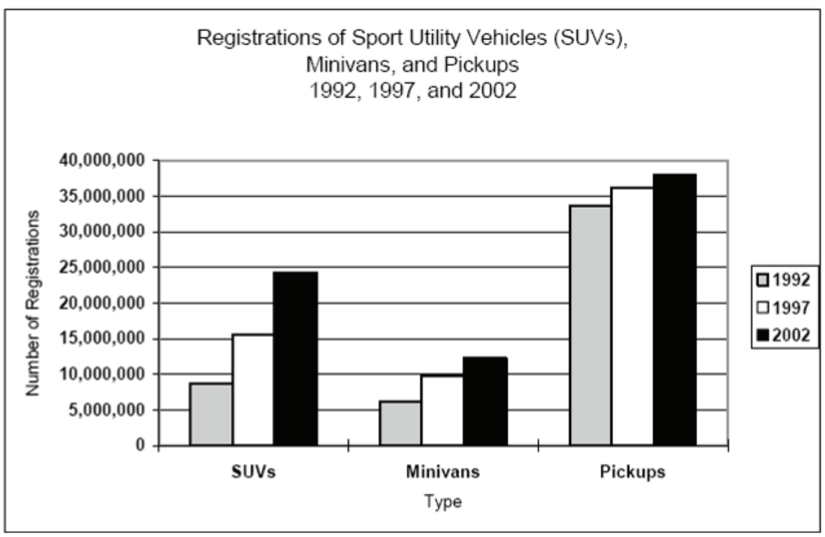


Figure 12. SUV, Minivan, and Pickup Registrations in 1992, 1997, and 2002. Source from U.S. Census Bureau's 2002 Vehicle Inventory and Use Survey (http://www.census.gov/prod/ec02/viusff/ec02tvff-us.pdf).

In 2006, *Consumer Reports* tested the length of blind spots on various vehicles. Using a 28-inch traffic cone positioned behind the vehicle in a centralized location, representing a child less than one-year-old (CDC, 2005), the researchers measured the position behind the vehicle at which the driver could just see the top of the cone. Figure 13 depicts the average blind spot using a driver (5'8") and a shorter driver (5'1") for mid-sized sedans, minivans, large SUVs, and pickups. It should be noted that, like NHTSA, Consumer Reports also found that, on average, SUVs had longer blind-spot distances than sedans, but that was not always the case. In fact, many sedans had longer blind-spot distances than some SUVs (Consumer Reports, 2006).

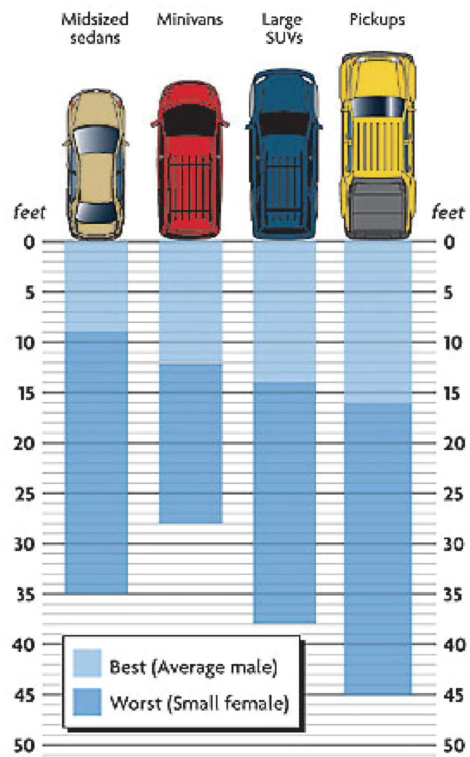


Figure 13. Blind spots according to vehicle type (from Consumer Reports, 2006). http://www.consumerreports.org/cro/cars/safety-recalls/mind-that-blind-spot-1005/overview/index.htm).

NHTSA (2006b) conducted a similar blind-spot study. In the NHTSA study three 28-inch cones were placed at various locations behind six vehicles. These cone placements were used to measure driver sight distances using a 5'10" driver. Figure 14 demonstrates the variability in the length of the blind spot according to cone locations. The left cone location had the longest blind spot in comparison to the center and right locations. The Cadillac Escalade had the longest blind spot (100 ft) at the left location and the Infiniti FX35, Toyota 4Runner, and BMW 330i had near similar recorded shortest blind-spot lengths of around 20 feet. The Cadillac Escalade had the greatest variability in blind-spot distances across the cone locations. Figure 14 also illustrates how the position of the object relative to vehicle center can greatly affect the length of the blind spot. If center-located objects are compared to those offset by a single foot, differences of blind-spot lengths from as little as just a few feet to upwards of 60 feet can be found (Figure 14).

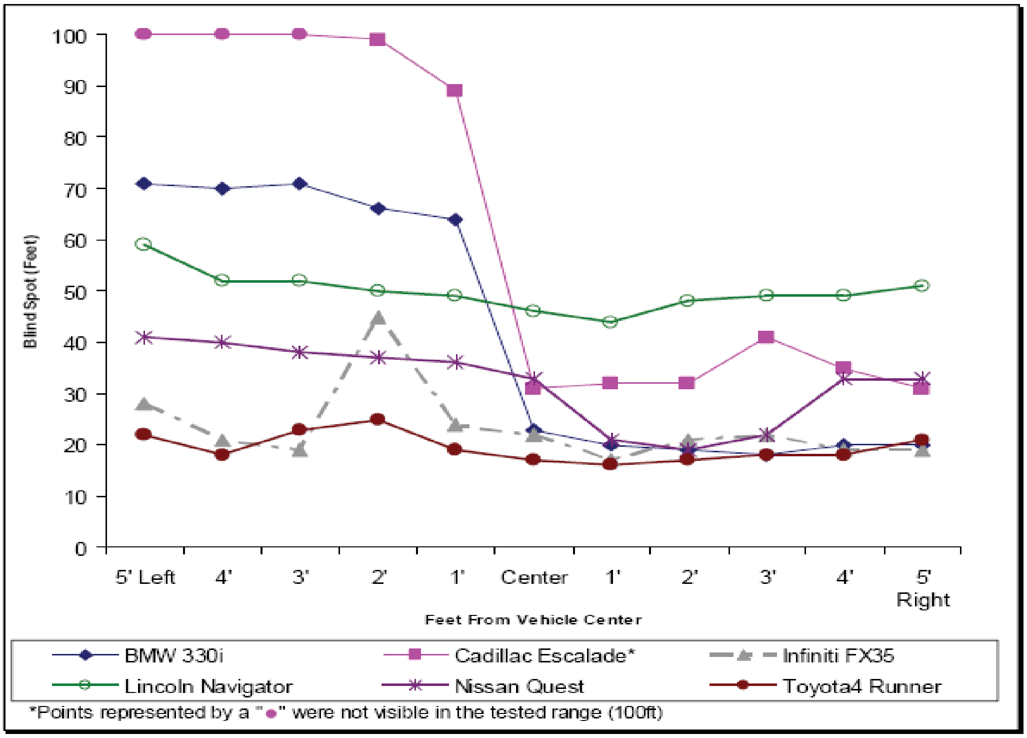


Figure 14. **Blind Spot Distances according to cone position for six common vehicles (from NHTSA, 2006).**

Pinkney et al. (2006) quantified the risk of driveway backover injuries to children by vehicle type: car, truck, SUV, and minivan. They found 1.62 injuries per 100,000 registered passenger vehicles in the State of Utah for persons under the age of 10 from 1998-2003. Children were 53 percent more likely to be injured by a truck than a passenger vehicle and 2.4 times more likely to be struck by a minivan. Figure 15 demonstrates the incidence rate of backover injuries by vehicle type.

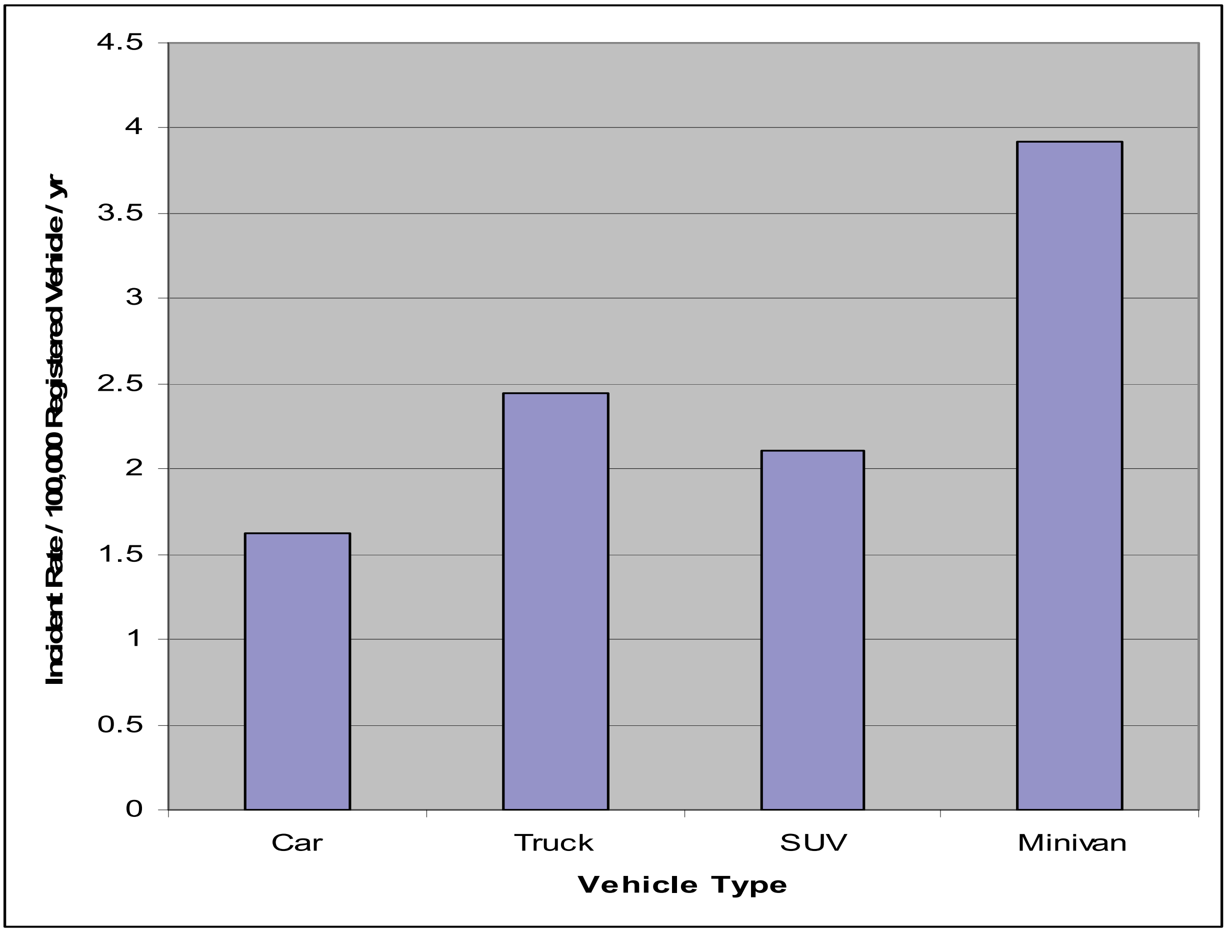


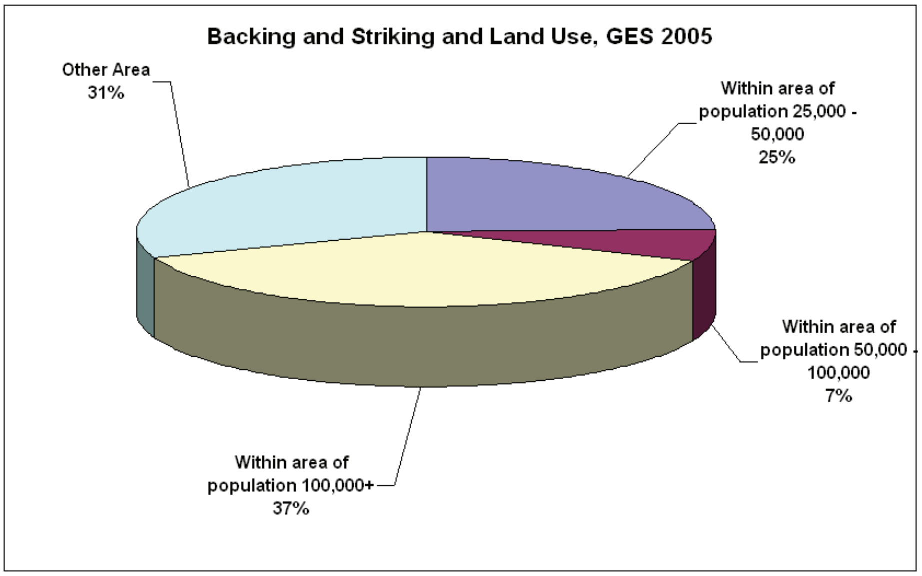
Figure 15. Backover crashes in Utah per 100,000 registered vehicles per year by vehicle type (Pinkney et al., 2006).

2.2.6.1 <u>Backing vehicle strikes another vehicle</u>

The second crash type (distinguished on the basis of the type of obstacle struck) was "backing vehicle strikes another vehicle." As was apparent in Table 1, the vast majority of the backing crashes estimated in the 2005 GES database arose from vehicle-to-vehicle backing crashes of various types (~94 percent altogether). Of these crashes involving the strike of another vehicle, the most common crash type was a backing vehicle striking another vehicle in transport (46 percent). This was followed by crashes in which the backing vehicle struck a parked car (30 percent) and those in which the backing vehicle struck a vehicle in a parallel path (10 percent).

The final major category of backing crash with another vehicle was when the backing vehicle itself was struck by another vehicle in transport. This crash type is not as conducive to being mitigated via backing crash countermeasures (because in this crash type, the backing vehicle is the "struck vehicle" – so these crashes are most likely to be averted or mitigated through actions taken by the other, striking, vehicle rather than by the backing vehicle – and hence, somewhat more amenable to forward-looking countermeasures on the striking vehicle than to backing countermeasures on the backing vehicle). This crash type was therefore excluded from this project, as being outside its scope. The project focused only on crashes in which the backing vehicle was the striking vehicle in the crash.

The most common backing crash type in which another vehicle was struck (namely, that in which a moving vehicle was struck) was further decomposed in terms of the areas in which it occurred and the types of junctions at which it occurred (based on the GES data set). As shown in Figure 16, over half of these backing and striking crashes with another vehicle occurred at a driveway, alley, or access road. This relation to driveway or alley was also represented in the *37 Crashes* data (Najm, Smith, and Yanagisawa, 2007) described earlier. Another 12 percent were either at an intersection or were intersection-related.



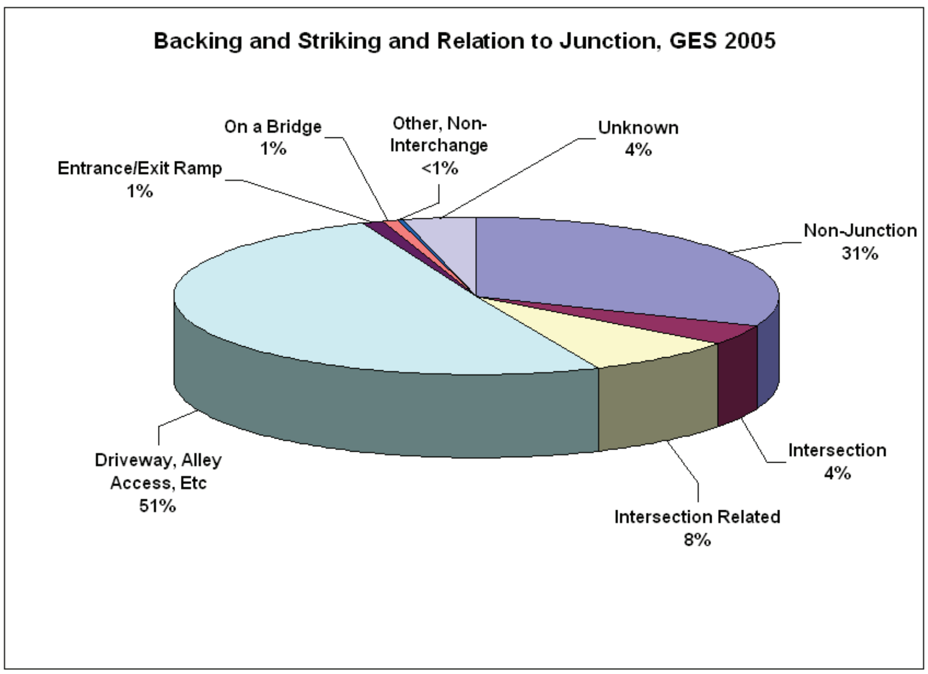


Figure 16. Backing and Striking a Motor Vehicle in Transport, broken out by area (top) and junction (bottom, with percentages).

2.2.6.2 Backing vehicle strikes a fixed object

The third crash type (distinguished in terms of type of object struck) was "backing vehicle strikes a fixed object." Fixed object crashes account for approximately 4 percent of the backing crashes in the 2005 GES data. Figure 17 shows the distribution of object types that are struck. Approximately 38 percent of the objects are post, sign, or other support, which represents the largest category by far. Also, in comparison to many of the other fixed objects, this category's objects are physically smaller. Therefore, to the extent that a countermeasure detects and responds to objects in this category, it may also be capable of detecting larger objects in some of the other object categories.

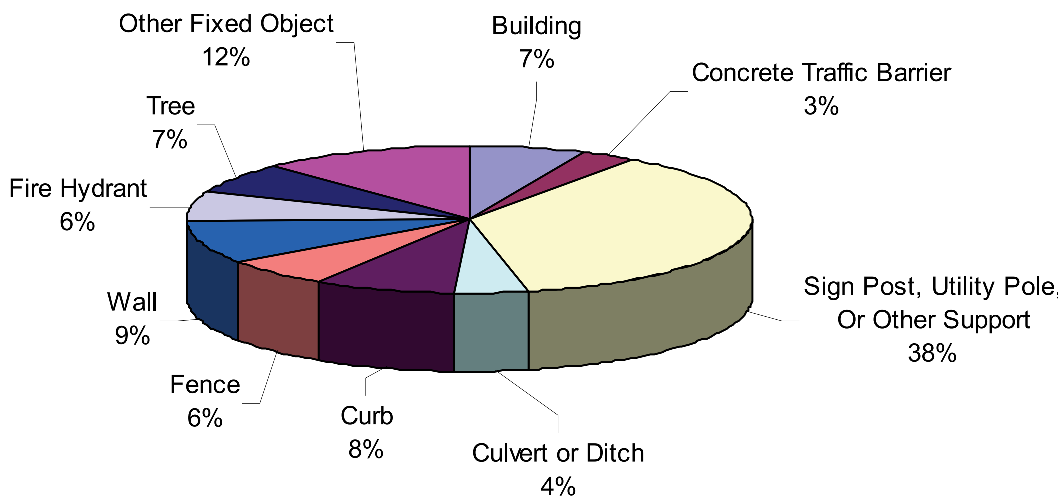


Figure 17. Distribution of objects struck in Vehicle-to-Fixed-Object Backing Crashes (2005 GES).

2.2.6.3 <u>Pre-Event Maneuvers</u>

Types of pre-event maneuvers may be distinguished by distance, speed, and geometry of the roadway/driveway/parking area. There are two main pre-event maneuvers which characterize backing crashes:

- *Backing during parking ingress/egress.* Backing done during parking ingress/egress tends to be associated with lower speeds, and tends to be associated with shorter driveways, or with parking lot settings (involving steering actions associated with those geometries).
- *Driving in reverse.* Driving in reverse maneuvers are those backing maneuvers done over longer distances (e.g., backing down a very long driveway or alleyway) and at higher speeds (e.g., speeds in the range from 6 mph to 30 mph, as shown in Figure 3). Thus, this pre-event maneuver differs in important ways from backing into or out of a parking space (which involves different geometry, steering actions, and slower speeds).

2.2.6.4 <u>Critical Event</u>

Two types of critical events distinguish types of backing crashes: Vehicle contacts a ***stationary*** obstacle located in path (but not known to be there), and Vehicle contacts an obstacle ***moving/incurring*** into its path (but not known to be approaching the backing path).

Both types of critical events represent significant percentages of backing crashes. There may be slightly more critical events which involve obstacles moving/incurring into the path of the backing vehicle. If the numbers of crashes in Table 1 are sorted by critical event (stationary versus moving obstacle) – based on category names –about 49% involved stationary obstacles and about 51% involved obstacles incurring/moving into the backing path. The detection and avoidance dynamics for obstacles incurring (a vehicle or pedestrian/pedacyclist) are different from those for a stationary object. The distinction of critical event is relevant both from the point of view of countermeasure and SIM development.

2.2.7 Definitions Important for Backing crash Countermeasures

In identifying countermeasures which might prevent or mitigate backing crashes, definitions of the sequence of key events and/or actions that typically occur during backing – and during backing conflict and crash – are fundamentally important. These two sequences (which were identified in the course of this work) provided a framework within which countermeasure development, as well as SIM development, could be done: (1) the backing sequence, and (2) the crash sequence. These are described below.

2.2.8 The Backing Sequence Common To All Backing Scenarios

The **backing sequence** is comprised of a number of associated **backing phases.** These are first described and then illustrated (the first three phases in Figure 18 and the last phase in Figure 19).

2.2.8.1 Backing Sequence Phases:

- **Vehicle approach:** the driver, outside of the vehicle, approaches it, and may be performing a partial or complete scan of the vehicle and surrounding environment.
- **Backing initiation:** the driver, who is now in the vehicle, proceeds to start the vehicle (if not already running). Once the driver engages reverse gear, there might be associated environmental scanning and planning of the backing path to avoid obstacles, which is followed by the initiation of backing movement.
- **Active Backing:** This phase involves an iterative process of assessment and avoidance of expected obstacles and continued environment scanning. If no obstacles are encountered then the backing maneuver is successful.
- **Conflict Assessment and Resolution:** If an obstacle is encountered, this phase allows for the assessment of such obstacle and engagement in an avoidance maneuver. If the avoidance maneuver is successful, then the backing maneuver continues. If an actual obstacle is not avoided appropriately, a crash results. Note that this phase also allows for drivers' false perception of obstacles (i.e., false alarms); while these would not result in a crash (since they are not present), drivers may adjust their backing behavior based on their faulty perception.

Note that a potential conflict can become present at any of these phases, but if the potential conflict is identified during the vehicle approach and backing initiation phases, the potential conflict can be removed averting a crash before the active backing phase. This is an important distinction between backing crashes (their attributes, and their countermeasures) and other crash types (and their associated countermeasures -- such as forward collision warning). Because the transition between pre-conflict and conflict may occur **before** backing is initiated (and before the vehicle is moving) – this makes backing crashes different from most other crash types (for which the transition from pre-conflict to conflict occurs when the vehicle is typically already moving, and thus has a different characteristic – such as in forward collision scenarios). Also, it is important to note that different backing crash countermeasures can provide assistance at one **or more** of phases of the backing sequence.

For example, a driver may observe a bicycle located in the vehicle's blind zone by glancing at a rear video display when reverse gear is engaged (i.e., during the Backing Initiation phase) – prior to rearward movement – and could remove the conflict before proceeding. However, if rearward movement occurred, the potential conflict would transform into an actual conflict. The rear video display would still be present during the ensuing Active Backing phase, and the driver may notice it during this phase (due either to the rear vision system display itself or to its availability in conjunction with other countermeasure systems that may become active during the conflict).

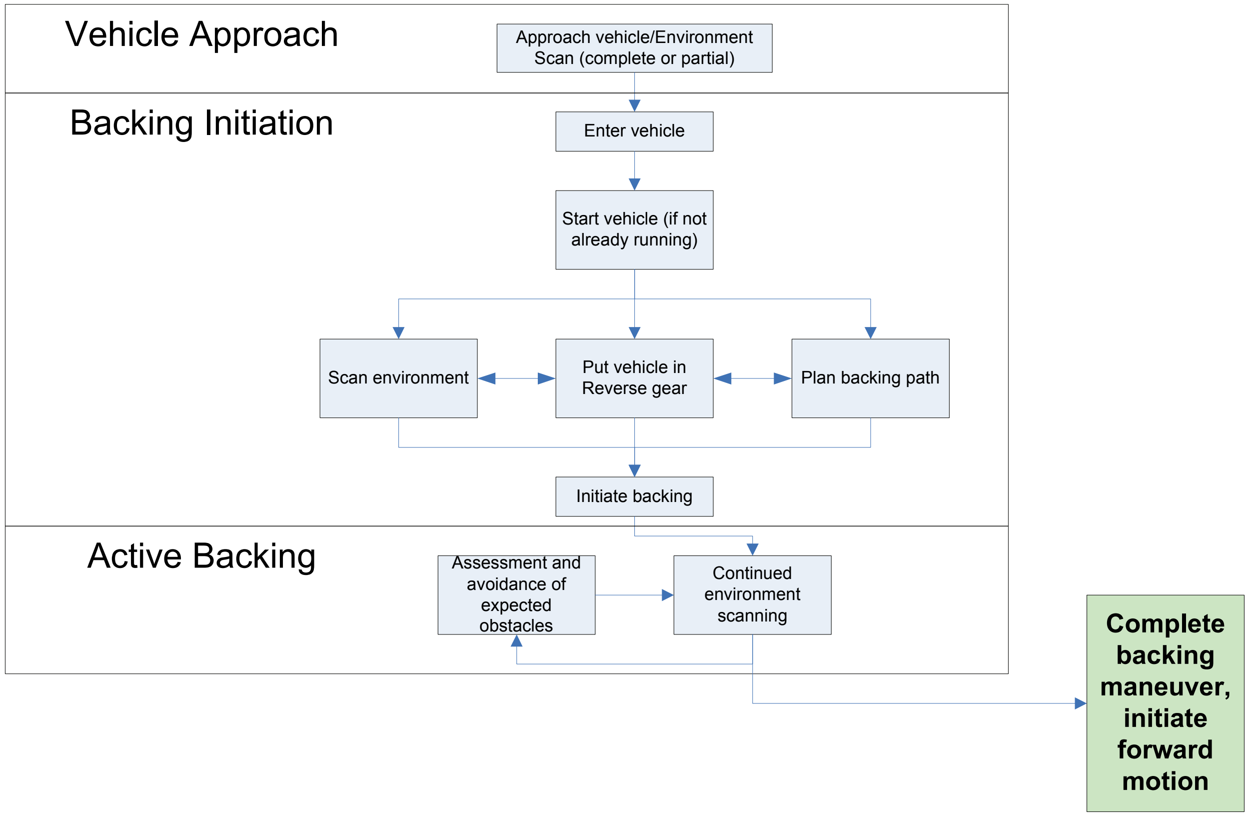


Figure 18. Pre-conflict backing sequence.

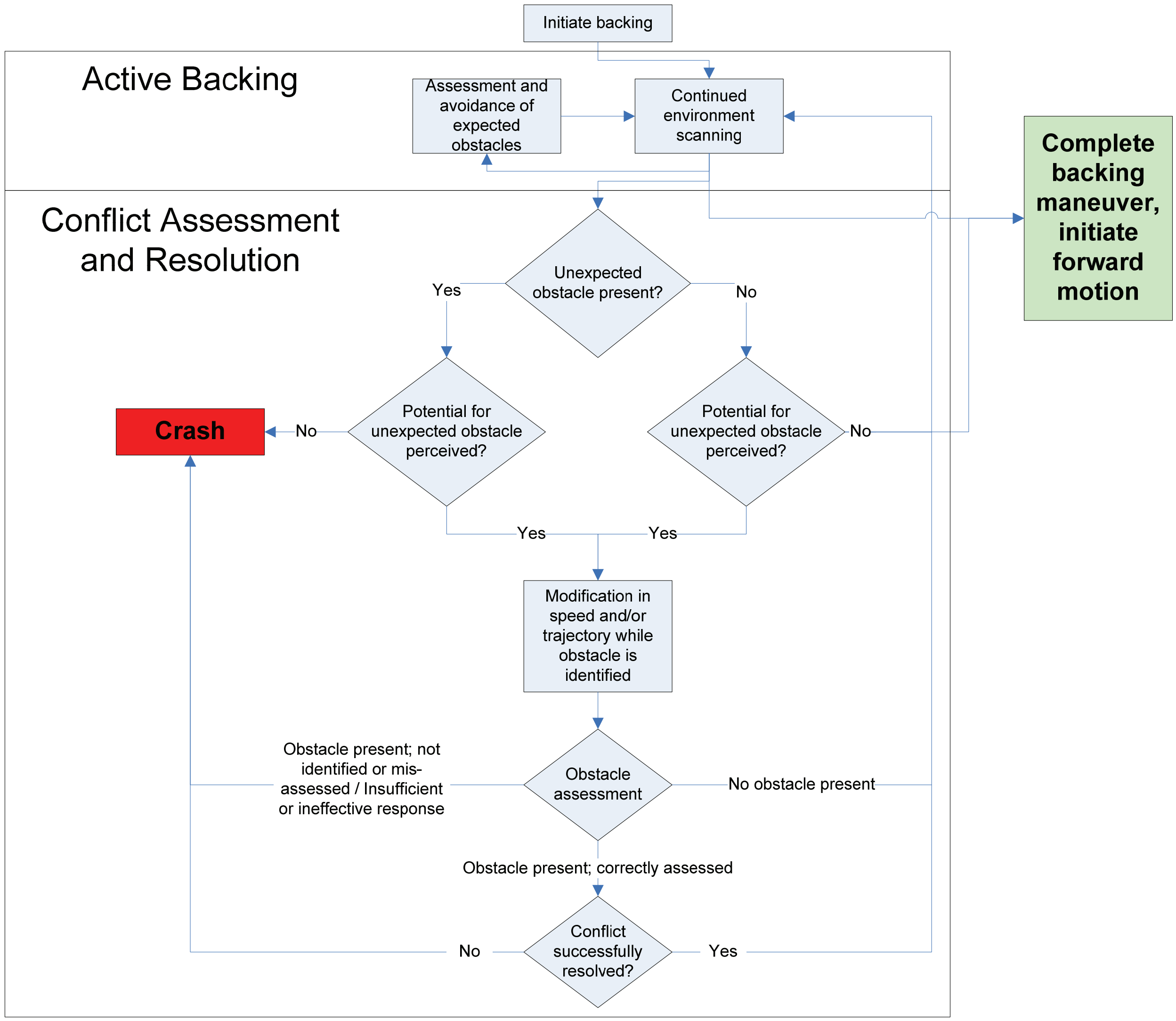


Figure 19. Conflict backing sequence.

2.2.9 The Crash Sequence (for Backing Crashes)

The second sequence which facilitated development of countermeasures and the SIM was that of the **crash sequence** (Figure 20). The crash sequence is a series of time epochs that describe how a crash evolves from the pre-conflict period to the post-crash period. Epochs include: (1) pre-conflict, (2) conflict, (3) critical situation, (4) imminent crash, (5) crash, and (6) post-crash. Within this sequence, two definitions are key: the definition of a "conflict" and that for a "crash." Those used for backing crashes are provided below:

- **Backing Conflict** exists when the path of a vehicle intersects with the location or path of an *obstacle*, including pedestrians. A conflict results in a *crash* if nothing changes to avert it.
- **Backing Crash**. Physical contact between the vehicle and an *obstacle* that results in one or more harmful events. To apply the term 'backing crash,' the following conditions also must apply: transmission is in Reverse gear at impact, the vehicle is backing at a speed greater than zero.

The **crash sequence for backing crashes** utilizes these concepts**, and** is composed of the following stages:

2.2.9.1 Crash Sequence Stages for Backing Crashes

- **Pre-Conflict:** Potential conflict that exists prior to the onset of backing movement.
- **Conflict:** Situation that exists when the path of a backing vehicle (already moving in reverse) intersects with the point at which an obstacle (including pedestrians) is or will be located (and will be struck if nothing changes to avert it). A conflict may also be more specifically described by one of the following terms depending on the proximity and kinematics of the vehicle and the obstacle.
- **Critical Situation:** Late stage in a conflict where a crash will occur unless the driver, vehicle, or the obstacle completes a rapid evasive maneuver.
- **Imminent Crash:** Point in the conflict where insufficient time remains for any action to avert the crash (but mitigation may still occur).
- **Crash:** Physical contact between the vehicle and an obstacle that results in one or more harmful events. The crash concludes when all harmful events are stabilized.
- **Post-Crash:** Time period immediately following the crash during which further mitigation may occur (e.g., through automatic crash notification). Countermeasures and outcomes from this phase were not considered in this project since its goal was to test and evaluate countermeasures that *prevent and/or mitigate* crashes (versus those that respond in the post-crash period to crashes which have already occurred).

The sequence of these stages for backing crashes is similar across all backing crashes.
As a result, the backing crash sequence establishes a useful framework within which to identify countermeasures which may assist in prevention and/or mitigation of backing conflict and crash.

Figure 20 shows potential actions of a backing ACAT as well as the driver during the backing sequence, once a critical situation exists. At the onset of the critical situation, a backing ACAT may increase the visibility of the obstacle, thereby increasing the potential for driver perception of it. Sometime after the onset of the critical situation, and assuming the conflict is not resolved, a backing ACAT may issue a warning or series of warnings, in an additional attempt to aid driver perception. If the driver perceives the obstacle at any point, that perception may be followed by a movement time where the driver is physically performing the necessary actions to complete a selected avoidance maneuver.

If the critical situation continues, the backing ACAT may assume some level of automated control of the vehicle (e.g., braking); the driver may assist the backing ACAT in this action. Finally, if a crash becomes imminent or actually occurs, both the backing ACAT and the driver may continue their actions to mitigate the severity of the crash. The combination of driver and backing ACAT actions therefore identify four meaningful time segments: a period where the system evaluates the threat, a period where the driver might generate a response once the system has issued a warning, a period where automated braking can still prevent the crash, and a period where the crash is unavoidable but mitigation may still occur. This sequence was useful in developing the countermeasure system which was evaluated in this project.

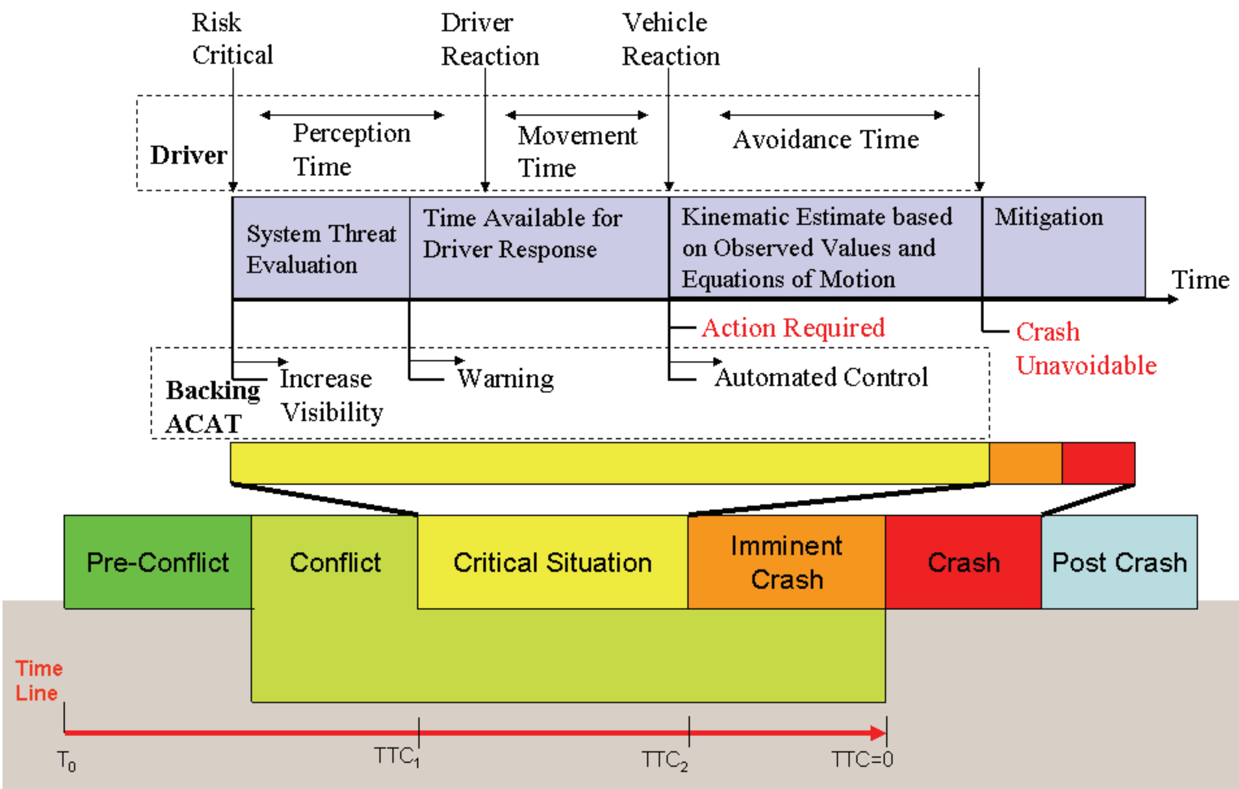


Figure 20. Crash sequence.

2.3 Countermeasure Description

An integrated suite of backing crash countermeasures was configured for evaluation in this project, using a research test bed incorporated into a 2008 Chevrolet Tahoe. It was comprised of four features which shared sensors and computational hardware:

- Rear Vision (which provided the "Enhanced View" function),
- Rear Park Assist, or Park Aid (which provided the "Proximity Information" function),
- Backing Warning (including an audible and separate brake pulse cue), and
- Automatic Braking.

This feature set (illustrated in Figure 21) was developed to provide support for the driver throughout the backing crash sequence (from pre-conflict through crash). The middle row of the figure's text (shown with the darker purple background shade) identifies the countermeasure element which supports each phase. A description of each countermeasure element is provided following the figure, along with an explanation of how that element of the countermeasure suite enters the crash time line. (These relationships remain the same across backing crash sub-types). Appendix D presents an analysis of contributing factors and causes for a sample of 35 pedestrian backover cases from NHTSA's SCI Unit; this analysis uses a Driving Reliability and Error Analysis (DREAM) Methodology to provide insights about contributing crash causes which may be used to develop potential countermeasures, as well as to confirm or refine objective tests.

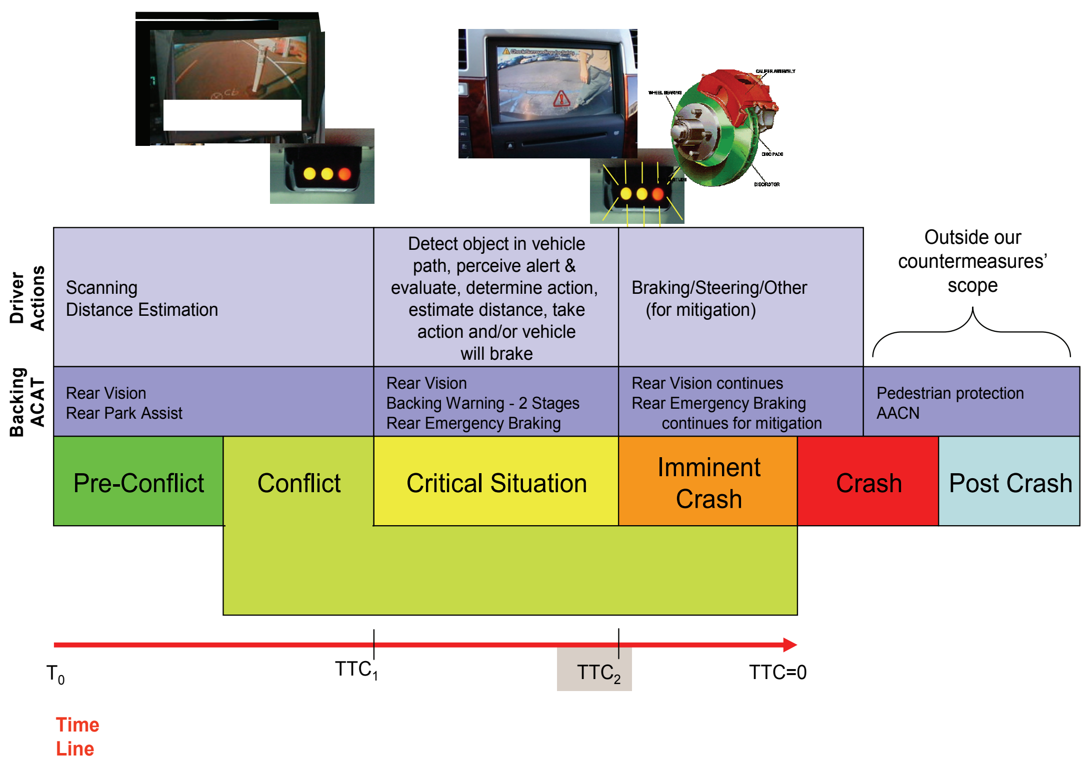


Figure 21. Countermeasures in Crash Sequence

2.3.1 Rear Vision (Enhanced View function)

This function provides the driver with a view of the area immediately behind the vehicle during pre-backing and backing phases to support vehicle positioning and driver search and detection of in-path obstacles. The Rear Vision system evaluated uses camera-based images transmitted to a display screen positioned in the center stack area. A video overlay is also used to highlight the location of detected obstacles using sensor inputs.

2.3.2 Rear Park Assist or Park Aid (Proximity Information function)

This function provides the driver with distance information about objects when the vehicle is backing at speeds below 4 mph and an object is within 8.2 ft. The driver receives two types of information: visual and auditory. The visual information is in the form of an Amber-Amber-Red light-emitting diode (LED) display placed near the rear window. More lights illuminate with closer proximity to an object, and flash at 5 Hz in the closest zone. The auditory warning consists of a single beep on first detect and 5 Hz beeping in the closest zone.

2.3.3 Backing Warning

This feature provides the driver with two distinct staged warnings based on anticipated conflict timing: a cautionary warning consisting of a single audible tone accompanied by visual LED indicators; and an imminent warning consisting of a momentary brake pulse accompanied by a series of rapid audible beeps. This feature is only available when the vehicle is backing at speeds that exceed 4 mph.

2.3.4 Automatic Braking

This function provides autonomous braking to a rear in-path obstacle while backing under certain conditions. The system has the capability to automatically bring the vehicle to a complete stop and hold for a brief period of time before releasing. Drivers may intervene to assume control with either the brake (following the automatic stop) or accelerator pedals (during automatic braking). Driver braking may become additive to system braking if the driver exceeds a certain brake pressure threshold.

It is this integrated suite of backing crash countermeasures that comprised the prototype system configured for evaluation in this project.

3 SAFETY IMPACT METHODOLOGY

This chapter describes the work completed to develop a SIM to estimate the potential benefits of future backing-collision avoidance countermeasures. The goal of this chapter is to provide the reader with an overview of the process followed to complete the SIM. This process is described in further detail throughout the remainder of this report. References to discussions of specific topics are provided within the summary presented in this chapter.

The primary goal of the SIM is to predict the proportion of certain crashes that might be eliminated or mitigated if a countermeasure is deployed. The SIM was designed with an emphasis on three key characteristics:

- Accuracy and Precision of Estimates – to the extent possible, ensure that the SIM estimates reflect the data that are collected or obtained from previously published literature or other efforts.
- Modularity – ensure that the SIM is designed so that some components can be added or subtracted as needed for the situation being modeled.
- Flexibility – ensure that the SIM is not technology-specific, but instead may accommodate countermeasures that are outside its original scope provided that sufficient data are available to characterize these technologies.

While all the steps followed to complete the SIM process for backing crashes are described in this document, it is important to note that users of the SIM model may not need to follow the complete methodology in generating new safety benefits estimates. If the countermeasures that will be modeled are already included in the SIM model, then no additional objective testing or data gathering would be required. In contrast, if the countermeasures to be assessed are substantially different from those in the model, but developed to address a similar set of crash scenarios, then new objective test runs will be needed but development of new test scenarios should not be required. In general, the user of the SIM model should carefully assess the need for new executions of different components of the SIM process to improve the accuracy of model estimates for the user's application.

The SIM process starts with information that is obtained to scope and understand the crash problem to be addressed. The SIM ends with the estimation of the potential safety benefits that may be obtained from a potential crash countermeasure. Figure 22 presents a vision of the steps that are followed between these two actions. This framework was developed by NHTSA as a general representation of the SIM process, and was used as a guide through the execution of the backing SIM process. The rest of this chapter describes the general accomplishments based on the high-level processes, and indicates which chapters of this document provide more detailed information about these accomplishments.

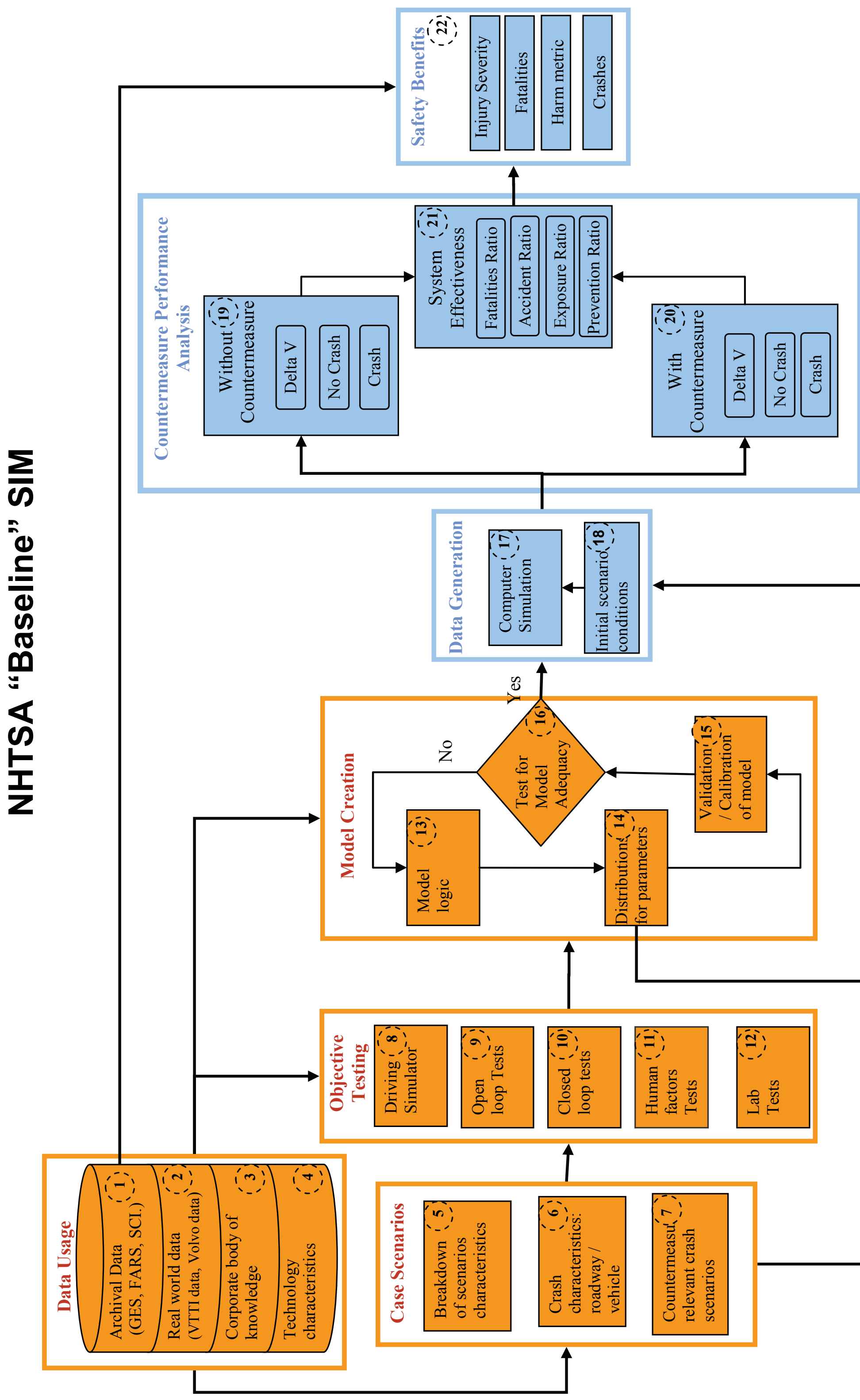


Figure 22. SIM Flowchart.

The first step in the SIM process was to explore the different data sources available ("Data Usage" in the diagram), which were used to inform the development of the case scenarios, assist in objective test development and model creation, and scope the estimation of the safety benefits. The efforts for this part of the process are documented in Chapter 4 of this document. The team consulted public literature, archival data, and empirical data from naturalistic and experimental studies. The team also benefited from a sizable corporate body of knowledge about the problem and potential countermeasures, as well as knowledge about the characteristics of the countermeasure technologies.

The acquisition and consultation of these data sources led to the parallel development of Case Scenarios, Objective Testing, and Model Creation. The first of these, Case Scenarios, are discussed in Chapter 5 of this document. The team used a structured approach in the development of these scenarios, which included the following steps:

1) Generate requirements
2) Identify backing crash schemas
3) Seek/Gather additional data
4) Generate list of factors and levels
5) Evaluate parsimony and reduce list
6) Document assumptions
7) Document additional factors
8) Generate scenarios

Development of the case scenarios was specially assisted by consulting SCI crashes and the Cognitive Reliability and Error Analysis Method (CREAM)/DREAM methodology.

The Objective Testing process is described in Chapter 6. Three different types of tests were developed: grid tests of system response performance, false alarm performance tests, and driver-in-the-loop tests. Substantial efforts were directed towards carefully defining the conditions and protocols for these tests to ensure they would efficiently calibrate and inform the SIM model that generated the safety benefits estimates. A total of 15 different objective tests were designed and conducted as part of this effort.

The final parallel step, Model Creation, is described in Chapter 7. The model, implemented within the Matlab engineering environment, is based on a Monte Carlo simulation process.   The Simulink simulation language, which is embedded within Matlab, was the main tool used in the development of the simulation component of the SIM model. There are two main structural components for the SIM model. The first is the control code which is in the form of Matlab script. The control code sets up the structure of the SIM, controls the inputs to Simulink, and processes the outputs from Simulink. The second component is the simulation model implemented in Simulink, which establishes a Monte Carlo simulation process that is repeatedly accessed by the control code to generate the SIM model results. Each time the Monte Carlo simulation process is accessed represents a single independent backing maneuver.   As part of the Model Creation process, there were different development tests to ensure that the model was properly calibrated and validated to the data that were available. Due to their relevance, these efforts are described in a separate chapter of this document, Chapter 8.

Data Generation, Countermeasure Performance Analysis, and Safety Benefits processed were accomplished via computer simulation of outcomes for each of the initial scenario conditions. The efforts to accomplish these steps of the SIM process are described in chapters 9 and 10. Chapter 9 describes how the calculation of the safety benefits was accomplished. Generally, these calculations were based on the outcomes of the simulation model (specifically, whether and how frequently crashes occurred with and without the countermeasure) and some properties of those crashes (e.g., impact speed). The basic equations for these estimates follow:

$$C_A = C_{wo} \times D_C \times SE \quad \text{(Equation 1)}$$

Where:

- C_A = annual number of the type of crashes of interest predicted to be avoided with a countermeasure's deployment
- C_{wo} = annual number of the type of crashes of interest prior to a countermeasure's deployment
- D_C = potential countermeasure deployment rate in the vehicle fleet
- SE = System Effectiveness – proportion of relevant crashes expected to be prevented by the countermeasure of interest

$$H_R = H_{wo} \times D_C \times SR \quad \text{(Equation 2)}$$

Where:

- H_R = predicted annual reduction in harm for the type of crashes of interest with a countermeasure's deployment (***for the purposes of the backing crash estimates, reductions in harm are calculated based on reductions in fatalities***)
- H_{wo} = annual total harm for the type of crashes of interest prior to a countermeasure's deployment (***i.e., for the backing crash estimates, the total number of annual fatalities due to these crashes***)
- D_C = potential countermeasure deployment rate in the vehicle fleet
- SR = System Harm-Reduction Effectiveness – estimated total effectiveness of the countermeasure in reducing the harm caused by the types of crashes of interest

Chapter 10 uses these equations to generate estimates of potential safety benefits for each of the scenarios developed to bind the backing crash problem in Chapter 5. As suggested by the equations above, potential safety benefits were estimated based on the number of potential crashes avoided and the number of potential fatalities avoided if one or more of these countermeasures were deployed.

The final chapter of this document, Chapter 11, summarizes the efforts and presents limitations of the current model and areas of potential future research to improve the accuracy of these estimates.

4 DATA SOURCES

Data sources which were used to create crash scenarios and to provide a foundation for the development of the SIM are identified in this chapter.

4.1 Data Sources used to Identify Crash Scenarios

A variety of data sources were used to identify crash scenarios. They are briefly described below, and appear together in Table 5 toward the end of this section.

4.1.1 National Databases

4.1.1.1 NHTSA General Estimates System (GES)

Data from the GES in 1992, 1994, 2004, and 2005 all served as a source for defining backing crashes and scenarios. However, primary focus was on the 2005 GES data.

4.1.1.2 NHTSA Fatal Accident Reporting System (FARS)

FARS data was used as well (from the time span 1991-2004), as reported by others.

4.1.2 NHTSA Special Crash Investigations Database

4.1.2.1 Background on NHTSA's Special Crash Investigations

NHTSA's SCI Unit began collecting data on backover and non-crash events in October 2006 and began publishing cases on NHTSA's website in September 2007. According to the report published by NHTSA in April 2008, there were a total of 50 backover cases reported to the SCI Unit (Chidester, 2008). These cases can be accessed by the general public at the following link: http://www-nass.nhtsa.dot.gov/BIN/logon.exe/airmislogon. A detailed analysis of the first 35 of these 50 cases that were released was conducted. These cases were investigated by Indiana University's Transportation Research Center School of Public and Environmental Affairs, Calspan Corporation's Crash Data Research Center and Dynamic Science, Inc. Sample cases were included that originated from the following states: Arizona, California, Florida, Hawaii, Illinois, Iowa, Michigan, Missouri, Nebraska, New Mexico, New York, North Carolina, Oregon, Texas, Tennessee, Utah, Virginia, Washington, and Wisconsin.

4.1.2.2 Overview of Methods Used in SCI

Unique to SCI reporting is the ability to garner detailed accounts of the entire incident from pre-crash sequencing through post-crash. These investigations are done by teams of specially trained crash investigators who travel to the site of a crash selected for investigation as soon as possible after the incident has occurred to undertake measurements, reconstruction, interviews with participants and witnesses, and other data collection. SCI reports provide more detail than, for example, the GES which relies upon data collected from police accident reports (PARs). Each SCI case provides a summary of the crash site, vehicle data, crash sequence (pre-crash, crash, post-crash), vehicle contact evidence, rear visibility measurements, nominal visibility diagram, a crash schematic, and a non-in-traffic surveillance form. A summary of each of these is provided in Table 3.

Table 3. Summary of SCI Case Elements and Example Descriptions

Crash site	Residential, street, direction vehicle is parked, direction vehicle traversing, grade of driveway, width and length of driveway, lighting conditions, pavement condition, weather conditions, if traffic was present.
Pedestrian data	Age, height, gender, weight, clothing type and color, type of shoes, injuries, if the pedestrian was transported to hospital and final condition (fatal/non-fatal).
Driver data	Age, height, gender, weight, frequency of the backing maneuver, relationship to pedestrian, wearing eyeglasses.
Vehicle data	Year, make, model, Vehicle Identification Number (VIN), the type of backup/parking aid (where applicable), tinting of windows, position of all headrests, measurements of wheelbase, overall length, distance from ground to bottom of bumper.
Crash sequence	*Pre-crash description:* if driver was talking with passengers or others outside the vehicle, how the driver approached the vehicle to enter, what the driver said to bystanders, pedestrian's position or activity and approach direction (if any), the driver's visual scan behavior. *Crash description:* the portion of the vehicle that impacted the pedestrian, the time between the start of the backing maneuver to impact, distanced traveled from impact to final rest, the vehicle's impact speed. *Post-crash description:* if the driver heard bystanders, how the driver discovered the struck pedestrian, if pedestrian was transported by ambulance.
Vehicle contact evidence	Evidence of an impact from the vehicle to the pedestrian is reported, such as back bumper, tire, undercarriage elements, etc.
Rear visibility measurements	Measurements from field of view through side-view and rearview mirrors, relevant blind zone measurements, whether the driver would have seen the pedestrian based upon the measurements.
Nominal visibility diagram	Driver's eye height from ground and sight distance from ground, blind zone measurements from driver's view (including head restraint positions).

Crash schematic	Top view drawing of the crash diagram.
Non-in-traffic surveillance form	Case number, date of crash, time of crash, light conditions, atmospheric conditions, temperature, type of area in which crash occurred, driver exterior sightline obstructions, crash location, non-motorist sightline obstructions, grade at parked position, estimated distance from parked position to impact, estimated speed at impact, grade at impact, estimated distance from impact to vehicle final rest. *Vehicle data:* VIN, model, year, and make, glazing, tire size and manufacturer recommended tire size, seat/head restraint position, vehicle measurements (beltline, top of trunk, bottom of bumper, trailer hitch, undercarriage, sensor height, camera height). *Camera data:* make/model, video monitor type, video display size, camera location, video image quality, if camera was functioning properly. *Ultrasonic/radar sensor data:* make/model, auditory warning activation, number of sensors, sensor locations, if functioning properly, if driver reacted to warning, if driver reported common false warnings. *Driver data*: age, sex, height, weight, eyewear worn, vision deficiencies, relationship to pedestrian, driver's approach to vehicle for entry, driver entry interruption, purpose of backing, where the driver was going, if driver was in a hurry, did driver check behind after vehicle entry, estimated time between vehicle entry and start of backing, direction driver was looking during backing, if driver was distracted, driver avoidance actions, did driver see pedestrian prior to impact, estimated time between start of backing and impact, driver interior sightline obstructions, driver's experience driving vehicle, driver's familiarity with the parking lot/driveway, driver impairment, alcohol/drug results. *Non-motorist data:* age, sex, height, weight, clothing and shoes, medical outcome, source of most severe injury, impairment, alcohol/drug results, attitude, motion, approach relative to rear of vehicle, first avoidance action, primary focus of attention, any other non-motorists present.

4.1.3 State Databases: Nebraska, Kentucky, North Carolina

State crash databases from Nebraska, Kentucky, and North Carolina were examined. Different coding schemes are used between states for some definitions, but some comparison between states was possible.

4.1.4 Supplemental Data Sources

An attempt was made to gather additional sources of data including: National Electronic Injury Surveillance System (NEISS), PARs, and death certificates. With the exception of NEISS, these other data sources were unavailable at the time of this writing. NEISS sampling was used to estimate that approximately 2500 people per year were admitted to emergency rooms due to backover incidents from 2001 to 2003 (CDC, 2005).

4.1.5 Non-Traditional Sources

Non-traditional sources were also inspected that track and record information on backing crashes. The information from non-traditional sources provides a record of backover incidents and basic information on the location and other aspects of the backing crash. These reports support an overall characterization of the problem. Depending on the source of information, various aspects of the incident are emphasized in relation to the mission and goals of each organization to provide a heightened level of awareness to these types of incidences. Even thought the information for these reports serve to support an awareness to the type of backover crashes that are occurring and some of the factors involves in the crashes, the records were not at a level of detail sufficient for this research in relation to identifying underlying trends and specific parameters need to support the characterization of backing crash scenarios or the depiction of these scenarios in a computer simulation environment.

4.1.6 Naturalistic Data Sources from Archives/Literature

Another source of information was previous naturalistic research (e.g., the 100-Car Study, Dingus et al., 2006). In the 100-Car Study, 12 backing crashes were recorded, but it is possible that others went unrecorded as data acquisition systems could take several minutes to begin recording. Thus, as with the other sources of data, this may represent an underestimate of the true extent of the backing crashes in the United States. The participant's vehicle was the striking vehicle in 2/3 of the instances. Where it could be discerned, these incidents took place in the following locations: parking lot (4), driveway (2), parking garage (1), and street (2). None of the crashes was police reported, and there were no pedestrian crashes. Therefore, none of these crashes would have been included in any crash database. Although there was minimal damage in most of these cases, their occurrence gives another indication that the total number of backing crashes may be underestimated. The following scenarios were captured from the 100-Car naturalistic study data; how these observed incidents mapped to the proposed scenarios is shown in parentheses.

- Lead vehicle pulls too far into intersection, backs into stopped vehicle directly behind (VV:S1)
- Vehicle backs out of parking space and strikes parked car (V-V: S3)
- Vehicle backs into fixed object (V-FO: S1)

Eighty-nine percent of the observed crashes involved a stopped vehicle or fixed object, with the majority being low-speed incidents with peak speed ranging between 1 and 6 mph; most were at or below 3 mph. The distance to obstacle at backing onset in three instances was less than 8 ft; one instance at 20 ft, and one at 60 ft.

These results also provided insight on contributing factors that may be important, such as driver distraction or emotional state and the fact that drivers sometimes seem to simply misjudge distances when backing.

Tsimhoni, Flannagan, and Green (2006) analyzed backing data from a field operational test (FOT) of a forward collision warning and adaptive cruise control system (see NHTSA, 2005). Some 6,000 naturalistic backing behaviors were observed from 96 drivers in southeastern Michigan. Data are shown in Table 4 and Table 5. The speed and distance data found here correspond fairly closely to those found in the 100-Car Study cited above.

Table 4. Naturalistic Backing Data (adapted from Tsimhoni, Flannagan, and Green, 2006).

Percentile	Avg Speed		Max Speed		Distance		Duration
	m/s	mph	m/s	mph	m	ft	s
50th	0.46	1.0	1.4	3.1	4.52	14.8	4.9
75th	0.81	1.8	2.0	4.5	8.17	26.8	7.4
85th	1.03	2.3	2.2	4.9	12.30	40.4	9.8
95th	1.47	3.3	3.1	6.9	22.6	74.3	15.8

As noted by the researchers, the 6,000 backing events may represent a biased sample, because on the majority of the trips, the first minute or so was not recorded due to the time it took for the recording system to become active after ignition. As a result, it is likely that some, perhaps many, backing maneuvers (i.e., those occurring at the beginning of the trip) were excluded from this data set (Tsimhoni, Flannagan, and Green, 2006).

Table 5. Summary and Highlighting of Supplemental Sources on Backing Crashes and Factors

	DATA SOURCES									
IDENTIFIED FACTORS	GES	FARS	SCI	State (KY,NE,NC)	Naturalistic [3]	Death Certificates	PARs (from Eberhard)	CDC, 2005 and NHTSA, 2006	Hospital Data (Nadler et al. 2001 or Patrick et al. 1998)	Utah state data (Pinkney, Smith, Mann, Mower, Davis, and Dean, 2006)
Roadway type	Yes	Yes	Yes, 73% driveway, 27% parking lot	Yes[2] (NE: 41% backing crashes not in traffic way, KY: 37% backing crashes on private property, NC: 2% backing crashes on private property)	No	?	Yes	No	No	Yes
Backing Maneuver Type	No	No	Yes	No	No	?	No	No	No	No
Struck Object Type	Yes	Yes	Yes	Yes[2]	No	Yes/NA	No	No	No	No
Pedestrian Age	Yes	Yes (under 5 at highest risk)	Yes	Yes[2]	No	Yes (under 5 at highest risk)	No	Yes (Ages 1-4 represent 50% of all cases)	Yes (under 5 at highest risk)	No
Struck Object Motion	Yes[1]	Yes[1]	Yes (27% stationary, 9% moving, 18% "playing", 46% unknown)	Yes[2]	No	?	No	No	Yes (59% unknown or "playing", 31% moving, 9% stationary)	No
Backing Direction	No	No	Yes (27% left, 9% right, 64% straight)	No	No	?	No	No	No	No
Direction of Approach of Struck Object	No	No	Yes (18% left, 45% right, 27% straight, 9% unknown)	No	No	?	No	No	No	No
Pedestrian Posture	Yes[1]	Yes[1]	Yes (18% standing, 18% prone, 18% "playing", 46% unknown)	Yes[2]	No	?	No	No	Yes (59% unknown or "playing", 41% standing)	No
Location of Pedestrian Relative to Vehicle Center	No	No	Yes(17% center, 33% right, 50% left)	No	No	?	No	No	No	No
Distance of Struck Object Behind Vehicle	No	No	Yes,Avg=9.8ft, max=19.7ft, min=3.3ft	No	No	?	No	No	No	No

[1]not representative since these are limited to trafficway accidents.
[2] inconsistencies among states on classification of nontrafficway crashes.
[3] no pedestrian related crashes in 100-Car naturalistic data.
Already Used

4.2 Data Sources for the Driver Model Components

This section describes the components of the driver model contained within the SIM. These components are described based on the Brake Reaction Time, the Braking Level, and the Glance Behavior.

4.2.1 Brake Reaction Time

A review of studies done on backing that contained brake reaction time data (Appendix F) revealed that there were several factors of importance in influencing brake reaction times. It is useful to categorize them into two sets: the first set contains the factors which are predominant in terms of the magnitude of effects that they contribute to brake reaction times. The second set contains additional factors that play more specific, and usually more minor, roles in affecting brake reaction times.

Predominant factors:

- Alerted versus Non-alerted State of Driver. Represents whether the driver received an alert about a potential threat (e.g., via a countermeasure) or was left to detect that threat on his own. Although some studies report the magnitude of this effect to be on the order of 0.30 s, some studies reveal larger effects – up to 0.50 s and beyond.
- Driver Foot Position at the time braking is initiated (on brake pedal, on accelerator pedal, or located elsewhere; can contribute up to 1 second of time in the brake reaction time). However, there are insufficient data available to model in the SIM.
- Type of Backing Conflict (or "Surprise Event") – differences fell within the range from 0.575 – 1.964 s, but scenario-specific values are not available in sufficient detail to allow for inclusion of this parameter in the SIM.

Additional factors which play more specific and minor roles:

- Age of the driver (younger, middle-aged, older), especially in combination with Alerted State. Usually non-significant as a main effect; but there is a hint of a possible interaction with "alerted" state in which younger drivers are slightly less facilitated by the alerts, and slightly slower to react than drivers of other ages – but significantly so – though the effect has been replicated.
- Backing Task or Maneuver Type being completed when a backing conflict occurs (brake reaction times for different types of backing tasks ranged from 0.45 s to 0.75 s).
- Vehicle Type – differences in the range of 0.48-0.73 s were found in one study between sedan and minivan.
- Type of Backing Countermeasure Alert – this can influence the nature of the driver response – e.g., whether a foot response is elicited, in addition to an attentional response – and hence may determine or contribute to the nature of facilitation from an alert.
- Timing of Backing Countermeasure Alert – early alerts allow more braking time, and drivers take more time – hence brake reaction times tend to be longer (means fall in the range from 0.7 to 2.1 s, depending on whether the timing of an alert is late to early).

The SIM model only considers in its driver model one of the predominant factors, which is the Alerted versus Non-alerted State of the Driver. Two basic distributions were selected for brake reaction times:

one for non-alerted and one for alerted brake reaction times. To identify the appropriate distributions to use, it was necessary to look across studies – at the range of effects observed for non-alerted and alerted brake reaction times. The ranges of brake reaction times for Non-Alerted versus Alerted states can be compared across studies using means and standard deviations (the most commonly reported data; see the chapter on Data Sources for full descriptions), as displayed in Table 6.

Table 6. Comparison of brake reaction time data across studies.

	NON-Alerted Brake Reaction Times		ALERTED Brake Reaction Times	
Research Study	**Mean**	**SD**	**Mean**	**SD**
Paine & Henderson (2001)	0.80 s	0.62	0.50*	0.62*
Mazzae & Garrott (2006)	1.17	0.31	0.54	--
Harpster, Huey, Lerner, et al. (1996)	--	--	0.54	0.31
Llaneras, McLaughlin, et al. (proprietary)	1.33	--	0.82	--
Llaneras, Neurauter, et al. (proprietary)	1.33	0.79	0.71	0.56

*Estimated based on reported effect sizes.

An examination of this table suggests that a Weibull distribution shaped like the one cited in Paine & Henderson (2001) as having been developed by Williams (1999) – but with a central tendency closer to that used by Mazzae & Garrott (2006) – may come the closest to comprehending the full range of Non-Alerted Brake Reaction Times observed in the backing studies reviewed here. Similarly, a Weibull distribution for Alerted Brake Reaction Times with a central tendency adjusted to reflect the Mazzae & Garrott (2006) mean for Alerted Brake Reaction Times may also do well in comprehending alerted brake reaction times. In the latter case, however, the means from two studies appear to lie considerably above the mean for the alerted Mazzae and Garrott distribution (Llaneras, McLaughlin, et al., proprietary; Llaneras, Neurauter, et al., proprietary). Since the Llaneras studies were done on systems that include backing countermeasures of the type that need to be addressed by the SIM model, their values were used to represent the central tendency of the distribution used for Alerted Brake Reaction Times. Therefore, the SIM model contains two separate reaction time distributions: an alerted distribution and a non-alerted distribution.

4.2.2 Glances Distribution

The literature (see Appendix F for a full review) suggests that there are several key factors in determining a driver's eyeglance behavior while backing. Countermeasures that are present and active are one of those key factors. Since most studies providing eyeglance behavior data are not comprehensive in their assessment of different backing countermeasure components, most of these data were extracted from the driver-in-the-loop tests (described in Chapter 6) or Mazzae et al. (2008). The data of Mazzae et al. were used to define the location of the initial glance as the backing maneuver in a simulation trial started. These data were also used to obtain glance duration, which was assumed not to vary based on countermeasure availability or response state. Countermeasure response, however, was considered in selecting successive glances (i.e., eyeglance sequence) as each simulation trial progressed.

Data to determine eyeglance sequence were selected based on the presence and type of countermeasures. The sources for these data varied as different countermeasures responded throughout a simulation trial. In the initial stages of each simulation trial, when no countermeasures were responding, the eyeglance sequence data from Mazzae et al. (2008) were used. These data were used regardless of backing scenario, since it was assumed that backing instances similar to those represented in the simulation scenarios were contained in these data. As countermeasures started responding, other data sources were accessed. When Enhanced Vision or Proximity Information countermeasures were responding, corresponding data from Mazzae et al. were used. Similar to periods with no countermeasure response, the same eyeglance sequence data were accessed regardless of backing scenario. As other countermeasures responded (i.e., Cautionary Backing Warning, Imminent Backing Warning, and Automatic Braking), data from driver-in-the-loop tests were used. These data were also backing scenario-specific.

The process for derivation of eyeglance sequence is dependent on a number of factors. These include whether Enhanced Vision is available as a countermeasure, whether any particular countermeasure is responding, the location of the current glance, and the duration of the current glance. The latter factor was used in response to the data from Mazzae et al. (2008), who saw differences in locations of the next glance based on the duration of the current glance. Specifically, their research differentiates between instances where the current glance lasted less than 1.75 s, between 1.75 and 3 s, and more than 3 s. The process to generate an eyeglance progresses as follows:

- Generate a first glance location and duration (duration is based on the location), if none has been generated.
- If a glance has already been generated and its duration has elapsed, generate a new glance location. The new location is generated by comparing a random number to a set of probabilities that location x will be the next glanced-at location. This probability varies depending on:
    - Availability of Enhanced Vision countermeasure
    - The response state of the different countermeasures
    - Location of the current glance
    - Duration of the current glance
- Once a new glance location has been generated, determine a glance duration for it.
- Repeat the process once a glance duration has elapsed, or sooner if a countermeasure responds during that time.

4.2.3 Driver Trust

A brief literature review was completed to examine the extent to which drivers have previously exhibited trust in the various countermeasures that are part of the suite that was tested. These probabilities were either available from previous research literature or within archival data. These studies are briefly described in Appendix F, but only values for Imminent Backing Warning were taken from this review since driver-in-the-loop test data were available (and considered appropriate) for all the remaining countermeasures.

4.2.4 Vehicle Kinematics

A comprehensive literature review (Appendix F) related to backing vehicle kinematics for a variety of backing maneuvers was conducted, and its results are presented in the chapter on Data Sources. The results of this literature review, along with some assumptions, were used to describe vehicle kinematics.

- First, a caveat. In using the results from the literature review, it was often the case that more than one vehicle type was tested. In those cases, the choice closest to the experimental vehicle (i.e., Chevy Tahoe) was selected. In the research cited in the chapter on Data Sources, that vehicle was typically a minivan.
- The "Minivan" values in Table F- 63, backing maneuvers 4, 1, and 3 were used to model the maximum speed for the various backing scenarios, following the logic described in the chapter on Data Sources to split the scenarios among different backing maneuvers. The spread observed between the 10th to 50th and 50th to 90th percentiles was averaged and used to infer a standard deviation for a normal distribution approximation, employing the 50th percentile values as empirical means (Table F- 63). The overall maximum and minimum were used as upper and lower limits, respectively.

Table 7. Distribution of maximum speeds (in mph) from Llaneras et al. (2001) across various different backing maneuvers, represented by their estimated normal distribution parameters.

Backing Maneuver	**Normal distribution parameters (Minivan vehicle):**
1. Parallel parking condition	μ=2.29 mph, σ=0.60 mph
3. Short Backing (Wall condition @ ~50 ft)	μ=4.47 mph, σ=1.48 mph
4. Backing out of a perpendicular parking slot	μ=2.13 mph, σ=1.01 mph

- The duration of the backing maneuver was modeled based on backing maneuvers 1 (to model parallel parking) and 3 (to model short backing) on Table F- 65 and the General Motors Corporation (GM) (proprietary) data (modeling backing maneuver 4 – backing out of a perpendicular spot). The maximum and minimums on Table F- 65 were used as upper and lower limits, respectively.
- The minimum time-to-collision (TTC) during the backing maneuver was modeled using the minivan data from Llaneras et al. (2001) for the parallel parking condition (backing maneuver 1, Table F- 66). Backing out of a perpendicular spot was represented by the minivan data from the same study that corresponds to the wall condition at ~50 ft (backing maneuver 3, Table F- 66). Note that these apply only to the Pedestrian Scenario 2 and Vehicle Scenario 3, which were the only ones where the driver would be backing towards a perceived obstacle. Also note that the TTC was calculated with respect to the perceived obstacle locations since this is what the driver would use as a reference. The spread observed between the 10^{th} to 50^{th} and 50^{th} to 90^{th} percentiles was averaged and used to infer a standard deviation for a normal distribution approximation, employing the 50^{th} percentile values as empirical means (Table F- 66). The overall maximum and minimum were used as upper and lower limits, respectively.

Table 8. Distribution of minimum TTC (in sec) from Llaneras et al. (2001) across various different backing maneuvers, represented by their estimated normal distribution parameters.

Backing Maneuver	Normal distribution parameters (Minivan vehicle):
1. Parallel parking condition	μ=3.00 sec, σ=1.79 sec
3. Short Backing (Wall condition @ ~50 ft)	μ=1.72 sec, σ=1.09 sec

- The time from reverse gear engagement to first backward movement for the parallel parking backing maneuver was selected from Table F- 69. For backing out of a perpendicular parking slot, data from GM (proprietary) were used. Data were not directly available for the short backing condition, so the data for the parallel backing maneuver were also used for this maneuver. In all cases, a minimum value of 0.5 s was set as a lower limit [based on the data from Mazzae et al. (2008)]; no upper limit was specified. The data from Mazzae et al. were also used to extend the time in instances where rear video is present. The average calculated rate increase of 11.4% was used.
- A user-selectable proportion of backing maneuvers was considered to occur under time constraint conditions ("hurried"). The default value for this proportion was assumed to be 0.10; note that this value was not based on any empirical data, since none were found. Llaneras et al. (2001) collected data under time constraint conditions for backing maneuver 3 (wall condition at ~50 ft), which was used here to model short backing behavior. Comparing the minivan values for the time constraint scenario (Table F- 70 and Table F- 71) against those obtained under a non-time constraint scenario (Table F- 63 and Table F- 66), there was a 92% increase in the mean maximum speed. There was also a 57% decrease in the mean minimum TTC with a corresponding 50% decrease in the standard deviation. These percentages were applied to obtain estimates for backing maneuvers 1 and 4 (Table 9 and Table 10).

Table 9. Distribution of maximum speeds (in mph) from Llaneras et al. (2001) across various different backing maneuvers in time-constrained backing, represented by their estimated normal distribution parameters.

Backing Maneuver	Normal distribution parameters (Minivan vehicle):
1. Parallel parking condition	Not applicable, obtained by applying change percentages to corresponding values in Table F- 63. - 92% increase in the value obtained from the distribution
3. Short Backing (Wall condition @ ~50 ft)	μ=8.61 mph, σ=1.38 mph
4. Backing out of a perpendicular parking slot	μ=4.10 mph, σ=0.94 mph

Table 10. Distribution of minimum TTC (in sec) from Llaneras et al. (2001) across various different backing maneuvers in time-constrained backing, represented by their estimated normal distribution parameters.

Backing Maneuver	Normal distribution parameters (Minivan vehicle):
1. Parallel parking condition	μ=1.29 sec, σ=0.90 sec
3. Short Backing (Wall condition @ ~50 ft)	μ=0.74 sec, σ=0.55 sec

- Given that planned travel distances are pre-determined for each of the scenarios, the SIM was provided with a range of planned backing travel distances applicable to each scenario. These distances were based on the values observed in the survey of relevant literature (see the chapter on Data Sources) and the characteristics of each scenario. Values to represent the planned travel distance for each simulation iteration were selected randomly from uniform sampling of that range.
- Minimum distance to object for Pedestrian Scenario 2 and Vehicle Scenario 3 was modeled using minivan data from Table F- 72 for backing maneuver 1 (parallel parking condition) and 3 (wall condition at ~50 ft), respectively. The spread observed between the 10th to 50th and 50th to 90th percentiles was averaged and used to infer a standard deviation for a normal distribution approximation, employing the 50th percentile values as empirical means. The 99th and 1st percentiles were used as upper and lower limits, respectively. Resultant values were μ=2.20 ft and σ=1.05 ft for backing maneuver 1; for backing maneuver 3, the values were μ=2.81 ft and σ=1.97 ft.
- The shape of the speed profile varied based on the type of maneuver.
    - With the exception of Vehicle Scenario 3, the profiles for backing out of a perpendicular space were assumed to use a single start-stop maneuver, based on the data from GM (proprietary). The speed profile was modeled via a bell-shaped curve whose shape was controlled by the maximum speed, backing duration, and intended travel distance for each simulation iteration.

- Speed profiles for Vehicle Scenario 3 were modeled using a similar bell-shaped curve, but were also constrained by the minimum TTC and continued until the intended travel distance had been traversed. The assumption was made that adjustments to the TTC were minor and made use only of a coasting/throttle interplay until the backing distance was traveled. Coasting was assumed to begin when the TTC was equal to 10% over the minimum TTC and stop when it was 20% over this value. Coasting decelerations and ensuing accelerations were assumed to occur based on values calculated from the distribution parameters shown in Table 11. When the vehicle distance traveled was within 0.5 m of the maneuver's planned backing distance, a constant acceleration was calculated and used to stop in the remaining distance.

Table 11. Weibull distributions parameters for acceleration and deceleration portions of the backing maneuvers, calculated from ORSDURVS data (Mazzae et al., 2008).

Backing Maneuver	**Weibull distribution parameters:**
Acceleration	Mean=0.05, Standard Deviation=0.05 *g* (translating to the following Weibull parameters in the model Scale = 0.045, Shape = 0.888)
Deceleration	Mean=0.04, Standard Deviation=0.06 *g* (translating to the following Weibull parameters in the model Scale = 0.028, Shape = 0.641)

- The speed profiles for backing into a parallel parking space were modeled using a succession of start-stop maneuvers (as described in Table F- 73) for duration of movement, maximum speed, and duration of pause. Each maneuver consisted of a constant acceleration to the maximum speed for half of the movement duration followed by a constant deceleration back to zero for the remaining half. These maneuvers were also constrained by the minimum TTC (Table F- 66) and continued until the intended travel distance had been traversed. As before, coasting was assumed to begin when the TTC was equal to 10% over the minimum TTC and stop when it was 20% over this value. Minimum individual movement durations were constrained to be 1 s, minimum maximum speeds to 0.5 s, and minimum pause durations to 1 s. Coasting decelerations and ensuing accelerations were assumed to occur based on values obtained from these empirical data. When the vehicle distance traveled was within 0.5 m of the maneuver's planned backing distance, a constant acceleration was calculated and used to stop in the remaining distance.
- A single start-stop maneuver was also assumed for short backing scenarios. The speed profile for short backing scenarios was modeled via a bell-shaped curve whose shape was controlled by the maximum speed, backing duration, and intended travel distance for each simulation iteration.

4.2.5 Braking Performance

In populating the SIM with data on deceleration during backing, the review of the literature (Appendix F) provided measures describing “peak deceleration during maneuver” and measures representing “average deceleration.” As noted in the literature, these two metrics describe slightly different properties of deceleration, and are sometimes affected by different variables. In terms of the range of values over which deceleration changes for backing maneuvers, the various studies surveyed converge with reasonable agreement on peak deceleration in the range from 0.40 – 0.72 *g*. This corresponds rather well with values/ranges used in prior analytical work done by Paine and Henderson (2001) and Eberhard et al. (1995). Furthermore, the survey illustrated that the factors which most significantly influence deceleration as it will be applied and used within the SIM model are an identification of the system element that is applying the brakes (the countermeasure system, the driver, or both) and the type of backing maneuver.

Based on these factors, the data from surveyed studies was used in the SIM model as follows. First, peak deceleration values were used as the endpoint of a triangular ramp-up shape, whose slope is defined by the actual (or average) deceleration values. Minivan data from Llaneras et al. (2001) were used to model instances where drivers brake before receiving an alert; specifically, the data from the "uninstructed" trials. The specific Minivan, "uninstructed" distributions from this study used in the SIM model were selected depending on the SIM scenario according to the following breakdown (see Chapter 5 for a description of each scenario):

- Llaneras et al., 2001, Minivan, uninstructed, *Backing out of a perpendicular parking space*: used for Pedestrian Scenario 1, Pedestrian Scenario 5, and Vehicle Scenario 3
- Llaneras et al., 2001, Minivan, uninstructed, *Backing into a parallel parking space*: used for Pedestrian Scenario 2
- Llaneras et al., 2001, Minivan, uninstructed, *Short backing (represented, due to lack of better data, by 50 ft. straight backing)*: used for Pedestrian Scenario 3, Pedestrian Scenario 4, Pedestrian Scenario 6, Vehicle Scenario 1, Vehicle Scenario 2, and Fixed Object Scenario

Given that there was no average acceleration reported data for parallel and perpendicular backing maneuvers, values corresponding to the 50-feet straight-backing trials (instructed) were used. A similar assumption was used to represent braking profiles after receiving a non-automatic braking alert (Alerted backing – 50 ft, normal speed), based on the data from Llaneras et al. (2002). No differences based on scenario were assumed for alerted conditions. Automatic braking parameters were obtained from and modeled after the expected system specifications. Namely, the peak deceleration possible with the system was assumed to be at a maximum 0.95 *g*, with the rate of application of that deceleration equal to 2 *g*/sec. Driver braking was additive to the extent that it exceeded at any time the deceleration provided by the automatic braking. Driver braking did not prevent activation of the automatic braking.

5 CASE SCENARIOS

5.1 Overview

For this project, a small set of representative backing crash scenarios was identified to serve as a basis for generating objective tests and for assessing a range of possible countermeasures. This set consisted of 10 scenarios selected to represent backing crashes (with special emphasis placed on pedestrian crashes). The set of backing crash scenarios included:

- Six scenarios involving backing conflicts with children (pedestrians)
- Three scenarios involving backing conflicts with vehicles
- One scenario involving a backing conflict with a fixed object.

These 10 scenarios are illustrated in Figure 23 below.

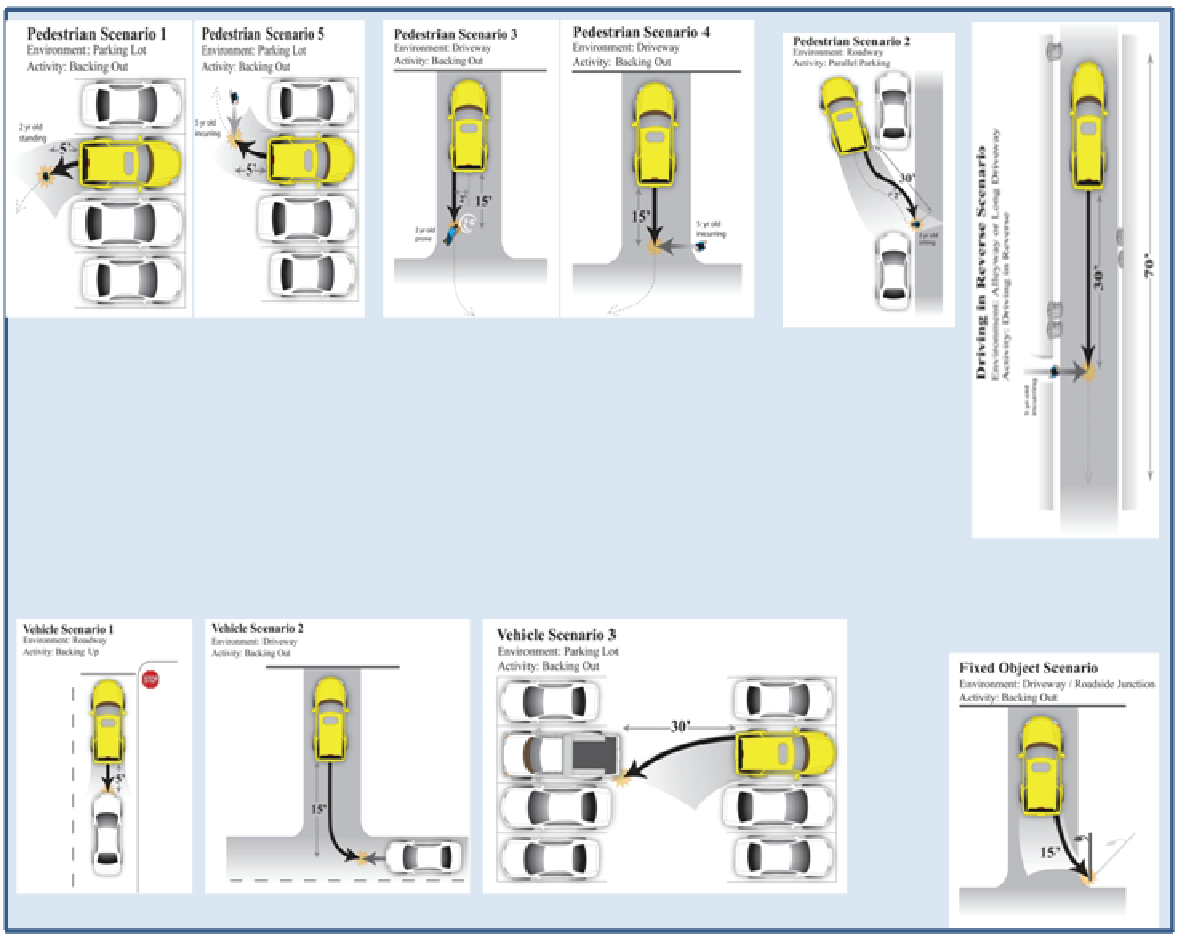


Figure 23. Illustrations of the 10 backing crash scenarios selected for this ACAT project.

With these 10 scenarios, it was possible to represent in some way all of the Eberhard et al. (1994) crashes with the exception of “Struck by a Vehicle in Transport” which, as discussed in Chapter 2, was excluded because it is a crash in which the backing vehicle was struck (not striking) and which would most likely be prevented by the striking vehicle. Within these 10 scenarios, the two types of backing crashes from the crash classification schema known as 37 Crashes (Najm, Smith, and Yanagisawa, 2007) were also represented, one completely and the other partially. (The pedestrian involvement in “backing with roadway departure” is covered, but not the roadway departure itself, since that would require some type of lane-keeping countermeasure in the rearward direction, not included here.)

Furthermore, the remaining scenarios focus on pedestrian backover conflicts, in which children of different ages represent the class of pedestrians. This emphasis was chosen because of the complexity of pedestrian backover crashes. These 10 scenarios are illustrated above, with the 6 pedestrian scenarios shown along the top row of Figure 23, and the 3 vehicle-to-vehicle scenarios in the bottom row (to the left), and the 1 vehicle-to-fixed-object scenario in the bottom row (to the right).

5.2 The Process of Scenario Development

These scenarios were identified through a 10-step process, shown in Figure 24. This process was largely analytic because, at the time, too few data were available on backing crash cases for the process to be done empirically (by sorting actual crash cases into types of scenarios). (As discussed in Chapter 2, the large national databases do not capture a large percentage of backing crashes because they cover only public traffic ways, and many backing crashes occur in private driveways, parking lots, or other areas [perhaps as many as 35-41 percent, according to state data from Nebraska and Kentucky] which are not encompassed by GES or other databases relying on PARs. Furthermore, while NHTSA’s SCI initiative *does* cover backover crashes, at the time when the scenario selection had to be done for this project, none of the SCI backing cases had yet been released publicly.) Therefore, scenario development and selection on the ACAT project for backing crashes had to be accomplished through a reasoned process, making best use of the limited data available at that time. However, it should be noted that the project established and subsequently completed a cross-check of the validity of the scenarios, both with the NHTSA Scenario Definition method (a conceptualization from Najm, et al. 2007, highlighted in section 5.2.8.2) and with empirical evaluation using a set of NHTSA SCI backing crash reports, when they became publicly available.

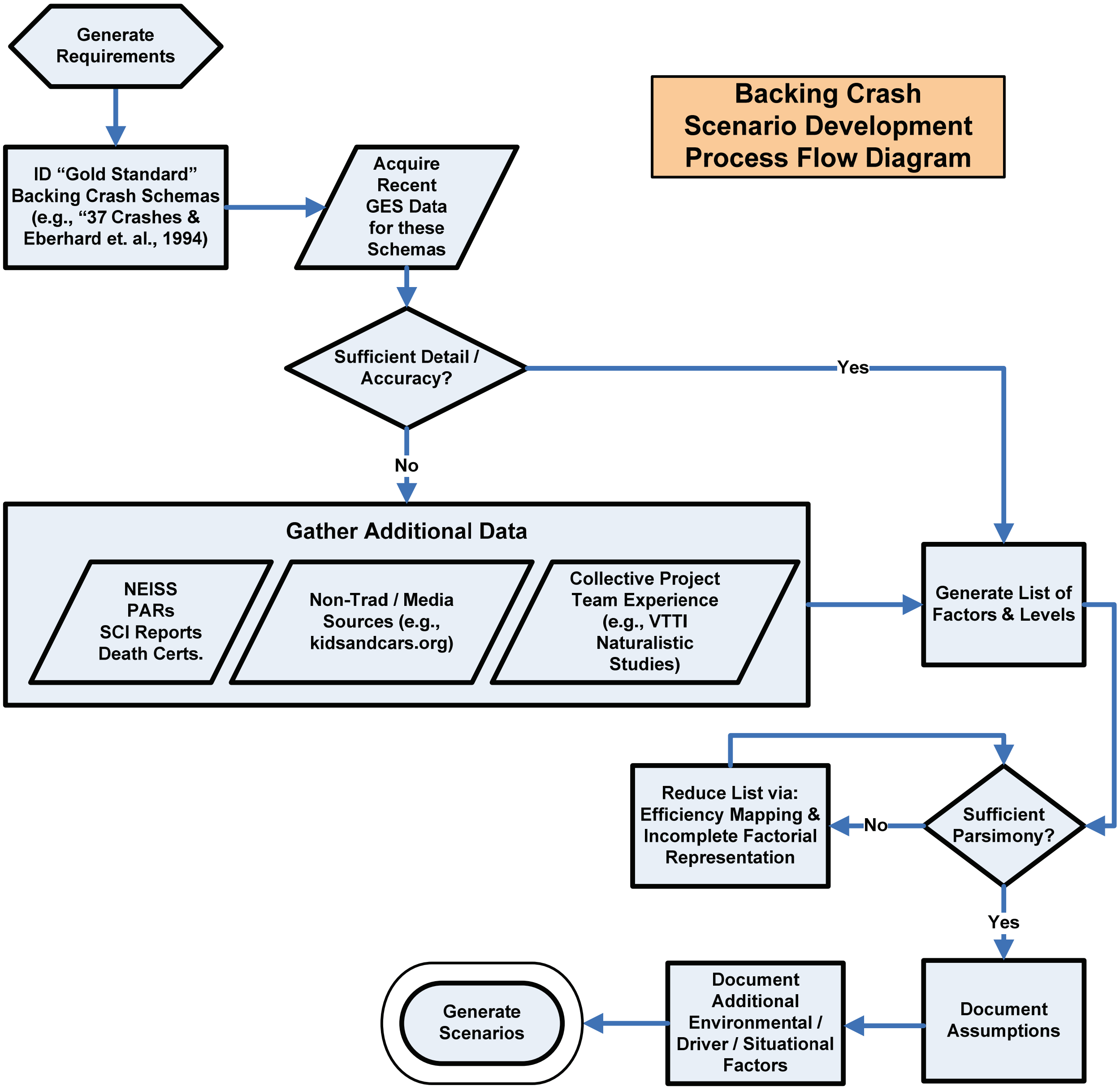


Figure 24. 10-step process through which backing crash scenarios were developed

Each step of this scenario-development process is described below:

5.2.1 Step 1. Generate Requirements

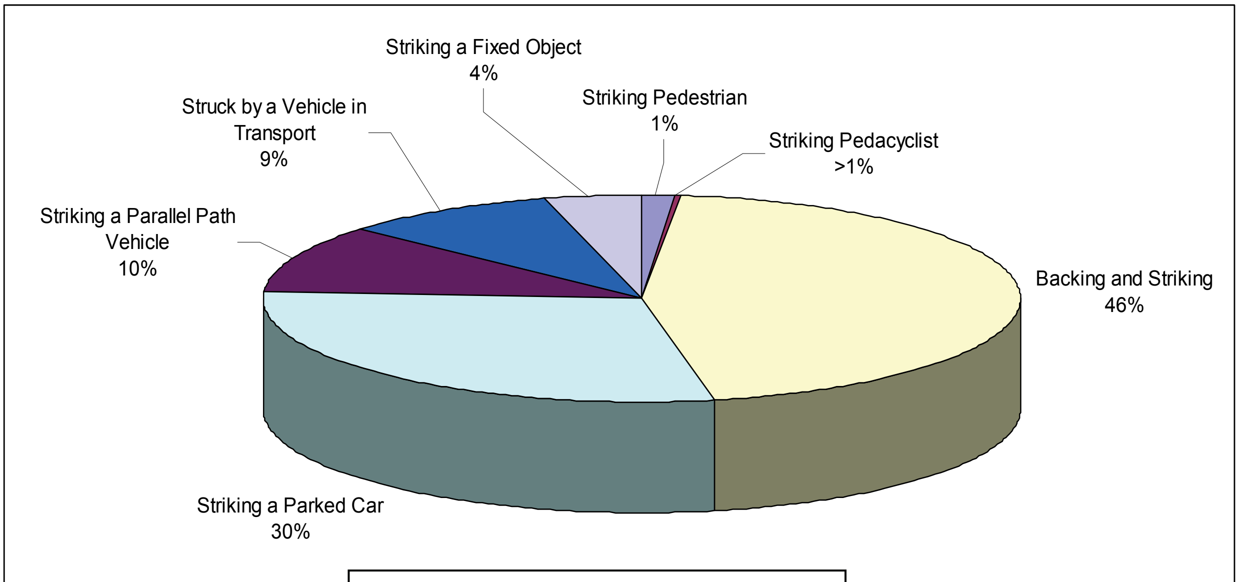
The first step in the process was to define the requirements that candidate scenarios had to meet– what was to be included and excluded. It was determined that the scenarios should meet the following requirements:

The scenarios must describe the *physical* elements of a variety of real-world backing *conflicts* in sufficient detail to serve as the basis for the subsequent development of a thorough set of objective tests that can be used to assess both near term potential countermeasures as well as future countermeasure concepts.

5.2.2 Steps 2 and 3. Identify Backing crash Schemas

Two backing crash schemas were identified that are relevant to this project, those of Eberhard et al. (1994) and *37 Crashes* (Najm, Smith, and Yanagisawa, 2007). These schemas were used to determine what types of backing crashes should be included and excluded in the scenarios. It also provided a mechanism to estimate the extent of the backing crashes that could be covered by the scenarios.

Eberhard et al. (1994) used data from GES to scope backing crashes in the United States at a high level in terms of the categories illustrated in Figure 25. The percentages from the original Eberhard et al. (1994) data have been updated with GES 2005 data in this figure. As described in more detail later, 10 scenarios were ultimately selected to capture these schemas as well as the other data described later. Mapping of these proposed scenarios to the Eberhard et al. (1994) schema is also illustrated in this figure (Figure 25). Six vehicle-pedestrian scenarios (V-P), three vehicle-to-vehicle scenarios (V-V) and one vehicle-to-fixed object scenario (V–FO) were developed. The backing schema that was excluded from consideration in the scenarios is vehicle-struck-in-transport. This crash type consists of the subject vehicle backing into the path of an oncoming vehicle and being struck by that vehicle. This crash type was excluded since the oncoming vehicle, and not the backing vehicle, is more likely to avoid these crashes. That said, it is likely that some of these specific crashes may be avoided by some backing crash countermeasures. This crash type accounts for approximately 9 percent of the backing crashes according to the GES 2005 data. As discussed previously, crashes on private property are likely underestimated in the GES so it is likely that the number of total backing crashes of this type is more than this 9 percent estimate.



Current Scenario Mappings

- V-V = Vehicle-Vehicle Crash Scenario (3 scenarios)
- V-P = Vehicle-Pedestrian Crash Scenario (6 scenarios)
- V-FO = Vehicle-Fixed Object Scenario (1 scenario)

Figure 25. Eberhard et al. (1994) backing crash schema with 2005 GES data and current scenario mappings. Note: "Backing into a motor vehicle in motion" is not shown above, because there were no observations in the 2005 GES data, but there was a small percentage (< 2 percent) in the 1993 data originally used to create the schema.

The study *37 Crashes* (Najm et al., 2007) identified two backing crash types that are relevant to this project. Table 12 shows how four of the proposed scenarios map to these crash types.

Table 12. *37 Crashes* backing crash schema.

37 Crashes **Backing Crash Scenarios**	**Current Scenarios Mapped to *37 Crashes* Scenarios**	**2004 GES Data**		
		Frequency Rank	**Number**	**% of Total**
Backing Up into another Vehicle	Vehicle-Vehicle: S1-3	14 of 37	131,000	2.20
Road Edge Departure While Backing Up	Vehicle-Pedestrian: S2	20 of 37	66,000	1.11

5.2.3 Step 4: Seek/Gather Additional Data

It was determined that these previously identified schemas, while valuable, do not provide sufficient detail to meet the requirements of identifying scenarios which describe the physical elements of pre-crash conditions. Therefore, an attempt was made to gather additional sources of data, including NEISS, PARs, SCI reports, and death certificates. The results of these efforts are described in sections 4.1.4, 4.1.5, and 4.1.6.

Specifically, naturalistic data from Tsimhoni, Flannagan, and Green (2006) provided information about the locations in which backing maneuvers tend to occur:

- 51 percent parking lots
- 15 percent driveways
- 15 percent residential areas
- 8 percent city street parking maneuvers
- 5 percent a result of turning around
- 3 percent in the lane
- 2 percent gas stations
- 2 percent parking structures

In addition, prior studies completed by this research team to evaluate backing and backing crash countermeasures (e.g., McLaughlin, Hankey, et. al, 2003) point to several important concepts:

5.2.3.1 <u>Conflict Before / After Backing Has Commenced</u>

It is important to distinguish between scenarios where a potential conflict exists *at onset* of a backing maneuver from those where the potential conflict comes to exist *after backing has commenced*. The main concept here is that it tends to be much more difficult to convince a driver to stop after backing has commenced (i.e., after s/he has already decided it's safe to proceed). Per NHTSA review of SCI cases, this is the most common condition in real world backover crashes.

5.2.3.2 <u>Parking Maneuver Backing versus Driving in Reverse</u>

A distinction should also made between *parking maneuvers* (i.e., backing into or out of a parking space) as opposed to *driving in reverse* which occurs during longer backing events and tends to involve higher backing speeds. The team's research has shown that these activities differ in several important dimensions, including the driver glance patterns and the speed selected. The environment where these two activities occur is also often different, such as the amount of visual clutter, the likelihood of an obstacle, or a pedestrian being present.

5.2.3.3 <u>Direction of Encroachment</u>

Finally, a pedestrian incurring from the driver's side of the vehicle (i.e., left) is substantially different than an encroachment from the passenger's side of the vehicle (i.e., right) due to driver's non-centered location in the vehicle and typical glance patterns.

5.2.4 Step 5: Generate List of Factors and Levels

The information extracted in the previous steps was used to develop the following factors and levels for consideration in the scenario development.

- Struck Object Type (Backing crash Type)
  - Pedestrian
  - Vehicle
  - Fixed Object
- Backing Pre-Event Maneuver Types
  - Parking ingress/egress
  - Driving in reverse (i.e., longer distances and possibly higher speeds)
- Critical Events (Motion of Struck Object)
  - Stationary
  - Moving
- Roadway Type / Environment
  - Driveway
  - Roadway
  - Parking Lot
- Backing Direction (L or R)
- Direction of Approach of Struck Object (L or R)
- Distance of struck object behind vehicle
  - Near (~5’)
  - Moderate (~15’)
  - Farther (~30’)
- Location of Pedestrian Relative to Vehicle Center (NHTSA, 2006)
  - On center line
  - 2’ offset
- Pedestrian Age
  - 2 (Stationary Behind) (Patrick et al., 1998)
  - 5 (Moving Behind)
  - 70+
- Pedestrian Posture
  - Standing
  - Sitting
  - Prone

5.2.5 Steps 6 and 7: Evaluate parsimony and reduce list

A full factorial representation of all of these factors and levels would result in literally thousands of scenarios. Therefore, a parsimonious method was needed to greatly reduce the number of scenarios, while still representing the importance of all of these relevant factors. One approach to accomplish this was *efficiency mapping* wherein certain factors or levels are mapped to others as appropriate, thereby reducing the total number. In this way, certain factors and levels are accounted for by others that can reasonably represent them.

For example, young children are over-represented in backover incidents, but elderly adults (70+) are often struck as well. It was assumed that if small children can be successfully detected and avoided, with or without countermeasures, then larger pedestrians (who present a larger profile to the driver and/or countermeasure sensor system) should also be detected and avoided. Furthermore, because older pedestrians may be over-represented in backing crashes due to age-related slowing of mobility and/or other issues – and may be unable to move quickly out of the path of a backing vehicle – a scenario in which a young, small child is stationary behind the vehicle should be a "worst case" representation of an immobilized pedestrian. Thus, it is likely that all pedestrian crashes can be mapped to scenarios using a child as the most difficult-to-detect representative of the class.

But even with such efforts, the list was not sufficiently reduced, so an incomplete factorial representation was used, wherein all remaining factors and levels were sampled, but not every possible combination. This is an efficient method of evaluating this multiplicity of factors; however, it also confounds them. This approach has the possibility of making it difficult to determine which factor may be causing a conflict to be successfully or unsuccessfully avoided.

5.2.6 Step 8: Document Assumptions

The assumptions included below are a subset of the assumption that will eventually be associated with this scenario development. As more is learned about backing crashes and how well these scenarios can represent their fundamental characteristics, additional assumptions will be added.

- Elderly pedestrians can be represented by child pedestrians in that child pedestrians are the worst-case scenarios.
- Vehicles-in-transport crashes are best avoided by the principal other vehicle (the striking vehicle) or by non-backing crash countermeasures.
- Pedestrian crashes represent a much larger part of backing crashes than can be captured by traditional crash databases.

There are many more backing crashes than are included in the backing crash databases that occur on private property so the estimates associated with the proposed scenarios are likely an underestimate of the total backing crashes that occur.

5.2.7 Step 9: Document Additional Factors

Because of the focus on the physical elements of crashes for scenario development purposes, it is important to note that there were also a wide variety of other factors identified that may play a substantial role in the etiology of any particular backing crash. These were considered as well in the development of subsequent objective countermeasure testing protocols. Such other factors included the following:

- environmental conditions (e.g., weather, light)
- struck pedestrian or object conspicuity (e.g., size, shape, color, reflectivity, etc.)
- camera / display / warning characteristics (e.g., design, learning, false alarms, and societal inertia)
- backing vehicle type and configuration (e.g., body type and size, window glazing, headrests, etc.)
- infrastructural elements (i.e., visual obstructions and clutter external to the vehicle)

- driver characteristics (e.g., age, height, visual ability, flexibility, etc.)
- transient situational factors (e.g., driver distraction)
- driver expectancy (i.e., novel versus typical situation)
- child under vehicle or directly behind tire
- roadway curvature (straight roadways account for over 97 percent of all known backing crashes)
- roadway grade (non-changing level ground accounts for over 78 percent of all backing crashes)

5.2.8 Step 10. Generate scenarios

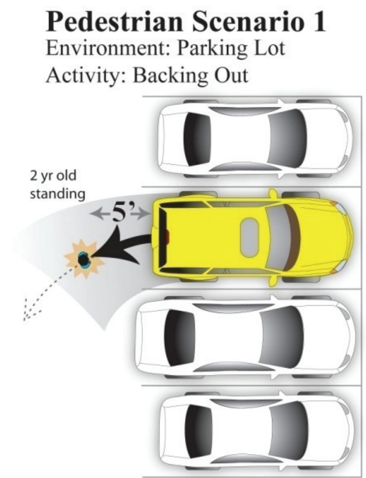
The final step of the process was to select the preliminary list of ACAT Backing crash Scenarios. As described at the outset of this chapter, 10 were selected as prototypical of important types of backing crashes:

- Six scenarios involving backing conflicts with children (pedestrians)
- Three scenarios involving backing conflicts with vehicles
- One scenario involving backing conflicts with a fixed object.

The preliminary list of 10 scenarios selected for the ACAT Backing project appears on the next several pages. First, each is described and diagrammed in greater detail. Then the scenarios are summarized in Table 13 through Table 17.

5.2.8.1 Diagrams, Descriptions, and Summaries of the Scenarios

Pedestrian Scenario 1 (SIM Model Scenario #1):
2-year-old pedestrian standing ~5' directly behind vehicle backing out of a parking space



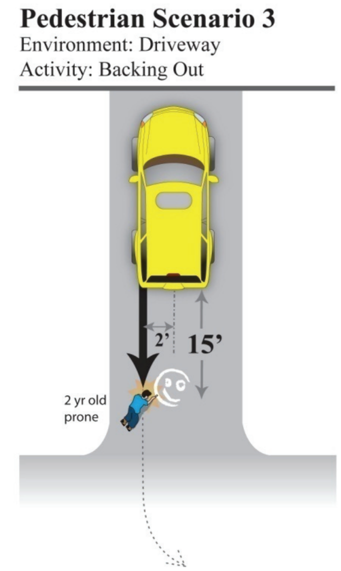
Supporting Analysis: Eberhard et al. (1994) performed an analysis of a number of PARs. They found that backing from a parking space was one of the high frequency environments where pedestrian strikes took place. NHTSA (2006) reported data showing that object offset from the vehicle's center line, even by as little as a single foot, can result in a huge change in sight distance (up to 60'). This will, of course, vary greatly by driver and vehicle characteristics and leads to this scenario including factors of distance off center line (0', in this scenario) and distance from the rear fascia (~ 5' in this scenario). Patrick et al. (1998) showed data that suggest that there may be a different etiology for struck pedestrians under the age of 5 based on age. Whereas, children around age 2 tend to be initially located behind the vehicle, pedestrians around age 5 tend to dart into the path of the vehicle after backing has initiated.

Pedestrian Scenario 2 (SIM Model Scenario #2):
2-year-old pedestrian sitting on curb ~ 30' behind parallel parking vehicle departing roadway

Supporting Analysis: GES 2005 data show that 40 percent of backing vehicle pedestrian strikes occur on or near a roadway. The PARs analysis of Eberhard et al. (1994) shows that on or near a roadway was one of the high frequency environments where pedestrian strikes took place. *37 Crashes* included a discussion of some 4,000 pedestrian strikes resulting from roadway departures while backing. Patrick et al. (1998) found data to suggest that struck pedestrians around age 2 tend to be initially located behind the vehicle.

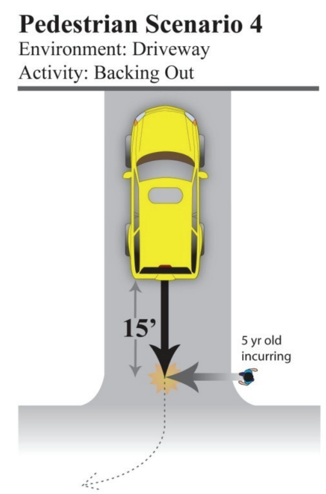
Pedestrian Scenario 3 (SIM Model Scenario #3):
2-year-old pedestrian lying prone 2’ offset from center line on driveway ~ 15’ behind vehicle backing out of a driveway

Supporting Analysis: GES 2005 data show that 42 percent of pedestrian strikes occur on or near a driveway. The PARs analysis of Eberhard et al. (1994) shows that on or near a driveway was the highest frequency environment where a backing vehicle-pedestrian strike took place. Patrick et al. (1998) found data to suggest that struck pedestrians around age 2 tend to be initially located behind the vehicle. NHTSA (2006) reported data showing that object offset even as little as a single foot from the backing vehicle’s center line can result in a notable change in sight distance (up to 60’), thus a 2’ distance offset from center line and ~ 15’ distance from the rear fascia are included in this scenario.



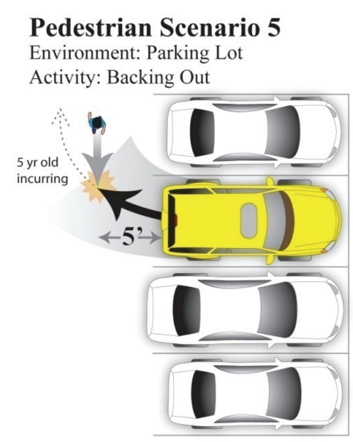
Pedestrian Scenario 4 (SIM Model Scenario #4):
5-year-old pedestrian darting from the right ~ 15’ behind vehicle backing out of driveway

Supporting Analysis: GES 2005 data show that 42 percent of pedestrian strikes occur on or near a driveway. The PARs analysis of Eberhard et al. (1994) shows that on or near a driveway was the highest frequency environment where backing vehicle pedestrian strike took place. Patrick et al. (1998) found data to suggest that struck pedestrians around age 5 tend to dart into the path of the vehicle after backing has initiated.

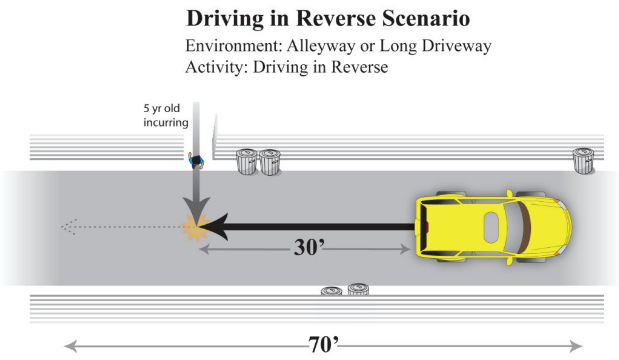


Pedestrian Scenario 5 (SIM Model Scenario #5):
5-year-old pedestrian darting from the left ~ 5’ behind vehicle backing out of parking space

Supporting Analysis: Eberhard et al. (1994) performed an analysis of a number of PARs. They found that backing from a parking space was one of the high frequency environments where pedestrian strikes took place. Patrick et al. (1998) found data to suggest that struck pedestrians around age 5 tend to dart into the path of the vehicle after backing has initiated.

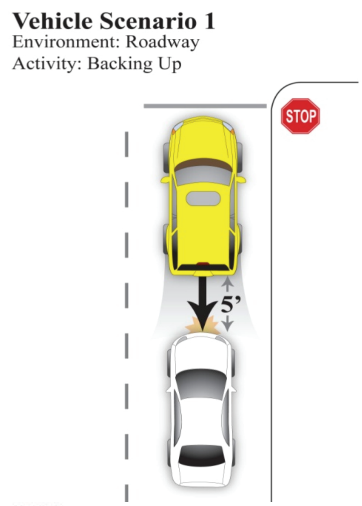


Pedestrian Scenario 6 (Driving-In-Reverse; (SIM Model Scenario #6):
5-year-old pedestrian incurring from the left ~ 30' behind vehicle driving in reverse down alleyway or long driveway



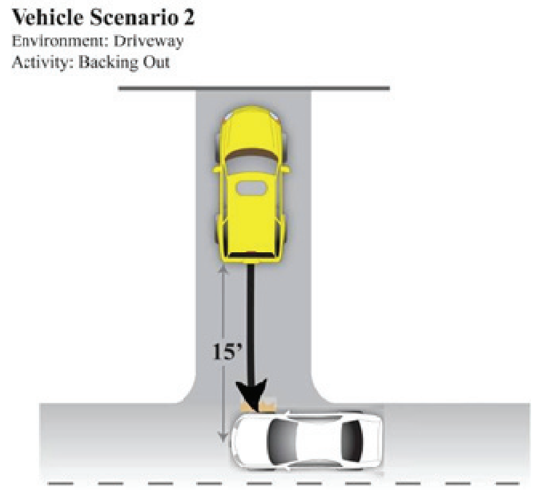
Supporting Analysis: GES 2005 data show that 42 percent of pedestrian strikes occur on or near a driveway. The PARs analysis of Eberhard et al. (1994) shows that on or near a driveway was the highest frequency environment where backing vehicle pedestrian strikes took place. Patrick et al. (1998) found data to suggest that struck pedestrians around age 5 tend to dart into the path of the vehicle after backing has initiated. The project team's backing crash research experience has suggested that there may be a fundamental difference between backing into or out of a parking space compared with driving in reverse, which tends to involve longer backing distances and higher speeds – thus, the long driveway in this scenario.

Vehicle Scenario 1 (SIM Model Scenario #7):
Vehicle protrudes into roadway; driver decides to rectify but strikes a parallel path vehicle directly behind



Supporting Analysis: GES 2005 shows that 10 percent of all backing crashes are parallel path crashes, and that 63 percent of these occur at or near an intersection. *37 Crashes* indicated that backing into another a vehicle was ranked 14th of 37 crashes.

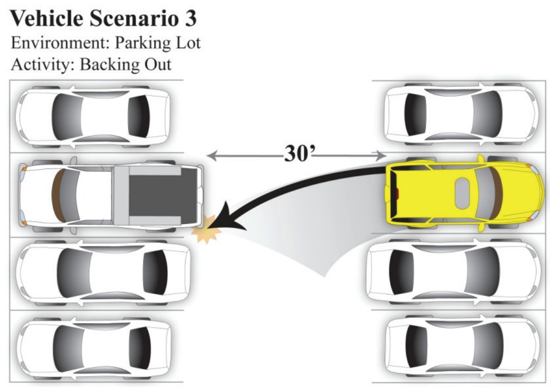
Vehicle Scenario 2 (SIM Model Scenario #8):
Vehicle backing out of driveway strikes a vehicle in motion on roadway



Supporting Analysis: GES 2005 shows that 46 percent of all backing crashes involve backing into vehicle in motion, and 45 percent of such incidents occur at a driveway / roadway junction. *37 Crashes* indicated that backing into another vehicle was ranked 14th of 37 crashes.

Vehicle Scenario 3 (SIM Model Scenario #9): Vehicle backing out of parking space strikes vehicle parked behind

Supporting Analysis: GES 2005 data show that 30 percent of all backing crashes involve backing into a parked vehicle. The PARs analysis of Eberhard et al. (1994) shows that of such crash types, a parking lot was one of the highest frequency environments. *37 Crashes* indicated that backing into another a vehicle was ranked 14th of 37 crashes.



Fixed Object Scenario (SIM Model Scenario #10): Vehicle backing out of driveway strikes a utility pole

Supporting Analysis: GES 2005 data show that 4 percent of all backing crashes involve backing into a fixed object, and that the most frequently struck object is a utility pole or other support structure. GES 2005 data also show that such incidents occur overwhelmingly on the roadside (83 percent), and 46 percent occur on or near a driveway or similar structure.

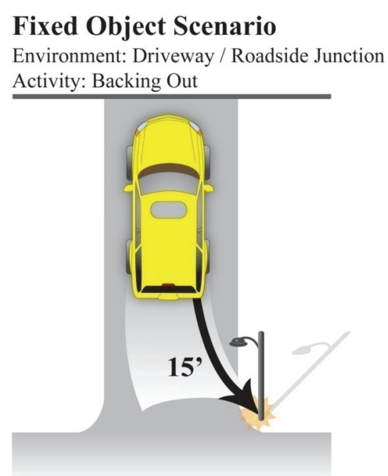


Table 13. Summary of Stationary Pedestrian Scenarios.

Scenario	Roadway Type	Maneuver	Pedestrian Posture / Motion	Pedestrian Age	Center Line Offset / Direction of Encroachment	Distance from Bumper at Initiation of Backing
1	Parking Lot	Backing out	Standing	2	On center line	Near (e.g., 5’)
2	Street	Parallel Parking	Sitting on Curb	2	Right (e.g., 2’)	Farther (e.g., 30’)
3	Driveway	Backing out	Prone	2	Left (e.g., 2’)	Moderate (e.g., 15’)

Table 14. Summary of Incurring Pedestrian Scenarios.

Scenario	Roadway Type	Maneuver	Pedestrian Posture / Motion	Pedestrian Age	Center Line Offset / Direction of Encroachment	Distance from Bumper at Initiation of Backing
4	Driveway	Backing out	Incurring	5	Incurring from right	Moderate (e.g., 15’)
5	Parking Space	Backing out	Incurring	5	Incurring from left	Near (e.g., 5’)

Table 15. Summary of Driving in Reverse Scenario.

Scenario	Roadway Type	Maneuver	Pedestrian Posture / Motion	Pedestrian Age	Direction of Encroachment	Distance from Bumper at Initiation of Backing
1	Alleyway or Long Driveway	Driving in Reverse	Incurring	5	Incurring from left	Farther (e.g., 30’)

Table 16. Summary of Vehicle-to-Vehicle Scenarios.

Scenario	Roadway Type	Maneuver	Vehicle Motion	Location / Direction of Encroachment	Distance from Bumper at Initiation of Backing
1	Intersection	Backing	Stopped behind	On center line	Near (e.g., 5’)
2	Driveway / Street Junction	Backing out	Approaching	From the left	Moderate (e.g.,15’)
3	Parking Lot	Backing out	Parked	Behind	Farther (e.g.,30’)

Table 17. Summary of Fixed Object Scenario.

Scenario	Roadway Type	Maneuver	Struck Object	Location	Distance from Bumper
1	Driveway / Roadside Junction	Backing out	Utility Pole	To the Right	Moderate (e.g., 15’)

5.2.8.2 Verification of Scenarios

A verification, or test of the appropriateness of the scenario set, was undertaken by examining whether actual individual backing crash cases could be successfully categorized into the six pedestrian scenarios. To the extent that real cases could be classified into the existing set of scenarios, this would demonstrate the set's validity and completeness. To the extent that some real cases could not "fit into" any of the scenarios, it would suggest that the scenario set was incomplete – and in need of extension. To the extent that real cases could be classified into scenarios, but their defining conditions or elements did not match those originally attributed to the scenario, it would suggest a need for refining the basic scenario definition(s). It was to provide such an empirical test of the scenario set that the cases reported through NHTSA's SCI unit were analyzed.

In addition, as part of Objective Test Development, it was necessary to define specific conditions that would be used when the tests are administered. Conditions or pre-crash elements (such as weather, pavement type, and lighting) can be thought of as "attributes" which add detail to the pre-crash scenario (which consists of the basic geometry of the driveway, the maneuver, and the critical event). It is useful to consider the NHTSA Scenario Definition method, a conceptualization from Najm et al., 2007 (Figure 26 below) in which the Pre-Crash Scenario (down the left side of the first rectangular plane) and the Pre-Crash Elements (across the top of that first rectangular plane) together define a particular Pre-Crash Setting (Scenario X Elements) such as would be seen in an actual backing crash case – or such as might be set up in a particular objective test.

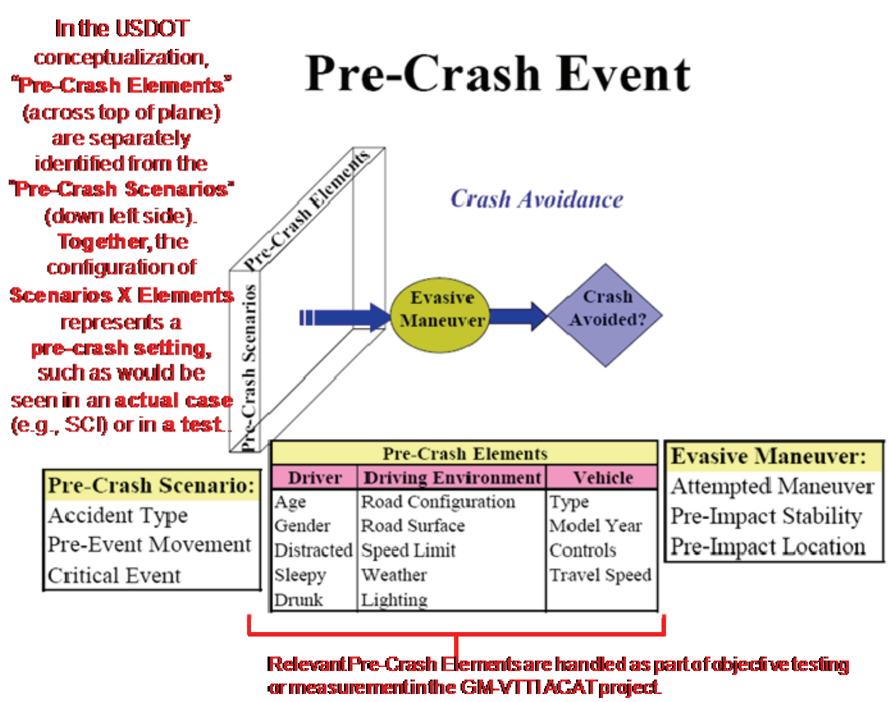


Figure 26. Detail for the scenario definition framework of Najm et al. (2007).

Some of the elements of backing crash scenarios that required definition during Objective Test Development (covered in Chapter 7) are listed below in Figure 27. The verification analyses also attempted to extract a rich matrix of information from the actual case data reported in the SCI documents, to support selection of elements for objective tests.

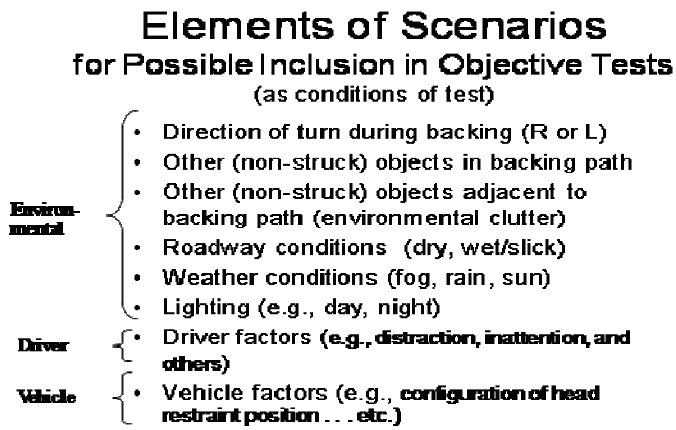


Figure 27. Grouped List of Pre-Crash Elements of Possible Relevance to Backing crashes

5.3 Examination of Special Crash Investigation (SCI) Cases

In this section of the report, the analytic work which was done on the SCI backing crash cases is described, from methodology through findings and conclusions.

5.3.1 Background On NHTSA's Special Crash Investigations

NHTSA's SCI Unit began collecting data on Backover and Non-Crash Events in October 2006 and began publishing cases on NHTSA's website in September 2007. According to the report published by NHTSA in April 2008, there were a total of 50 backover cases reported to the SCI unit (Chidester, 2008). These cases can be accessed by the general public at the following link: http://www-nass.nhtsa.dot.gov/BIN/logon.exe/airmislogon. The description that follows provides a detailed analysis of the first 35 cases released publicly. The cases were investigated by Indiana University's Transportation Research Center School of Public and Environmental Affairs, Calspan Corporation's Crash Data Research Center, and Dynamic Science, Inc. Sample cases were included that originated from the following states: Arizona, California, Florida, Hawaii, Illinois, Iowa, Michigan, Missouri, Nebraska, New Mexico, New York, North Carolina, Oregon, Texas, Tennessee, Utah, Virginia, Washington, and Wisconsin.

5.3.1.1 Overview of Methods Used in SCI

Unique to SCI reporting is the ability to garner detailed accounts of the entire incident from pre-crash sequencing through post-crash. These investigations are done by teams of specially trained crash investigators who travel to the site of a crash selected for investigation as soon as possible after the incident has occurred to undertake measurements, reconstruction, interviews with participants and witnesses, and other data collection. SCI reports provide more detail than, for example, the GES which relies upon data collected from PARs. Each SCI case provides a summary of the crash site, vehicle data, crash sequence (pre-crash, crash, post-crash), vehicle contact evidence, rear visibility measurements, nominal visibility diagram, a crash schematic, and a non-in-traffic surveillance form.

5.3.1.2 General Motors (GM) – Virginia Tech Transportation Institute (VTTI) Method in Extracting Data from the SCI Cases

From each of the 35 SCI technical reports, the following dependent variables were extracted and entered into a comprehensive matrix of elements for analysis (using Excel). The variables included in the matrix are listed below.

1. Driver's age, gender, height
2. Struck pedestrian age, gender, height, position, location, clothing
3. If driver was distracted
4. Vehicle model
5. Vehicle measurements (beltline height, bottom of bumper, undercarriage elements height)
6. Sight distance/line of sight
7. If other vehicles were present in area
8. Speed of vehicle
9. If backup device was installed
10. Point of impact
11. Direction of travel
12. Direction of path relative to impact point
13. Location characteristics
14. Nature of locale
15. Presence of low-lying objects
16. Driver expectation notes
17. Weather/lighting conditions
18. Fatal/Non-Fatal
19. Most unique characteristic of the SCI case (that was not included in the developed scenarios)
20. The scenario that the SCI case most resembled

Moreover, notes on drivers' expectations and the resulting sequence of events were included in the reports and also entered into the matrix (in short form).

5.3.2 SCI Findings: Descriptive Statistics

Based on the contents of the matrix which was constructed from coding the 35 SCI cases available on the NHTSA website at the time of this research, analyses of key variables were carried out. Those analyses, including descriptive statistics, are reported below. The reader is advised to bear in mind that the number of cases in this sample is still very small – and, while interesting, the patterns of findings should be treated with the caution due to such small numbers. Additionally, the way in which cases are drawn for SCI does not reflect a random sampling of backover cases. Rather, it reflects cases judged of greatest interest for understanding the etiology, prevention, and mitigation of these crashes. This, too, should be kept in mind while reviewing the findings reported below.

5.3.2.1 AGE AND GENDER OF DRIVERS INVOLVED IN SCI CASES

Female Driver Age

Of the 35 SCI cases, 16 of the drivers were females with a mean age of 37, ± 17 years, ranging from 20 to 83 years of age. A majority of the female drivers were less than 50 years of age. It may be hypothesized that the younger females are the mothers of the children who were struck based upon the data discovered by Pinkney et al. (2006) who studied children under the age of 10 and found that a family member was directly at fault in 48 percent of the backover cases. Furthermore, a CDC study found that a parent was the primary driver of the backing vehicle 57 percent of the time (CDC, 2002).

Male Driver Age

A few more male drivers (N=19) were reported than female drivers (N=16), with the average age of the male driver at 39, ± 18 years of age. This was consistent with a finding from FARS, based on data from 1991 to 2004, which indicated that more males were involved in backing-related cases. Specifically, 77 percent of the backing-related cases (a percentage that includes crashes beyond just backovers), involved a male driver (FARS, 1991-2004). Brison et al. (1988) found that a family member or a visiting family friend was involved in 71 percent of the fatalities – and the family member was most often the father of the child.

In contrast to the female drivers (whose ages were all over 20 years in this sample), male drivers as young as 15 to 20 years of age were reported as the primary driver. The 30- to 35-year-old age group had the highest reported frequency but, as Figure 7 below indicates, the variability across ages is very high. The ages of male drivers ranged from 15 to 80 + years, with the hint of three modal regions emerging from the distribution: (1) young male drivers (ages 15 to 25 years), (2) mid-age male drivers (ages 30 to 35 years), and (3) experienced/mature male drivers (ages 45 to 65 years).

5.3.2.2 AGES, HEIGHTS, AND POSITIONS OF STRUCK PEDESTRIANS IN SCI CASES

Struck Pedestrian Age

Two of the 35 cases reported unknown values for the age of the struck pedestrian. The age data that were available revealed that a preponderance of cases were children. However, there were instances of adults being struck as well, though these were much rarer and perhaps reflect some different contributing causes. Specifically, over half (67 percent) of the struck pedestrians in these SCI cases were below the age of 5 and 82 percent were under 15 years old. As can be seen in Figure 8, the age distribution is broad (ranging from 8 months old to 89 years of age) – and highly skewed, making the mean an inappropriate indicator of central tendency. The mode for age of struck pedestrians in these cases lies in the range between 8 months of age and 2.5 years of age.

A CDC report (2005) described similar results based upon the estimated annual number of nonfatal motor-vehicle-related backover injuries treated in emergency departments and found that those from 1 to 4 years of age were involved in half of all cases. Supplementary findings include those by NHTSA where children under the age of 5 were found to be at the highest risk for a backover incident (NHTSA, 2006) and Nadler et al. (2001), who found the mean age to be 3.4 years, with children under the age of 5 accounting for 41 of the 51 driveway-related backover accidents. From the backover fatalities recorded in FARS and the data in 1998 death certificates: 38 percent were children under 5 years old and 42 percent were children under 15 years old. In summary, this small sample of SCI cases is consistent with the data from prior work in terms of the age of pedestrians struck in backover crashes.

Standing Heights of Struck Pedestrians

Seven of the 35 cases reported unknown heights for the struck pedestrians. The reported heights, like pedestrian ages, were highly variable. Because the distribution of struck pedestrians is really comprised of two separate sub-distributions (one for children and one for adults), it is most meaningful to report standing heights of these pedestrian types separately rather than reporting a composite mean for the whole distribution (though, if desired, the statistics for the distribution treated as a single entity are: mean height was 3.5 ft [42 inches] ± 1.3 ft [15.6 inches]; the minimum height reported was 1.7 ft and the maximum height was 6.2 ft). This corresponds well with the poles (which stand 40 inches tall) defined by the International Standards Organization (ISO) for use in objective tests of imaging systems, and also with the child mannequins selected for use (whose standing heights range from 33 in to 44 in to represent children who are 2 and 5 years of age, and whose shoulder widths are also age-matched to represent children 2 to 5 yrs [10-11 in]). A majority of those struck were of non-adult heights (< 105 cm, or < 41.34 in), and the mode was slightly less than 3 ft (just under 36 in, or just under 91.4 cm), again confirming that both the test poles identified for use in objective testing and the child mannequins developed for use in objective testing are appropriately sized to represent the struck pedestrians who are children. These findings are also comparable to those determined by Agran, Winn, and Castillo (1991) who found that the heights of children involved in these types of crashes ranged from 2.2 to 3.4 ft, with a median height of 2.8 ft.

However, a few individuals in the SCI cases were of adult heights (over 5 ft). From a practical engineering perspective, it is usually the case that an object detection system which is capable of detecting child-sized images is also capable of detecting larger pedestrians. Thus, the analysis of SCI cases provided confirmation of the heights of objects identified for use in testing object detection performance of backing crash countermeasure systems.

Position and Posture of Struck Pedestrians Prior To Crash

The posture of the pedestrian prior to the crash was examined. Eleven of the 35 cases reported unknown postures for the pedestrian prior to impact. Of the postures which could be determined and reported, the most common posture was “standing” at start-of-incident. In addition, a majority of the pedestrians were in a static position (e.g., standing, sitting in stroller, on stomach, on back, kneeling, bending at waist). In seven of the cases, the pedestrian was in a dynamic position – either walking, running, or on a bike. These results are similar to those of Patrick et al. (1998), who found that of the 32 driveway-related backover incidents they studied, the children were struck by the vehicles under the following circumstances: 19 were playing under or behind a parked vehicle; 10 were walking behind a moving vehicle; and 3 were standing behind a parked vehicle (i.e., 22 were in static position, and 10 in dynamic movement – versus the SCI cases where 17 were in static position, 7 in dynamic movement, and 11 unknown).

5.3.2.3 OTHER RELEVANT FINDINGS

Locale: Type of Driveway/Roadway Setting

Most of the incidents (66 percent) occurred in a residential private home locale. This is where exposure tends to be highest. It is near private residences that both children and vehicles backing in-and-out of driveways are found in combination. The second leading locale was in a parking lot (26 percent) where pedestrians also frequent; this was followed by a street location (3 percent).

Conditions

Time of day. Most of the backovers occurred during the daytime during clear conditions; this is another aspect of exposure, since most pedestrians frequenting the areas above would be outside during daylight hours, and most typically during dry conditions.

Role of distraction. Based on post-hoc interviews done by investigators, whether the primary driver of the vehicle was distracted prior to the crash was examined. A majority (79 percent) of the drivers said they were not distracted during the incident, while the remainder (21 percent) reported that they were distracted. These findings are similar to those determined from the 2005 GES data, where approximately 10 percent of the crashes in which a pedestrian was struck were reported to have included distraction. Care should be taken regarding any interpretations about whether distraction may or may not have been a factor, since "distraction" was self-reported from the driver's perspective, and a driver may be hesitant in admitting to distraction for legal reasons. Of those who stated they were distracted, the types of distraction included adjusting the radio, talking with passengers, or talking with people outside the vehicle.

Presence/Role of Parking Aids in SCI Cases

Of the 35 vehicles involved in the cases analyzed here, only 3 of the vehicles had a backing/parking aid installed. This is likely due to the relatively low numbers of vehicles that have any sort of backing/parking aid installed at this time, coupled with the low probability of backing crashes. NHTSA sought to sample a few where a backing aid may have been available – given that sampling these cases could perhaps help in understanding whether the devices were used and, if so, whether they were used properly, whether issues arose with their use, and/or whether any unintended consequences arose. Specific details of the three vehicles equipped with a backing/parking aid included:

1. 2003 Ford Expedition had an ultrasonic/radar sensor system (installed by the original equipment manufacturer), with two sensors on the left and right bumpers that were deemed to be functioning properly. The driver reported hearing the three warning beeps but continued his backing sequence, stating that he did not see or feel the impact.
2. 2004 Cadillac Escalade had an Ultrasonic Rear Parking Assist with four sensors installed and was reportedly turned off because the driver frequently backed in congested areas that triggered false alarms.
3. 2005 Cadillac Escalade had an Ultrasonic Rear Parking Assist installed; however, the device had been turned off for reasons unknown.

The first case (in which the warnings were ignored) reinforces key findings from work done by the GM-VTTI team showing that if drivers cannot visually confirm a threat about which they are warned, they have a tendency to ignore the warning. In a study of a rear vision system (McLaughlin et al., 2003), drivers who did not expect an obstacle behind the vehicle at the initiation of a backing maneuver always ignored audible and visual alerts that were provided, and collided with the object.

All three SCI cases involving vehicles on which Parking Aids were installed confirm the importance of including a False Alarm Rate test as part of the Objective Test battery to assess whether warnings are ignored. For the three vehicles that had parking aids present, two of the three systems were turned off at the time of the incident.

Objects/Transitions Present in Addition to Struck Pedestrian

A number of the SCI cases reported low-lying objects in the vicinity of the vehicle's backing path and/or objects immediately adjacent to the backing path. These objects may have attracted the driver's attention, blocked the driver's view, conflicted with the driver's expectations of the surroundings, or could potentially have produced extraneous false alarms in a parking aid or backing countermeasure system. Noted low-lying objects included: a garden hose, construction materials, pallets, landscaping timbers, tree stumps, toys, cracks in driveway surface, curbs, guttering, and wood piles.

Aside from low-lying objects in the vicinity of a vehicle's backing path, there were sometimes objects immediately adjacent to the backing path, which included vehicles routinely parked along one side of a driveway, structural elements of the house (such as porch posts or rails), and the like.

Also playing a role in some cases may have been the gradient of the driveway's slope or the gradient of the driveway's transition to the sidewalk/street, which can sometimes extend a driver's blind zone (and can also trigger false alarms in object detection systems). Forty percent of the SCI crashes examined involved a grade ±2 percent or more, with the most significant grade reported of +13.5 percent.

5.3.3 Classification of SCI Cases into Scenarios

Once descriptive statistics had been computed, the 35 actual SCI cases were each examined in order to determine whether they could be sorted into the six pedestrian scenarios, how well they matched the original scenario descriptions, and to what extent they could be used to enhance the basic scenario descriptions with more detailed identification of conditions and attributes. This was, in turn, expected to provide input to the development of the Objective Tests (described in Chapter 7).

To conduct this analysis, each SCI case was first categorized into one of the six pedestrian scenarios using the following categorical variables:

1. **Pre-Event Maneuver.** Recall that pre-event maneuver types are distinguished by geometry, distance, and speed of the roadway/driveway/parking area and maneuver (e.g., backing at low speed versus parallel parking versus driving in reverse down a longer driveway). They may be further distinguished by the direction of any turn that may be involved, which will be treated as a "test condition" applied to the basic scenario. For purposes of this analysis, the sorting relied most heavily on the geometry of setting and maneuver (whether backing in a parking lot, long driveway/driving in reverse, short driveway, or parallel parking).
2. **Critical Event**. Recall that for backing crashes, in this analysis, "critical event" refers to whether the struck pedestrian was static or dynamic (incurring) at the time of crash. Once the SCI cases were categorized, comparisons could then be made between the original scenario description and the actual cases which were instances of that scenario – in terms of the age and location of the pedestrian, and the speed at which the vehicle was (estimated to be) moving.

At the highest level, it was interesting to observe how the individual crash cases in this sample of 35 were distributed among the original six pedestrian scenarios after classification. This is shown in Table 18 below. It should be noted that there was some "fuzziness" in the crash cases (not in the scenarios) that affected the clarity with which they could be classified. This fuzziness arose from the fact that some information was not available to the investigating SCI team on some cases (e.g., information on vehicle speed, position of the pedestrian at the onset of the conflict, and/or the movement of the pedestrian). This missing information meant that while the cases could be sorted on the basis of pre-crash maneuver (essentially on the basis of the setting's geometry and the maneuver of pre-conflict situation), they could not always be further classified in terms of critical event. For example, some cases were clearly "backing-out-in-a-parking-lot" scenarios, but it was not possible to discern whether they were Scenario 1 or 5 cases – since information about pedestrian age, posture, distance from vehicle, and/or movement could not be obtained by the SCI investigators.

Thus, a row is provided in Table 18 below for cases that could be sorted into "either scenario 1 or 5," but not exclusively into one of the scenarios. The same held true for the low-speed driveway scenarios. As can be seen from the table, the highest frequency of cases within this SCI sample occurred within the driveway scenarios (22 total cases), followed by the parking lot scenario (10 total cases), then the driving-in-reverse scenario (2 total cases), and finally the parallel parking scenario (only 1 total case).

Table 18. The Distribution of 35 SCI Cases across the Original Six Pedestrian Scenarios.

Pre-Crash Scenario Type	Original Scenario (Scenario ID #)	Classification of SCI Cases By Original Scenario (# Cases)	Total Incidence of Actual Crash Cases (# Total Cases)
PARKING LOT Scenarios	1	6	10
	1 or 5	4	
Low-Speed DRIVEWAY Scenarios	3	5	22
	3 or 4	6	
	4	11	
DRIVING in Reverse Scenario	6	2	2
PARALLEL PARKING at Curb	2	1	1

5.3.4 Summary of Findings from Classification of SCI Cases into Scenarios

In summary, what was learned from classifying actual SCI cases into the six pedestrian scenarios was that the six scenarios provide a framework which comprehends all the actual SCI cases in this sample. There were no cases that could not be categorized into a scenario. Further, the degree of match between the scenario definitions and the actual cases was remarkably close for those scenarios represented by *more than* just one or two cases. Table 19 provides a summary of the number of cases, the location of the struck pedestrian, and the difference in (mean) distance between the scenarios developed to represent backing crashes and the corresponding SCI case classification. As shown, the difference between the mean struck-pedestrian location of the scenarios developed for the parking lot and low-speed driveway backing scenarios and the SCI cases are within a couple of meters, most being less than 1 m. For the remaining two scenarios, there were too few cases of each, to obtain any determination of a pattern or its correspondence to the original scenario description formulated for this project. The cases for the parking lot and low-speed driveway scenarios correspond and confirm the robustness of those pedestrian scenarios as originally set forth.

Table 19. Summary Findings of Developed Scenarios versus SCI Scenarios

Pre-Crash Scenario Type	Original Scenario (Scenario ID #)	(# Cases)	Scenario Struck Ped. Location (m)	SCI Struck Ped. Location (m)	Difference (m) [Scenario – SCI]
PARKING LOT Scenarios	1	6	1.5	2.4	-0.9
	1 or 5	4	1.5	1.4	0.6
Low-Speed DRIVEWAY Scenarios	3	5	5	4.6	0.4
	3 or 4	6	5	4.8	0.2
	4	11	5	6.7	-1.7
DRIVING in Reverse Scenario	6	2	9	1 and 7 Mean,4	5.0, but based on only two cases at this time
PARALLEL PARKING at Curb	2	1	9	9	0.0, but based on single case at this time

5.4 Examination of Other Supplemental Data Sources (Including State Data)

As a final step in examining backing crash data to confirm the robustness of the backing crash scenarios, and to facilitate the development of Objective Tests, supplemental sources of crash data were examined. These are summarized in Table 20, below, along with key points from GES and FARS data – to provide a single matrix with comprehensive information about factors related to backing crashes. This matrix identifies the sources from which data were drawn in the construction of the scenarios, and identifies key facts that were noteworthy relative to factors of interest. As can be seen, state crash databases from Nebraska, Kentucky, and North Carolina were examined; top-level findings are included in the table. (If there are discrepancies between percentages based on SCI and those reported elsewhere in this report, they are due to the fact that the computations in the table were done at a different point in time and, hence, based on a different number of cases than the rest of the report.) The table entries are self-explanatory. There is substantial convergence between different sources of data, adding robustness to the scenarios (and objective tests) developed with these data as a basis.

Table 20. Summary and Highlighting of Supplemental Sources on Backing Crashes and Factors

	DATA SOURCES									
IDENTIFIED FACTORS	**GES**	**FARS**	**SCI**	**State (KY,NE,NC)**	**Naturalistic [3]**	**Death Certificates**	**PARs (from Eberhard)**	**CDC, 2005 and NHTSA, 2006**	**Hospital Data (Nadler et al. 2001 or Patrick et al. 1998)**	**Utah state data (Pinkney, Smith, Mann, Mower, Davis, and Dean, 2006)**
Roadway type	Yes	Yes	Yes, 73% driveway, 27% parking lot	Yes[2] (NE: 41% backing crashes not in traffic way, KY: 37% backing crashes on private property, NC: 2% backing crashes on private property)	No	?	Yes	No	No	Yes
Backing Maneuver Type	No	No	Yes	No	No	?	No	No	No	No
Struck Object Type	Yes	Yes	Yes	Yes[2]	No	Yes/NA	No	No	No	No
Pedestrian Age	Yes	Yes (under 5 at highest risk)	Yes	Yes[2]	No	Yes (under 5 at highest risk)	No	Yes (Ages 1-4 represent 50% of all cases)	Yes (under 5 at highest risk)	No
Struck Object Motion	Yes[1]	Yes[1]	Yes (27% stationary, 9% moving, 18% "playing", 46% unknown)	Yes[2]	No	?	No	No	Yes (59% unknown or "playing", 31 % moving, 9% stationary)	No
Backing Direction	No	No	Yes (27% left, 9% right, 64% straight)	No	No	?	No	No	No	No
Direction of Approach of Struck Object	No	No	Yes (18%left, 45% right, 27% straight, 9% unknown)	No	No	?	No	No	No	No
Pedestrian Posture	Yes[1]	Yes[1]	Yes (18% standing, 18% prone, 18% "playing", 46% unknown)	Yes[2]	No	?	No	No	Yes (59% unknown or "playing", 41% standing)	No
Location of Pedestrian Relative to Vehicle Center	No	No	Yes(17% center, 33% right, 50% left)	No	No	?	No	No	No	No
Distance of Struck Object Behind Vehicle	No	No	Yes,Avg=9.8ft, max=19.7ft, min=3.3ft	No	No	?	No	No	No	No

[1]not representative since these are limited to trafficway accidents.
[2]inconsistencies among states on classification of nontrafficway crashes.
[3] no pedestrian related crashes in 100-Car naturalistic data.
Already Used (highlighted)

6 OBJECTIVE TESTING

6.1 Overview

A set of 15 objective tests were developed to characterize the performance of backing crash countermeasures and provide data to the SIM for estimating the effectiveness and potential safety benefits of the backing crash countermeasure systems. Three basic types or classes of objective tests were developed: 1) Grid Tests of Obstacle Detection Performance, 2) Tests of False Alarm Rate Performance, and 3) Driver-In-The-Loop Tests of Crash Avoidance. Together, these tests examine both the system's performance capabilities and the driver's interaction with the countermeasure system.

Data are also presented in this chapter highlighting test results for an integrated suite of backing crash countermeasures; evaluations were performed using the set of objective test procedures. While data from the three basic test types are summarized here, it is important to remember that these objective tests are designed to provide inputs to the SIM model and not to provide direct assessment of system effectiveness. Thus, results of different test types are presented in a manner to aid in understanding of how tests were measured, scored, and characterized in the SIM; however, the results of any given test type, or subset of tests, should not be used in isolation, since the SIM model is required to integrate the performance results as a whole.

6.2 Objective Test Types

Three types of objective tests were defined to capture different aspects of backing crash countermeasure system performance. Grid Tests of System Response Performance measure the system's ability to respond to obstacles, including coverage and response zones for static and incurring obstacles under a range of situations. False Alarm Performance Tests assess the extent to which countermeasures are likely to issue unhelpful alerts, warnings, or interventions (false system activations). Driver-in-the-Loop Performance tests use naive participants to drive the vehicle and exercise the system in a context resembling a conflict scenario in order to gauge driver interactions and performance in response to the system. Table 21 lists each objective test and associated test conditions, including the number of trials to be performed. Appendix A contains the detailed test procedures, conditions, and protocols for developing, administering, and scoring each of these tests. The information included as part of the objective tests ensures that evaluations are performance-based, repeatable, reproducible, and intended to evaluate the performance of the system of interest. Test conditions specify the settings under which tests are to be conducted and will include details related to: 1) environment and roadway (laboratory, test-track, etc), 2) obstacle, 3) host (or equipped) vehicle, driver state, and backing or parking maneuvers to be performed. Similarly, procedures for conducting each test are detailed in a manner that allows the test to be reliably implemented and repeated, and includes key performance outcome measures and metrics to be derived.

Table 21. Summary of Objective Tests and Conditions

Test Class	Test Type & Number	Test Name & Purpose	Test Objects and Conditions
Grid Tests	**Trained Observer (Driver Out Of Loop)**	**Grid Tests of System Response Performance over Coverage Zone.** Evaluate the performance of the countermeasure's obstacle detection system in responding to objects to establish the zone of coverage.	
Proximity-Based	1. Camera Field of View (FOV)	Assess camera FOV	<u>Test Object</u> ○ Cardboard Cylinder, 1 meter tall (40 inches), 30.5 cm diameter (12 inches) ○ Surrogate test mannequin of 2-year-old standing child **(Total of 2 Testing Conditions)**
	2. Static Field of Response	Static vehicle and static obstacles positioned in squares moving horizontally and lengthwise across test grid	<u>Test Objects</u> ○ PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches) ○ Surrogate Test Mannequins ▪ 2-year-old Standing ▪ 5-year-old standing ▪ Sitting ▪ 5-year-old Prone ○ Both Objects and Vehicle Stationary **(Total of 5 Testing Conditions)** **(Total of 15 Trials)**
	3. Field of Response with Incurring Obstacles	Static Vehicle, Incurring Obstacles	<u>Test Objects</u> ○ PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches) ○ Surrogate Test Mannequins ▪ 2- year-old Standing Upright Walking ▪ 5- year-old Standing Upright Walking <u>Test Object Movement Rates</u> ○ Two speeds of 2 and 4 mph (3.2 and 6.4 km/h respectively) **(Total of 6 Testing Conditions)** **(Total of 24 Trials)**
Warning-Based	4. Dynamic Longitudinal	Dynamic Vehicle, Static Obstacles. Vehicle backing on straight path toward object	<u>Test Objects</u> ○ PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches) ○ Surrogate Test Mannequins ▪ 2-year-old Standing ▪ 5-year-old standing ▪ Sitting ▪ 5-year-old Prone <u>Vehicle Movement Rates</u> ○ Three backing speeds of 4, 8, and 15 mph (6.4, 12.9, and 24.1 km/h) **(Total of 15 Testing Conditions)** **(Total of 45 Trials)**

Test Class	Test Type & Number	Test Name & Purpose	Test Objects and Conditions
	5. Dynamic Horizontal, Full Lock	Full Lock at Parking Speed. Identify the horizontal field of response, any path prediction	Test Objects o PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches) o Surrogate Test Mannequins ▪ 2-year-old Standing ▪ 5-year-old Standing ▪ Sitting ▪ 5-year-old Prone Vehicle Movement Rates o A single backing speed of 5 mph (8 km/h) **(Total of 5 Testing Conditions)** **(Total of 20 Trials)**
	6. Dynamic Horizontal, Incurring Obstacles	Backing Straight With Incurring Obstacles (with and without preview - clear versus obstructed line of sight). Identify the horizontal field of response	Test Objects o PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches) o Surrogate Test Mannequins ▪ 2-year-old Standing ▪ 5-year-old Standing Vehicle Movement Rates o Two backing speeds of 4, 8 mph (6.4, 12.9 mph) Object Movement Rates o Two speed of 2 and 4 mph (3.2, 6.4 km/h) Line-of-sight Conditions o Obstructed and Unobstructed **(Total of 24 Testing Conditions)** **(Total of 96 Trials)**
False Alarm	**Trained Test Driver**	**False Alarm Performance.** Characterize and estimate system false activations via use of a standardized test course.	
Residential	7. Driveway	Evaluate false alarm potential for elements commonly found in residential driveway environments.	o 17 test objects/features in actual and simulated driveways o Mix of driveway types (straight and curved) o Mix of vehicle movement rates of 4 and 8 mph (6.4 and 12.9 km/h)
	8. Garage	Evaluate false alarm potential when backing into and out-of a residential garage.	o 5 tests in actual garage environments (both backing into and out of garage) o A single vehicle movement rate of under 5 mph (under 8 km/h)
Commercial	9. Parking Lot	Assess the false alarm potential for commercial parking lot situations.	o 6 test objects/features in actual parking lot environments o Mix of backing approach angles & directions o A single vehicle movement rate of under 5 mph (8 km/h)
Public	10. City Street	Assess the false alarm potential for driving environments on public roadways and street parking environments.	o 12 tests in actual public street and parking environments o Mix of vehicle movement rates of 4 and 8 mph (6.4 and 12.9 km/h) o Mix of Approach directions

Test Class	Test Type & Number	Test Name & Purpose	Test Objects and Conditions
Driver-In-Loop		**Conflict Scenarios.** Evaluate countermeasure system performance in terms of the driver's interaction with the system (trust, understanding, and use) by examining driver's response in conflict situations with the system.	
Pedestrian	11. Intermediate Static Pedestrian	Pedestrian Scenario 3 with a 2-year-old surrogate prone 15 ft behind vehicle backing out of driveway. Located off-center. Present prior to maneuver. *Pedestrian object enhanced to enable system to reliably respond*.	○ 8 Drivers (age 30-65, gender balanced) ○ Novice users ○ Vehicle backing out of driveway ○ Obstacle: 2-year-old surrogate prone (or comparable object). Present at time of backing, approximately 15 ft behind vehicle.
	12. Near Incurring Pedestrian	Pedestrian Scenario 5 (scenario 5) with a 5-year-old surrogate incurring from driver's side at 5 ft from vehicle backing down drive. *Pedestrian object enhanced to enable system to reliably respond*.	○ 8 Drivers (age 30-65, gender balanced) ○ Novice users ○ Vehicle backing from perpendicular parking space ○ Obstacle: 5-year-old surrogate (or comparable object), incurring into the vehicle's line of travel from the driver's side, 5 ft from bumper. The test object moving at a rate of 2 mph (3.2 km/h) to be consistent with pedestrian walking speeds.
	13. Intermediate Incurring Pedestrian	Pedestrian Scenario 4 with a 5-year-old surrogate incurring from passenger side at 15 ft behind vehicle when backing out of driveway. *Pedestrian object enhanced to enable system to reliably respond*.	○ 8 Drivers (age 30-65, gender balanced) ○ Novice users ○ Vehicle backing out of driveway ○ Obstacle: 5-year-old surrogate incurring from passenger side at 15 ft from bumper. The test object moving at a rate of 2 mph (3.2 km/h) to be consistent with pedestrian walking speeds.
Vehicle, Fixed Object	14. Near Static Vehicle	Vehicle 1 (scenario 7) with stationary vehicle located directly behind (5 ft) host vehicle (in same traffic lane).	○ 8 Drivers (age 30-65, gender balanced) ○ Novice users ○ Vehicle backing down straight path (driveway) ○ Obstacle: PVC pole (1 meter tall, 75 mm diameter) as surrogate for vehicle. Present at time of backing; located 5 ft behind vehicle
	15. Intermediate Static Pole	Fixed Object (scenario 10) with a fixed pole located 15 ft behind host vehicle while backing out of driveway; pole located along passenger side of the vehicle.	○ 8 Drivers (age 30-65, gender balanced) ○ Novice users ○ Vehicle backing down driveway or garage ○ Obstacle: PVC pole (1 meter tall, 75 mm diameter). Obstacle present at time of backing; located 15 ft behind vehicle and to the passenger side of the vehicle

6.2.1 Grid Tests of System Response Performance

Grid Tests of System Response Performance (Grid tests) measure countermeasure system response to in-path obstacles-of-interest along a longitudinal and lateral set of axes relative to the vehicle under both static and dynamic conditions. Test situations involve prescribed movement of the test vehicle and/or obstacles. The Grid tests establish response envelopes surrounding the rear of the vehicle, noting the repeatability and time delay of system response. A test driver, or trained observer, is needed in order to execute the tests and confirm that the system responds to the obstacle. For example, rear vision-based countermeasures which display rearward images will require a test driver to confirm that the displayed views show the test object(s). Six grid tests are defined, each intended to address one or more aspects related to the system's response performance:

1. Proximity-Based, Camera Field of View
2. Proximity-Based, Static Field of Response
3. Proximity-Based, Field of Response for Incurring Obstacles
4. Warning-Based, Dynamic Longitudinal
5. Warning-Based, Dynamic Horizontal, Full Lock
6. Warning-Based, Dynamic Horizontal, Backing Straight With Incurring Obstacles

The first set of three tests are designed to map the coverage zone for near-field objects, and relates to the functional performance of proximity-based systems such as Park Assist and Rear Vision. The second group of tests is intended to define the response performance for more advanced, dynamically acting functions such as Backing Warning and Automatic Braking - functions requiring more extended range, non-linear paths, and dynamic capabilities.

6.2.2 False Alarm Performance Tests

This family of tests characterizes system false activations and situations leading to these types of events. Evaluations rely on the development of a standard test course that includes opportunities for occasioning false activations. A "false alarm" is an erroneous system activation (e.g., the system issues a backing warning when no in-path obstacle is present). High levels of false alarms may negatively impact driver acceptance and responsiveness to valid system alerts. Although the tests detailed below are intended to examine false activation behavior(s) for a given countermeasure, establishing the level of acceptable rates or the rate of exposure to these situations in real world driving remains an open question as it will depend on individual behaviors and regional factors.

Assessments require a single test driver to negotiate a "course" comprised of a series of representative backing settings and maneuvers. Four basic types of environmental settings are defined to include:

1. Residential Driveway
2. Residential Garage
3. Commercial Parking Lot
4. Public City Street

The procedures for designing and conducting these false alarm tests are presented in Appendix A; they prescribe a set of environmental conditions (including relevant objects and elements common to a setting) and backing maneuvers. Tests may be implemented by using a combination of real-world and artificial testing approaches which require: 1) locating existing real-world environments which adequately capture the elements of interest, as well as 2) constructing an artificial environment (part-task setting) to accurately represent the desired conditions. The goal is to adequately represent and capture system responses to known or expected elements and settings likely to trigger false alarm events.

The elements and environments detailed in these false alarm tests are derived on the basis of the best information currently available, including the SCI cases and operational experience with prototype backing crash countermeasure systems. While efforts were made to draw from a plausible range of environmental characteristics and elements commonly found in these environments, these are by no means exhaustive. The full range of potential situations and objects, as well as the base rate occurrences for these types of scenarios (i.e., the number of times any particular driver may experience these same conditions under normal usage), is unknown. Additional data are needed to understand and map the exposure rates for these specific situations.

6.2.3 Driver-in-the-Loop Tests

Driver-in-the-Loop tests are intended to characterize performance of the driver when interacting with the system across a variety of conflict situations. Unlike the Grid tests, Driver-in-the-Loop tests are not meant to assess the system's response performance. Rather, these tests yield measures of driver responsiveness to the information, warnings, and control assistance provided by the backing countermeasures. These tests characterize driver performance with the system. Tests are administered in five different scenarios encompassing pedestrian, vehicle, and fixed-object crash scenarios as detailed below (scenarios were derived from the set of 10 ACAT crash scenarios):

1. Intermediate Static Pedestrian (Scenario 3)
2. Near Incurring Pedestrian (Scenario 5)
3. Intermediate Incurring Pedestrian (Scenario 4)
4. Near Static Vehicle (Scenario 7)
5. Intermediate Static Pole (Scenario 10)

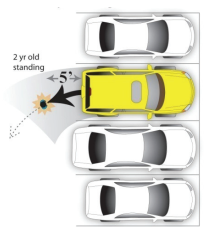
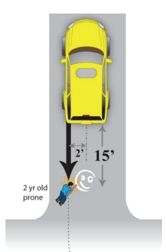
Three of the scenarios involve a stationary test object, and two involve a moving or incurring pedestrian. The Driver-in-the-Loop tests emphasize pedestrian-related crashes (with three represented scenarios), including the most frequently occurring pedestrian crash scenarios as revealed by the SCI cases (e.g., Pedestrian 3). Unlike the other testing approaches, Driver-in-the-Loop tests require the use of individuals recruited from the larger population of drivers. Special considerations are required for staging and executing these types of tests, including delineating specifications for the amount of practice or exposure each driver is to have with the countermeasures, driver demographics (age, gender, driving history, etc.), experience and familiarity with production backing aids and associated countermeasures, as well as setting the stage for the level of driver expectancy and the predictability of events.

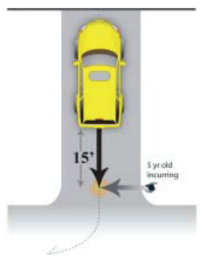
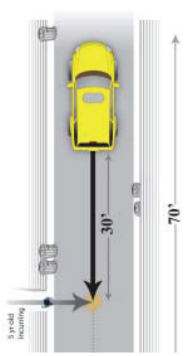
6.3 Basis for Objective Test Scenarios

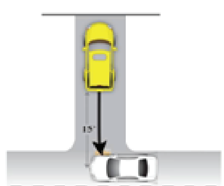
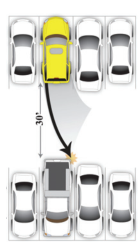
One primary goal of the ACAT project is to estimate the effectiveness of a given technology towards reducing and/or eliminating crashes (in this case, backing crashes). As a result, objective tests must ultimately be traceable back to the real-world crash problem. In other words, objective tests must be able to confirm that the countermeasure is effective at interrupting the crash sequence observed in the real world. Earlier in this project a set of 10 ACAT backing scenarios intended to be representative of the backing crash problem was identified and developed (refer to Chapter 5, Figure 23 of this report). This work used a variety of sources to frame crash scenarios (crash databases, previous empirical work, targeted crash investigations, etc.) and has also identified key factors and moderating variables contributing to the crash problem. The approach is aimed at developing a set of objective tests that evaluate the effectiveness of a given countermeasure for breaking the chain-of-events leading to a crash, and provides usable data that can be fed into the SIM model.

The approach to objective testing also seeks to accomplish this in an efficient manner using a combination of different test methods and by integrating backing scenarios using common underlying factors to collapse across scenarios (e.g., reduce the number of necessary tests). All of the tests outlined and described in this chapter have a direct relationship to underlying backing crash scenarios identified and documented in Chapter 5 of this report. Table 22 presents and summarizes all 10 ACAT backing scenarios. Each of the objective tests references one or more of these backing crash scenarios in an effort to clearly delineate and map these relationships. Data from each of these objective tests are used by the SIM in modeling and estimating system effectiveness and potential safety benefits of backing crash countermeasures.

Table 22. List of ACAT Crash Scenarios and Relationship to Objective Tests

Scenario Number & Diagram	Type of Obstacle	Maneuver & Location	Obstacle State	Obstacle Position Relative to Bumper	Distance From Rear Bumper at Onset	Obstacle Present at Onset?	Relevant Objective Tests
1 	Pedestrian (2-year-old)	Backing Out (Parking Lot)	Stationary, Standing	Center	Near (5ft)	Yes	• Test 1: Camera Field of View • Test 2: Static Field of Response • Test 5: Full Lock at Parking Speed • Test 9: Commercial Parking Lot
2 	Pedestrian (2-year-old)	Parallel Parking (Street)	Stationary, Sitting	Right (2 ft)	Far (30 ft)	Yes	• Test 1: Camera Field of View • Test 2: Static Field of Response • Test 4: Dynamic Longitudinal • Test 5: Full Lock at Parking Speed • Test 10: Public City Street
3 	Pedestrian (2-year-old)	Backing Out (Driveway)	Stationary, Prone	Left (2 ft)	Moderate (15ft)	Yes	• Test 1: Camera Field of View • Test 2: Static Field of Response • Test 4: Dynamic Longitudinal • Test 7: Residential Driveway • Test 11: Intermediate Static Pedestrian

Scenario Number & Diagram	Type of Obstacle	Maneuver & Location	Obstacle State	Obstacle Position Relative to Bumper	Distance From Rear Bumper at Onset	Obstacle Present at Onset?	Relevant Objective Tests
4 	Pedestrian (5-year-old)	Backing Out (Driveway)	Incurring	Right	Moderate (15 ft)	No	• Test 3: Field of Response for Incurring Obstacles • Test 4: Dynamic Longitudinal • Test 6: Backing Straight with Incurring Obstacle • Test 7: Residential Driveway • Test 13: Intermediate Incurring Pedestrian
5 	Pedestrian (5-year-old)	Backing Out (Parking Space)	Incurring	Left	Near (5 ft)	No	• Test 3: Field of Response for Incurring Obstacles • Test 5: Full Lock at Parking Speed • Test 9: Commercial Parking Lot • Test 12: Near Incurring Pedestrian
6 	Pedestrian (5-year-old)	Backing (Driveway, Long)	Incurring	Left	Far (30 ft)	No	• Test 3: Field of Response for Incurring Obstacles • Test 4: Dynamic Longitudinal • Test 6: Backing Straight with Incurring Obstacle • Test 7: Residential Driveway

Scenario Number & Diagram	Type of Obstacle	Maneuver & Location	Obstacle State	Obstacle Position Relative to Bumper	Distance From Rear Bumper at Onset	Obstacle Present at Onset?	Relevant Objective Tests
7 	Vehicle	Backing (Intersection)	Stopped, Behind	Center	Near (5 ft)	Yes	• Test 1: Camera Field of View • Test 2: Static Field of Response • Test 10: Public City Street • Test 14: Near Static Vehicle
8 	Vehicle	Backing Out (Driveway)	Approaching	Right	Moderate (15 ft)	Yes	• Test 3: Field of Response for Incurring Obstacles • Test 5: Full Lock at Parking Speed • Test 6: Backing Straight with Incurring Obstacle • Test 7: Residential Driveway
9 	Vehicle	Backing Out (Parking Lot)	Parked	Behind	Farther (30 ft)	Yes	• Test 1: Camera Field of View • Test 2: Static Field of Response • Test 5: Full Lock at Parking Speed • Test 6: Backing Straight with Incurring Obstacle • Test 9: Commercial Parking Lot

Scenario Number & Diagram	Type of Obstacle	Maneuver & Location	Obstacle State	Obstacle Position Relative to Bumper	Distance From Rear Bumper at Onset	Obstacle Present at Onset?	Relevant Objective Tests
10 	Fixed Object (Pole)	Backing Out (Driveway)	Fixed	Right	Moderate (15 ft)	Yes	• Test 1: Camera Field of View • Test 2: Static Field of Response • Test 5: Full Lock at Parking Speed • Test 7: Residential Driveway • Test 15: Intermediate Static Pole

6.4 Testing Method and Approach

This section overviews the approach and methods used to support objective testing and data collection, including testing facilities, test objects, test-bed vehicle, and data reduction schemes. Detailed procedures and protocols are presented in Appendix A of this report.

6.4.1 Test Grid

Nearly all Grid Tests of System Response Performance are performed on a level asphalt pad which is overlaid with a painted test grid measuring 8 meters wide by 30 meters long (approximately 26 x 100 ft). Individual cells comprising the grid were 30 x 30 cm square (approximately 1-foot square); the cell lines themselves measure approximately 5 cm in thickness. Use of the grid enabled the location of the test objects and the vehicle to be precisely measured and recorded; grid rows and columns were also numbered and lettered to aid in this process (refer to Figure 28).

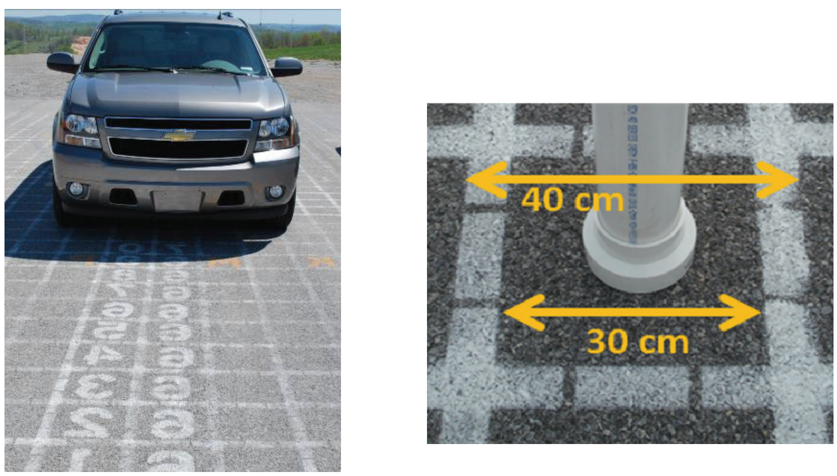


Figure 28. Test Grid

A second test grid was used to perform the Dynamic Horizontal Full Lock test. This grid was actually a circle measuring approximately 30 ft in diameter which represented the vehicle's path when backing with the steering wheel rotated to full lock position. As shown in Figure 29 the grid was overlaid with marks to allow locations to be determined; marks designated distances along the curved path (in units of 3 inches).

Figure 29. Circular Test Grid showing 3" scaled units

6.4.2 Test Objects & Movement Platforms

A set of standardized test objects (see Appendix E for more information about the standardization process) was developed and used to perform the objective tests. Test objects were designed to serve as surrogates for real-world objects such as pedestrians and "hard" obstacles. (e.g., vehicles, bicycles, poles, etc.). Substantial development effort was devoted to the design of the surrogate pedestrian objects to ensure their fidelity vis-a-vis the vehicle's sensor systems. In this case, the radar cross section of the surrogate test mannequins was matched to profiles of actual 2- and 5-year-old children under various orientations (e.g., standing, sitting, prone). A cardboard cylinder 12 inches in diameter and 40 inches high was used for camera FOV tests, and a PVC pole (3 inches in diameter and 40 inches high) was used to represent worst case "hard" obstacles for many of the proximity and warning-based grid tests of system response performance. Figure 30 shows the family of test objects and illustrates their relative size against the vehicle and test grid (refer to Appendix A and Appendix D for a more detailed description of the test objects).

For tests requiring objects to incur into the vehicle's path (dynamic test objects), mechanisms were developed and constructed to achieve this function; one mechanism to support the Grid Tests, and another for use in Driver-in-the-Loop tests (refer to Figure 31). Both allowed object movement speeds to be varied, as specified in the objective test procedures, without altering the radar cross section of the test objects themselves.

Figure 30. Test Objects

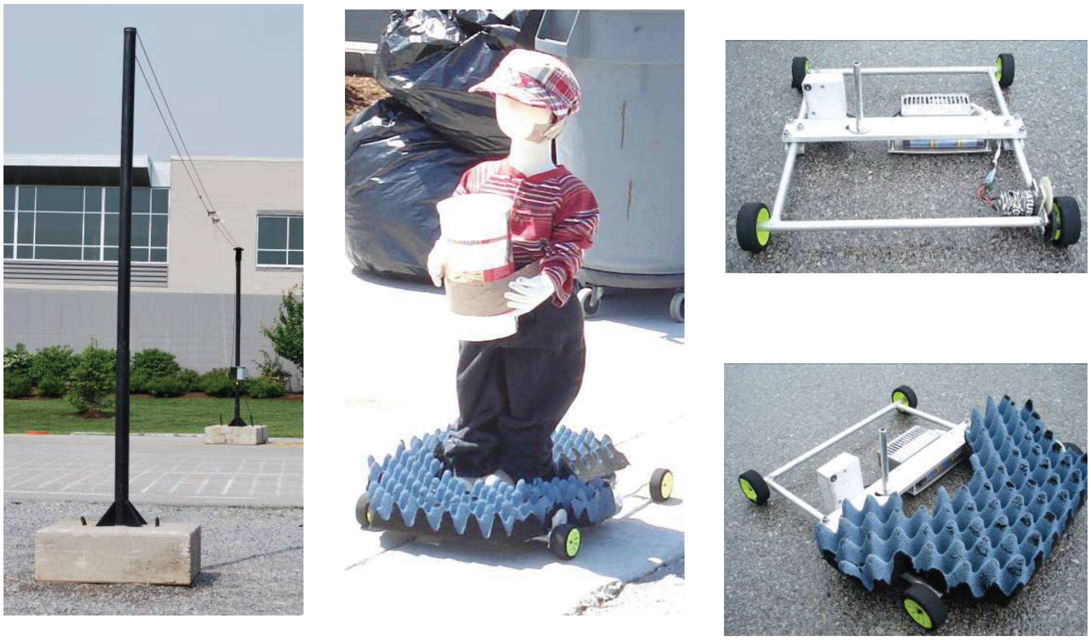


Figure 31. Movement platforms used for Grid Tests (Left) and Driver-in-the-Loop Tests (center & right)

6.4.3 Vehicle Instrumentation

The prototype test vehicle (a 2008 Chevrolet Tahoe) was outfitted with a Data Acquisition System (DAS) to allow backing crash countermeasure system performance as well as driver interactions with the system to be recorded and quantified. This instrumentation package did not require access to the vehicle's computer network, yet provided the basic functionality necessary to capture key performance measures of interest specified in the Objective Test Protocols for all three types of tests. This was accomplished through the use of video/audio recordings which captured data at a rate of approximately 30 frames per second. Camera units were installed to provide multiplexed views of the following elements: driver's face, rear-facing views of the area behind the vehicle from different perspectives, forward view of the roadway, countermeasure displays, and vehicle brake and accelerator pedal controls (Figure 32). Images were reconfigurable allowing different sets of views to be captured for the Grid Tests of System Response Performance and Driver-in-the-Loop Performance test.

Figure 32. Multiplexed camera views captured for the Grid Tests of system response performance

As shown in the figure, two camera perspectives of the area behind the vehicle were captured: a wide-angle elevated view (top right quadrant), and a view from the Rear Vision system camera (bottom left quadrant). Together, these perspectives afforded a unified view of the test grid, allowing close-in detail and longer range elements to be discerned; the top right quadrant view was particularly helpful for tests with incurring objects, making it easier to determine the precise location (column) of the test object at onset of system responses. The bottom-right quadrant shows a split-screen view of the primary visual display for the countermeasure suite (left portion of this quadrant), and the brake and accelerator pedals. The brake pedal view allowed Brake Pulse and Automatic Braking events to be identified since both occasioned autonomous brake pedal movements. All views were synchronized and a time-stamp applied to the multiplexed video output.

6.4.4 Data Reduction

The data reduction process required analysts to review the captured video and then code events and performance outcomes using a standardized set of reduction protocols; this activity involved frame-by-frame analysis of the video to identify events and distance measures. Table 23 details the performance measures of interest (e.g., system response probabilities, response latencies, distance at response onset, driver eye glances, etc.) extracted using the video. Two basic types of reduction schemes were used: one for Grid Tests and False Alarm tests, and another for Driver-in-the-Loop tests. Appendix B details the key performance measures and coding schemes for data reduction associated with the Grid Tests, as well as the data reduction schemes applied to Driver-in-the-Loop tests.

Table 23. Overview of key performance measures for objective test types

OBJECTIVE TEST TYPE	BASIC OBJECTIVE PERFORMANCE MEASURES
Grid Tests	**Camera Field of View**. Defines the breadth and width (in feet) of the visible area behind and to the sides of the vehicle using the enhanced view system; objects are coded as completely, partially, or not visible in the rear vision system display. **System Response Probability**. Measures likelihood that the system will respond to an in-path obstacle under the measured conditions. Expressed as a ratio (percentage of trials where countermeasure was observed to respond). **System Response Latency**. Quantifies the lag (in seconds) in responding once the system is activated by shifting into reverse. **Distance at First Response**. Defines the physical location (in feet) associated with the countermeasure's first response to the object. Depending on the test, response points may correspond to lateral distances relative to the vehicle's position on the grid, longitudinal distance from the vehicle's bumper to the test object at the onset of the system's first response, or both.
False Alarm Performance Tests	**Incidence of False System Activation**. Estimates the degree to which the backing countermeasure is prone to false system activation under typical backing environments and conditions. Expressed as a ratio for each individual test object (number of triggered trials/number of total trials).
Driver-In-The-Loop Tests	**Avoidance Outcome.** Percent of the sample observed to successfully avoid the in-path obstacle. **Detection Outcome.** Percent of the sample observed to detect the in-path obstacle. **Method of Detection.** Characterizes the driver's interaction with and reliance on the available backing crash countermeasures and its role in enabling the driver to detect the obstacle. **Driver Search and Glance Behavior.** Quantifies driver glance patterns immediately before and during the conflict scenario; includes glance frequency and durations to key spatial locations such as the rear vision system display. **Driver Response**. Characterizes driver responses to countermeasure outputs (or in-path obstacles), including braking to a stop, searching, ignoring or overriding system responses.

6.5 Overview of Test Results

A prototype suite of integrated backing crash countermeasures was evaluated and its performance characterized using a set of objective test protocols. These protocols involved the application of unique tests designed to assess system parameters. The tests produced information relating to response sensitivity to stationary and moving obstacles (of varying types and sizes) under a range of backing conditions, false alarm rate performance, as well as driver interactions and responsiveness to system information, warnings and interventions. Together, these test results provide data for use in the computer-based SIM model to estimate the effectiveness and potential safety benefits of the backing crash countermeasure system evaluated.

This section details the results for each of the 15 objective tests spanning Grid Tests of System Response Performance, tests of False Alarm Performance, and Driver-in-the-Loop Performance tests. Results of the Grid Tests of System Response Performance detail the performance of the six grid tests; the first set of three tests is designed to map the coverage zone for Enhanced View and Park Aid for near-field objects, while the second group of tests defines the response performance for Backing Warning and Automatic Braking. Data from the False Alarm Performance tests are intended to quantify and estimate the degree to which backing countermeasures are prone to falsely activate under typical operating environments. Lastly, Driver-in-the-Loop Performance tests are intended to characterize performance of the driver when interacting with the integrated system across a variety of conflict situations.

While data from the three basic test types are summarized here, it is important to remember that these objective tests are designed to provide inputs to the SIM and not to provide direct assessment of system effectiveness. Results of different test types are presented in a manner to aid in understanding of how tests were measured, scored, and characterized in the SIM; however, the results of any given test type, or subset of tests, should not be used in isolation, since the SIM model is required to integrate the performance results as a whole.

6.5.1 Grid Tests of System Response Performance

This set of tests measures countermeasure system response to in-path obstacles-of-interest along a longitudinal and lateral set of axes relative to the vehicle under both static and dynamic conditions. As such, some of the test situations involve prescribed movement of the test vehicle and/or obstacles. The Grid tests establish response envelopes surrounding the rear of the vehicle, noting the repeatability and time delay of system response. A test driver, or trained observer, is needed in order to execute the tests and confirm that the system responds to the obstacle. For example, rear vision-based countermeasures which display rearward images will require a test driver to confirm that the displayed views show the test object(s).

The following sections detail the results of the six grid tests, each intended to address one or more aspects related to the system's response performance. The first set of three tests is designed to map the coverage zone for near-field objects, and relates to the functional performance of proximity-based systems such as Park Assist and Rear Vision. The second group of tests is intended to define the response performance for more advanced, dynamically acting functions such as Backing Warning and

Automatic Braking - functions requiring more extended range, non-linear paths, and dynamic capabilities. Complete details relating to the test protocols for implementing each grid test are contained in Appendix A.

6.5.2 Test 1: Proximity-Based, Camera Field of View

This test assessed the coverage zone for enhanced view systems (e.g., Rear Vision camera-based systems) using a detection grid and two test objects (cardboard cylinder, and 2-year-old surrogate test mannequin), refer to Figure 33. Assessments were conducted using a stationary host vehicle equipped with Rear Vision and static test objects. All testing was conducted on a straight, level, dry surface under daytime conditions.

Figure 33. Grid Test objects used to assess camera Field Of View (FOV)

Evaluations were performed using the vehicle's Rear Vision display, located in the center console area, to assess whether all or any part of the test object was visible in the displayed area. Results are presented in Figure 34 and Figure 35 which plot the FOV (breadth and width of the visible area) for each of the two test objects; areas represented in green (darker shaded areas) indicate that the entire object is visible, while areas in light grey (lighter shaded areas) indicate that only part of the test object was visible. Results found that the vision system's FOV extended well beyond the width of the vehicle, even when objects are positioned in the near field adjacent to the bumper, and expands as the distance from the bumper increases. However, areas near the bumper (light-shaded areas) tended to provide a partial view of the test object. Patterns for the two test objects were comparable.

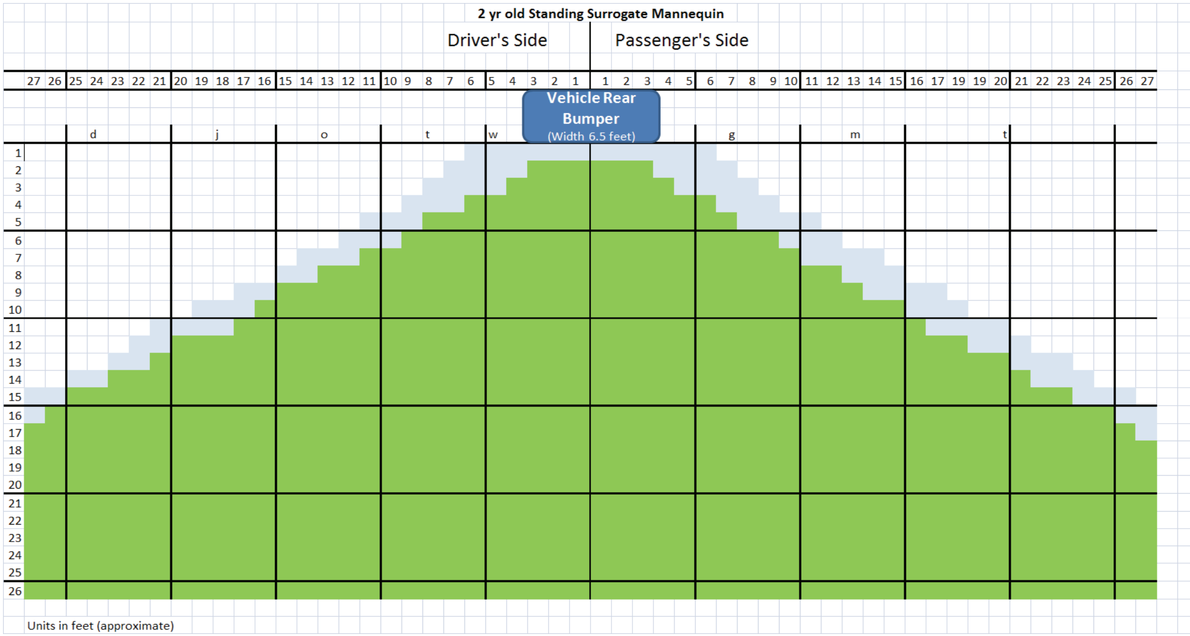


Figure 34. Camera Field of View mapped with cardboard cylinder. Dark areas (green) represent areas where entire object is visible

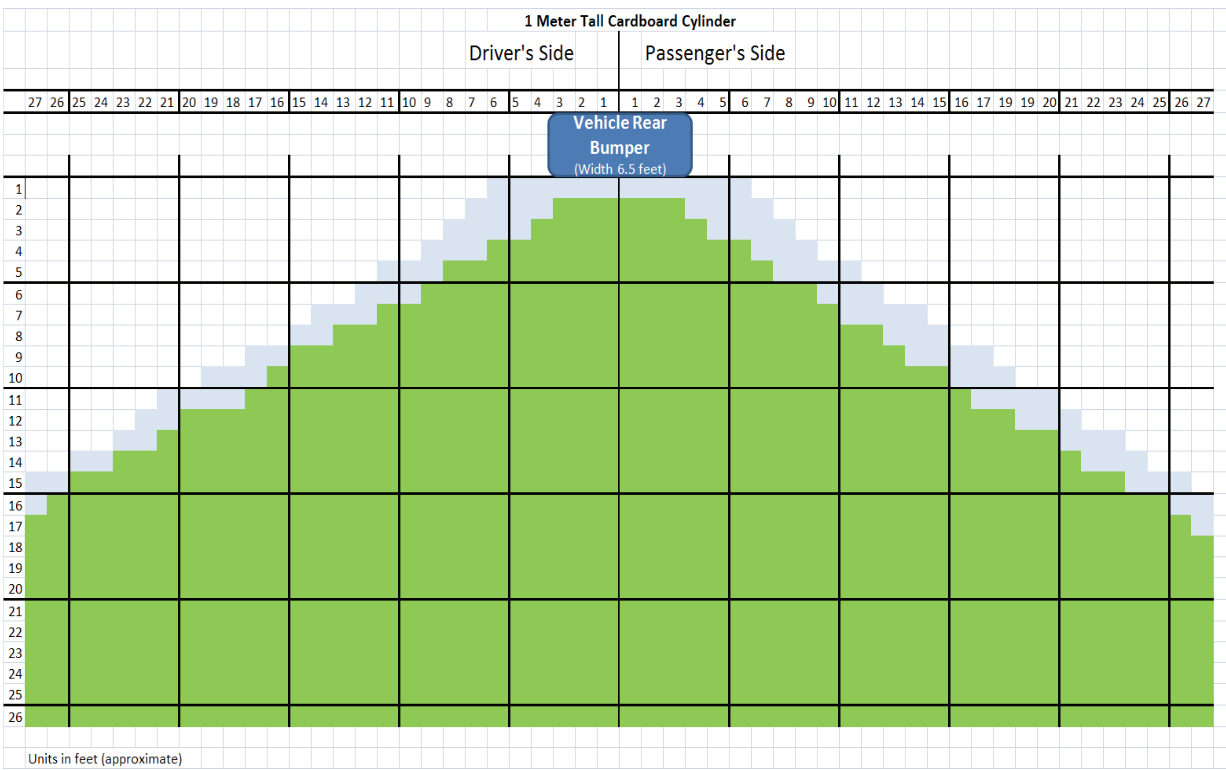


Figure 35. Camera Field of View mapped with surrogate 2-year-old standing mannequin. Dark areas (green) represent areas where entire object is visible

6.5.3 Test 2: Proximity-Based, Static Field of Response

This grid test assessed the longitudinal and lateral coverage zones for proximity-based systems (including systems that provide proximity information such as Park Assist) using a detection grid and a set of static test objects of varying heights and sizes (including a 1-meter-tall, 75-mm-diameter pole; and special test mannequins representative of pedestrians). Test objects were placed within the grid, illustrated in Figure 36, with system responses captured following the protocol detailed in Appendix A. Tests used a stationary host vehicle equipped with the backing countermeasures and static test objects, and were conducted on a straight, level, dry surface under daytime conditions. Five testing conditions were performed as detailed below, each was repeated 3 times:

- PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches)
- Surrogate test mannequin, 2-year-old standing
- Surrogate test mannequin, 5-year-old standing
- Surrogate test mannequin, 5-year-old prone (lying perpendicular to the vehicle bumper)
- Surrogate test mannequin, sitting

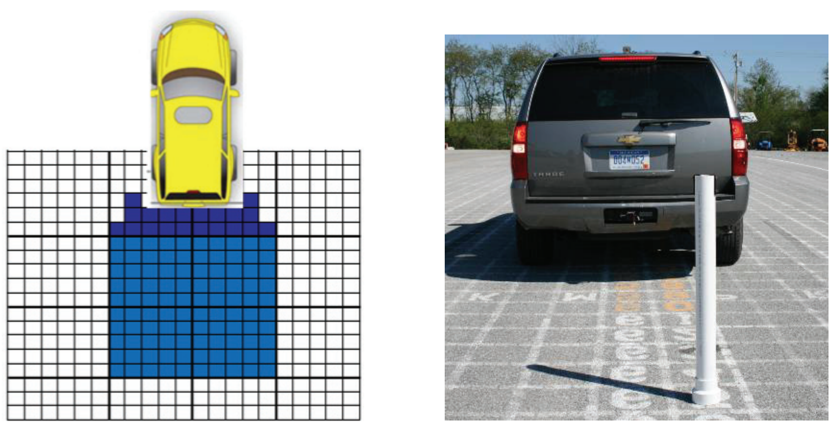


Figure 36. Static field of response tests performed on Test Grid to map longitudinal and lateral response zones

Data from each trial were recorded using vehicle-based video instrumentation and analyzed post-hoc to identify countermeasure responses; in this case, outputs from the Park Aid system which provided both audible and visual cues to indicate the presence of a rear obstacle. Analysts coded responses from the Park Aid's visual display, pictured in the lower left quadrant of Figure 37, using the LED display activations to index a response (illumination of one or more of the LED units in response to the test object). Thus, analysts used the Park Aid display to note whether or not the system responded to each test object. Trials eliciting no system responses (no LED indications) following a 5-second exposure were designated as a non-response trial.

Figure 37. Video instrumentation excerpt for static field of response trial with standing 2-year-old mannequin. LED display (lower right quadrant) indicates a response.

This test yields information pertaining to the longitudinal and lateral coverage zone for proximity-based systems. Two basic measures are defined and modeled in the SIM; these include: 1) system response probabilities that estimate the likelihood the system will respond to in-path obstacles (field of response zones), and 2) response latencies that quantify the lag in issuing an alert once the system is activated by shifting into reverse.

Data collected as part of this test were successful in clearly defining areas behind the stationary vehicle where an object is likely to trigger a system response (i.e., response zones). Overall, the system (in this case, the proximity-based Park Aid countermeasure) was found to respond to test objects within the span of the vehicle's 6-foot bumper out to a distance of up to 8 ft. The system did not generally respond to objects outside of this area, nor to locations close-in to the bumper (1 ft from the bumper). Response profiles among test objects were also found to vary, particularly for the hybrid sitting and 5-year-old prone pedestrian test mannequins – both of these objects proved difficult for the system when placed within 3-4 ft from the bumper. On average, system responses were issued within 200 milliseconds of shifting into reverse. Detailed results are presented in the sections that follow.

6.5.3.1 Response Probabilities

Figure 38 and Figure 39 plot the test results, mapping out the near horizontal and longitudinal field of response (FOR) for each of the five test objects across all grid cells. In these graphs, cell values represent the likelihood of a system response averaged over three repetitions. Results generally indicate a high level of response performance across the test objects with the FOR finely tuned to areas within the bumper's width (in-path area). Response performance tends to drop out completely at distances beyond 9 ft under these static testing situations (stationary vehicle and test objects). One interesting finding relates to the near-field response performance profile (adjacent to the vehicle's bumper) which shows that some objects are unlikely to trigger a system response, particularly when objects are located within 1 ft from the bumper (the first grid row). This characteristic is particularly pronounced for the prone and sitting pedestrian test objects. Data were fed to the SIM to model response performance for a stationary vehicle and test objects.

Values in feet
Object: PVC pole

Vehicle Rear Bumper (Width 6.5 feet)

Row	7.9	6.8	5.7	4.5	3.4	2.3	1.1	0.0	1.1	2.3	3.4	4.5	5.7	6.8	7.9
0.6						33%	33%								
1.7					100%	100%	100%	33%	100%	100%	100%				
2.8					100%	100%	100%	100%	100%	100%	100%				
4.0					67%	100%	100%	100%	100%	100%	67%	33%			
5.1						100%	100%	100%	100%	100%	100%	33%			
6.2						100%	100%	100%	100%	100%	100%	67%			
7.4						100%	100%	100%	100%	100%	100%	100%			
8.5						33%		33%		33%					
9.6															
10.8															

Values in feet
Object: 2 year old standing pedestrian

Vehicle Rear Bumper (Width 6.5 feet)

Row	7.9	6.8	5.7	4.5	3.4	2.3	1.1	0.0	1.1	2.3	3.4	4.5	5.7	6.8	7.9
0.6									100%	33%					
1.7					100%	67%	67%	67%	100%	100%	100%				
2.8					100%	100%	100%	100%	100%	100%	100%				
4.0					100%	100%	100%	100%	100%	100%	100%				
5.1					100%	100%	100%	100%	100%	100%	100%				
6.2					100%	100%	100%	100%	100%	100%	100%				
7.4					67%	100%	100%	100%	100%	100%	100%				
8.5									33%						
9.6															
10.8															

Values in feet
Object: 5 year old standing pedestrian

Vehicle Rear Bumper (Width 6.5 feet)

Row	7.9	6.8	5.7	4.5	3.4	2.3	1.1	0.0	1.1	2.3	3.4	4.5	5.7	6.8	7.9
0.6							33%		33%						
1.7					100%	100%	100%		100%	67%	100%	33%			
2.8					100%	100%	100%	100%	100%	100%	100%				
4.0					100%	100%	100%	100%	100%	100%	100%				
5.1					67%	100%	100%	100%	100%	100%	100%		33%		
6.2					67%	100%	100%	100%	100%	100%	100%				
7.4					67%	100%	100%	100%	100%	100%	100%				
8.5						67%	33%	33%	33%	33%					
9.6															
10.8															

Figure 38. Response zones for PVC pole, and 2- & 5-year-old surrogate test mannequins. Cell values represent likelihood of system response for each cell location. Blank cells indicate no response

Values in feet
Object: Sitting pedestrian

Vehicle Rear Bumper
(Width 6.5 feet)

Row	7.9	6.8	5.7	4.5	3.4	2.3	1.1	0.0	1.1	2.3	3.4	4.5	5.7	6.8	7.9
0.6															
1.7															
2.8										33%					
4.0					33%	100%	100%	33%	100%	67%					
5.1					33%	100%	100%	100%	100%	100%	67%				
6.2					33%	100%	100%	100%	100%	100%	67%				
7.4					67%	100%	100%	100%	100%	100%	100%				
8.5						100%	67%	33%	33%		33%				
9.6															
10.8															

Values in feet
Object: 5 year old prone pedestrian

Vehicle Rear Bumper
(Width 6.5 feet)

Row	7.9	6.8	5.7	4.5	3.4	2.3	1.1	0.0	1.1	2.3	3.4	4.5	5.7	6.8	7.9
0.6															
1.7															
2.8															
4.0															
5.1					50%	33%		67%							
6.2				67%	100%	100%	100%		33%	67%					
7.4				67%	100%	100%	100%	100%	100%	100%					
8.5					33%	33%	33%	33%	33%	33%					
9.6								33%							
10.8															

Figure 39. Response zones for 5-year old prone and hybrid sitting surrogate test mannequins. Cell values represent likelihood of system response for each cell location. Blank cells indicate no response.

6.5.3.2 Response Latencies

System response latency data (time from trial onset to initial system response) were also coded in order to model and understand the response time-frame associated with a standard test object and how this might vary over the response zone. Analysts extracted these values for the PVC pole test object since it was among the test objects with the broadest response area. These data are presented in Figure 40, and show response latencies ranging from 0.1 to 3.8 s, with an average response latency of approximately 0.2 s.

Values in Seconds
Object: PVC Pole

Vehicle Rear Bumper
(Width 6.5 feet)

	7.9	6.8	5.7	4.5	3.4	2.3	1.1	0.0	1.1	2.3	3.4	4.5	5.7	6.8	7.9
0.6						3.8	1.1								
1.7					0.1	0.1	0.1		0.1	0.1	0.1				
2.8					0.1	0.1	0.1	0.1	0.1	0.1	0.1				
4.0					0.1	0.1	0.1	0.1	0.1	0.1	0.1	3.1			
5.1						0.1	0.1	0.1	0.1	0.1	0.1	0.1			
6.2						0.1	0.1	0.1	0.1	0.1	0.1	0.1			
7.4						0.2	0.1	0.1	0.1	0.1	0.1	0.1			
8.5										0.1					
9.6															
10.8															

Figure 40. Observed response latencies for PVC pole test object

6.5.4 Test 3: Proximity-Based, Field of Response for Incurring Obstacles

This test evaluated the longitudinal and lateral response zones for proximity-based systems (e.g., proximity information) with dynamic test objects and a stationary host vehicle. Test objects were moved into the path of a stationary vehicle in order to map out horizontal boundary points corresponding to the point of the system's first response. Three test objects were used, including a PVC pole and two mannequins representing 2- and 5-year old children. Objects were presented at two speeds, moving across the vehicle's path at 2 and 4 mph. Prescriptive assessment procedures for this test are presented in Appendix A. Testing was conducted on a straight, level, dry surface under daytime conditions. Figure 41 illustrates the basic set-up on the test grid with an example case showing an incurring PVC pole.

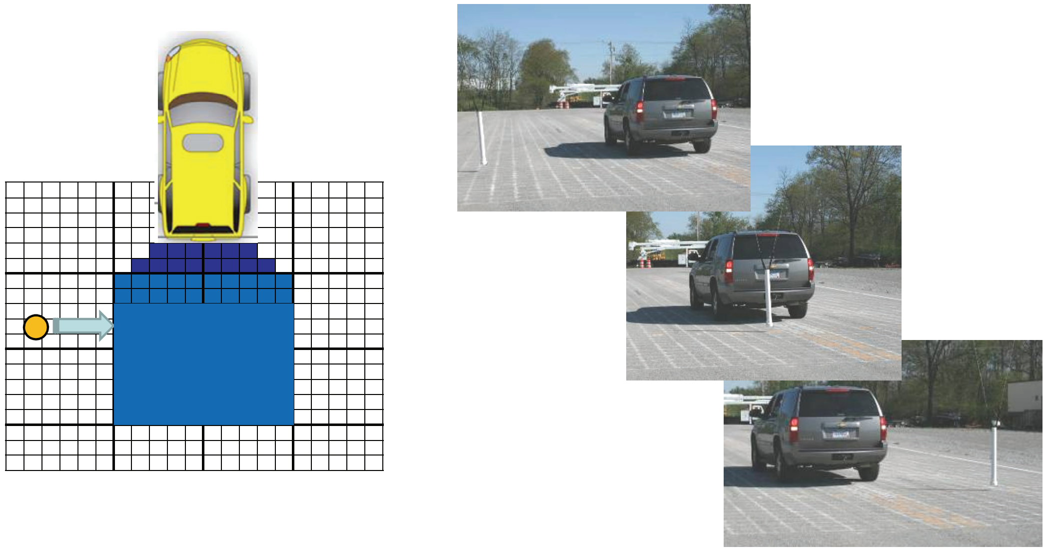


Figure 41. Field of response for incurring objects; as conceptualized (left) and example trial illustrating an incurring PVC pole with stationary vehicle positioned on the Test Grid (right)

Six test conditions were run; these were derived from the combination of three test objects and two travel speeds. Each test condition was repeated 4 times, counterbalanced with objects incurring from each direction, passenger and driver's side, of the vehicle. Test objects were suspended and moved over the grid using a motorized cable tower system illustrated in Figure 42.

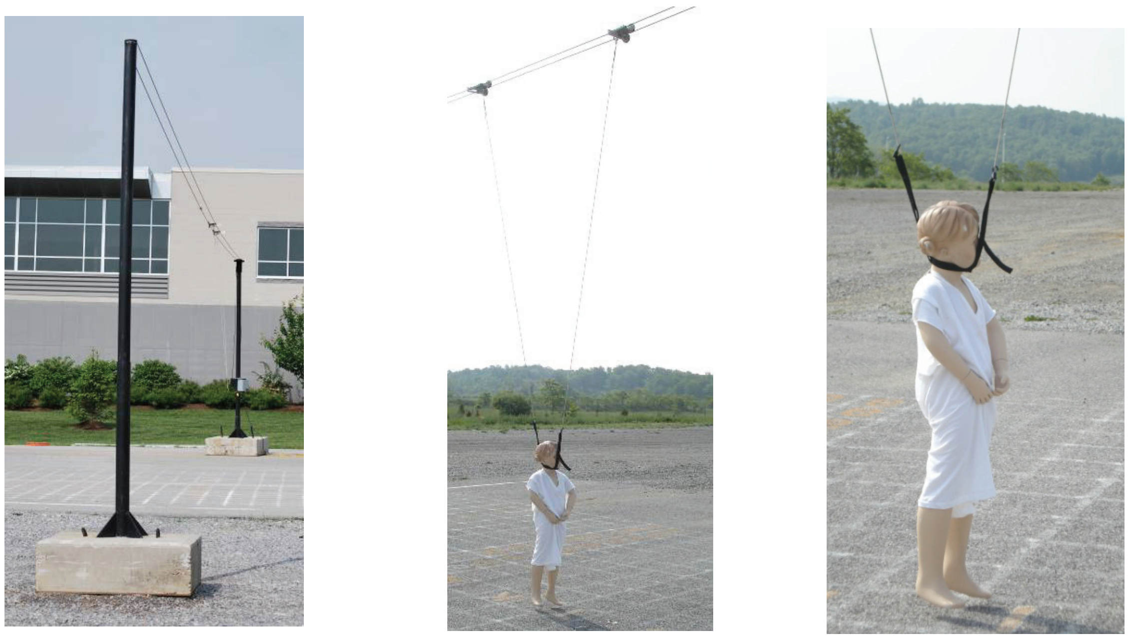


Figure 42. Method of suspending and moving test objects over the Test Grid

Data from this test allow the SIM to model the countermeasure's ability to respond to laterally incurring objects, and to determine how responses vary as a function of test object, test object speed, and distance from the vehicle. The primary measure used to quantify system performance for this test is the lateral distance at the system's first response to the incurring test object; response performance is detailed across a range of longitudinal distances from the vehicle.

Overall, the system (in this case, the Park Aid countermeasure) was found to respond to 56% of the trials, collapsing across test objects and movement speeds. Response rates were fairly uniform across the three test objects ranging from an average response rate of 55% for the PVC pole, 56% for the 5-year-old standing mannequin, to 58% for the 2-year-old standing mannequin. Movement speeds were found to affect the countermeasure's response rate with increased performance for slow moving (2 mph) versus faster moving (4 mph) test objects: 61% versus 52%, respectively. On average, the system responded to an incurring object by the time it penetrated -2.3 ft (laterally) into the vehicle's path (collapsed across all test objects, movement rates, and longitudinal distances). Lateral distance at first response was also found to vary as a function of test object. The sections that follow present detailed information relating to these lateral distance measures.

6.5.4.1 Distance at First Response

Analysts reviewed the video to identify the physical location or boundary points (grid columns) associated with the countermeasure's first response as the object incurred into the vehicle's path. Assessments were made starting 1 ft from the vehicle's bumper (first grid row) and continued down subsequent rows until no more responses were registered. The Park Aid system's visual cues (LED display) were used to index system responses. Use of the test grid allowed response points to be translated into distance measures representing the lateral distance (in feet) relative to the vehicle's location. Data are presented in two formats: graphically and in table form.

Figure 43 –Figure 45 graphically illustrate the results for each of the test objects and movement speeds. Each graph depicts the point of first response across each grid row; a total of eight trials were run, four in each incurring direction. Cell values correspond to the percentage of trials for which the system first responded, with values accumulating in order to illustrate the variation in response locations. For instance, as shown in Figure 43 (top left panel), no system responses were registered when the 5-year-old mannequin incurred from the driver's side for the first row. Encroachments along the second row (2 ft from the bumper) triggered system responses with 50% of the trials responding at column "1" and 100% of the trials (represented by the black cell) responding by the time the mannequin had reached column "0" (representing the bumper mid-point). Together, these charts illustrate the horizontal boundary points for each test object under the two movement speeds for encroachments from either direction. They essentially show how far a test object can penetrate into the vehicle's path before the system responds by issuing an audible and/or visual alert when the vehicle is stationary.

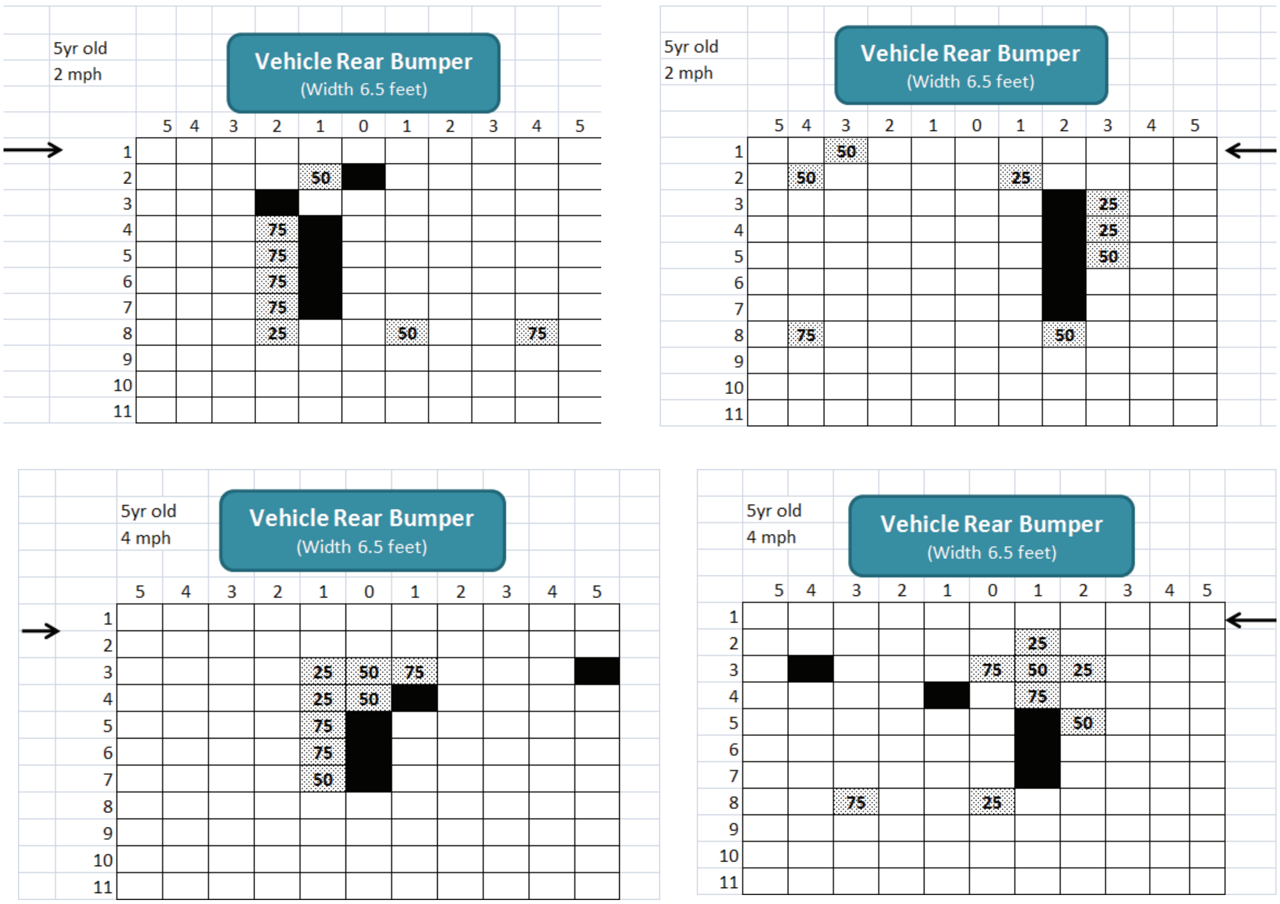


Figure 43. Response boundaries, 5-year-old mannequin incurring, 2 mph (top panels) and 4 mph (bottom panels): Cells represent locations associated with the countermeasure's first response, and the cumulative percentages across four trials (black cells represent 100%). Arrows indicate direction of encroachment

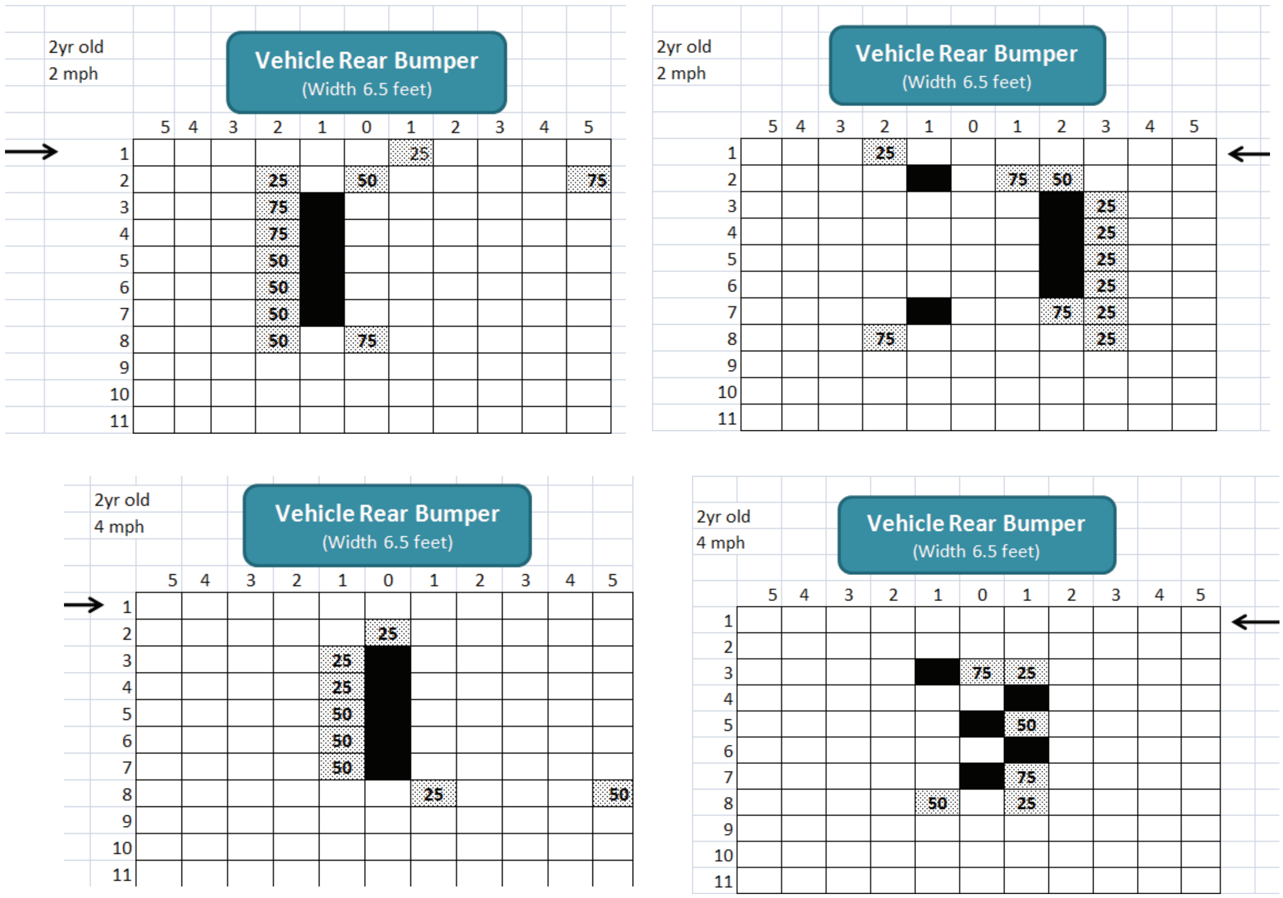


Figure 44. Response boundaries, 2-year-old mannequin incurring, 2 mph (top panels) and 4 mph (bottom panels): cells represent locations associated with the countermeasure's first response, and the cumulative percentages across four trials (black cells represent 100%). Arrows indicate direction of encroachment

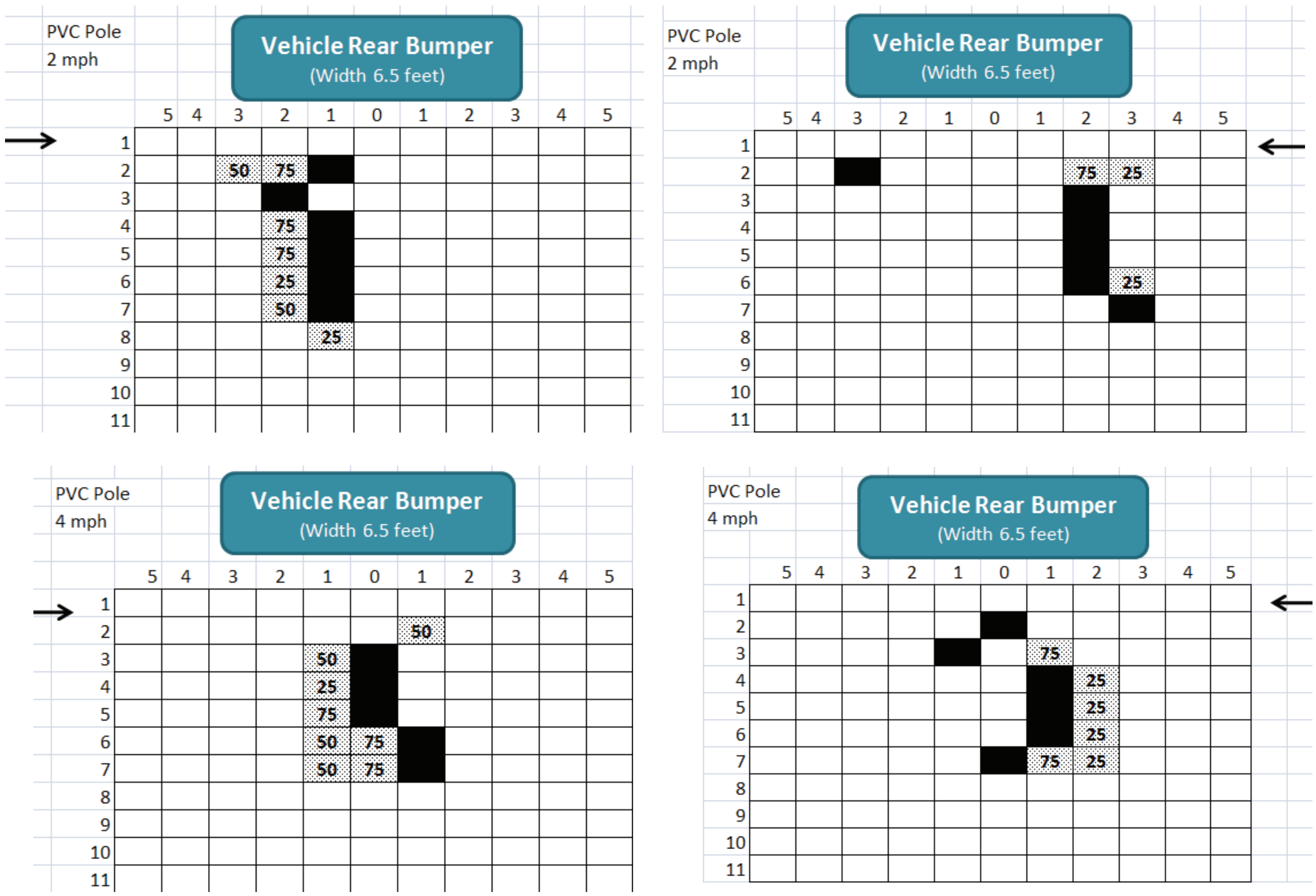


Figure 45. Response boundaries, PVC pole incurring, 2 mph (top panels) and 4 mph (bottom panels): cells represent locations associated with the countermeasure's first response, and the cumulative percentages across four trials (black cells represent 100%). Arrows indicate direction of encroachment.

Data are also presented in tabular form using distance values to map response points (the SIM codes distance values as depicted in the above figures with the midpoint of the bumper representing the zero point). In order to aid interpretation, distance values in this report are expressed relative to the leading edge of the vehicle's bumper, noting whether the system responded before or after the object incurred into the vehicle's path (within the bumper width). This approach, illustrated in Figure 46, enables the magnitude of the penetration into the vehicle's path at response onset to be clearly discerned, regardless of encroachment direction. System responses to objects that occur before the object reaches the vertical plane corresponding to the leading edge of the vehicle's bumper are coded as positive values (before intersection with the vehicle). Responses beyond this vertical plane are scored as negative values (past the leading edge, in-path). Thus, data in Table 24 and Table 25 express distance values associated with the system's first response relative to the leading edge of the vehicle's bumper;

positive values indicate the first response occurred before the object intersected the vehicle's path, while negative values indicate that the response occurred once the object was within the path of the vehicle.

Tabled values indicate that all system responses, regardless of object movement speed, occurred within the vehicle's bumper width – no responses were issued before the test object moved into the vehicle's path boundary.

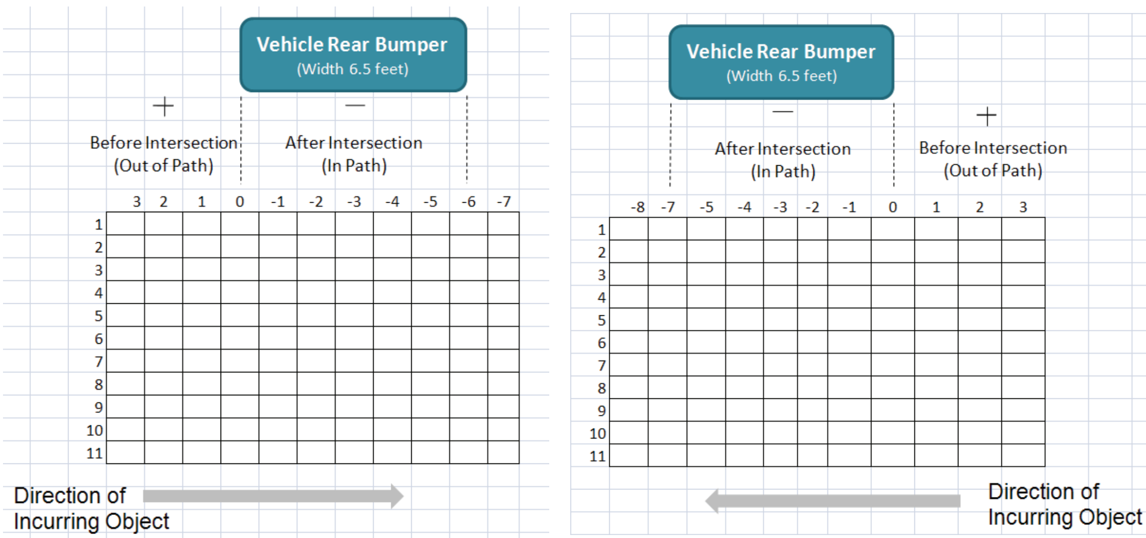


Figure 46. Illustration of coding scheme used to derive tabled distance values for test 3

Table 24. Driver's side encroachments, distance at first response relative to the leading edge of the rear bumper (test 3: dynamic horizontal, incurring obstacles)

Lateral Distance (ft)	Object Incurring Speed							
	2 mph				4 mph			
	Mean	Min	Max	N*	Mean	Min	Max	N*
1 ft								
5 yr old standing	.	.	.	0/4	.	.	.	0/4
2 yr old standing	-4.6	-4.6	-4.6	1/4	.	.	.	0/4
PVC Pole	.	.	.	0/4	.	.	.	0/4
2 ft								
5 yr old standing	-2.9	-2.3	-3.4	4/4	.	.	.	0/4
2 yr old standing	-3.4	0	-9.2	4/4	-3.4	-3.4	-3.4	1/4
PVC Pole	-0.9	0	-2.3	4/4	-4.6	-4.6	-4.6	2/4
3 ft								
5 yr old standing	-1.1	-1.1	-1.1	4/4	-4.9	-2.3	-9.2	4/4
2 yr old standing	-1.4	-1.1	-2.3	4/4	-3.2	-2.3	-3.4	4/4
PVC Pole	-1.1	-1.1	-1.1	4/4	-2.9	-2.3	-3.4	4/4
4 ft								
5 yr old standing	-1.4	-1.1	-2.3	4/4	-3.7	-2.3	-4.6	4/4
2 yr old standing	-1.4	-1.1	-2.3	4/4	-3.2	-2.3	-3.4	4/4
PVC Pole	-1.4	-1.1	-2.3	4/4	-3.2	-2.3	-3.4	4/4
5 ft								
5 yr old standing	-1.4	-1.1	-2.3	4/4	-2.6	-2.3	-3.4	4/4
2 yr old standing	-1.7	-1.1	-2.3	4/4	-2.9	-2.3	-3.4	4/4
PVC Pole	-1.4	-1.1	-2.3	4/4	-2.6	-2.3	-3.4	4/4
6 ft								
5 yr old standing	-1.4	-1.1	-2.3	4/4	-2.6	-2.3	-3.4	4/4
2 yr old standing	-1.7	-1.1	-2.3	4/4	-2.9	-2.3	-3.4	4/4
PVC Pole	-2.0	-1.1	-2.3	4/4	-3.2	-2.3	-4.6	4/4
7 ft								
5 yr old standing	-1.4	-1.1	-2.3	4/4	-2.9	-2.3	-3.4	4/4
2 yr old standing	-1.7	-1.1	-2.3	4/4	-2.9	-2.3	-3.4	4/4
PVC Pole	-1.7	-1.1	-2.3	4/4	-3.2	-2.3	-4.6	4/4
8 ft								
5 yr old standing	-4.6	-1.1	-8.0	3/4	.	.	.	0/4
2 yr old standing	-1.9	-1.1	-3.4	3/4	-6.9	-4.6	-9.2	2/4
PVC Pole	-2.3	-2.3	-2.3	1/4	.	.	.	0/4
9 ft + No Response								

*N = number of system activations/number of trials

Table 25. Passenger side encroachments, distance at first response relative to the leading edge of the rear bumper (test 3: dynamic horizontal, incurring obstacles)

Lateral Distance (ft)	2 mph incurring				4 mph incurring			
	Mean	Min	Max	N*	Mean	Min	Max	N*
1 ft								
5 yr old standing	-6.9	-6.9	-6.9	2/4	.	.	.	0/4
2 yr old standing	-6.9	-6.9	-6.9	1/4	.	.	.	0/4
PVC Pole	.	.	.	0/4	.	.	.	0/4
2 ft								
5 yr old standing	-4.2	-2.3	-8.0	3/4	-2.3	-2.3	-2.3	1/4
2 yr old standing	-2.3	-1.1	-4.6	4/4	.	.	.	0/4
PVC Pole	-2.3	0	-6.9	4/4	-3.4	-3.4	-3.4	4/4
3 ft								
5 yr old standing	-0.9	0	-1.1	4/4	-3.7	-1.1	-8.0	4/4
2 yr old standing	-0.9	0	-1.1	4/4	-3.4	-2.3	-4.6	4/4
PVC Pole	-1.1	-1.1	-1.1	4/4	-2.9	-2.3	-4.6	4/4
4 ft								
5 yr old standing	-0.9	0	1.1	4/4	-2.9	-2.3	-4.6	4/4
2 yr old standing	-0.9	0	1.1	4/4	-2.3	-2.3	-2.3	4/4
PVC Pole	-1.1	1.1	1.1	4/4	-2.0	-1.1	-2.3	4/4
5 ft								
5 yr old standing	-0.6	0	-1.1	4/4	-1.7	-1.1	-2.3	4/4
2 yr old standing	-1.1	-1.1	-1.1	4/4	-2.9	-2.3	-3.4	4/4
PVC Pole	-1.1	-1.1	-1.1	4/4	-2.0	-1.1	-2.3	4/4
6 ft								
5 yr old standing	-1.1	-1.1	-1.1	4/4	-2.3	-2.3	-2.3	4/4
2 yr old standing	-0.9	0	-1.1	4/4	-2.3	-2.3	-2.3	4/4
PVC Pole	-0.9	0	-1.1	4/4	-2.0	-1.1	-2.3	4/4
7 ft								
5 yr old standing	-1.1	-1.1	-1.1	4/4	-2.3	-2.3	-2.3	4/4
2 yr old standing	-1.7	0	-4.6	4/4	-2.7	-2.3	-3.4	3/4
PVC Pole	0	0	0	4/4	-2.3	-1.1	-3.4	4/4
8 ft								
5 yr old standing	-3.4	-1.1	-8.0	3/4	-5.7	-3.4	-6.9	3/4
2 yr old standing	-3.8	0	-5.7	3/4	-3.4	-2.3	-4.6	2/4
PVC Pole	.	.	.	0/4	.	.	.	0/4
9 ft + No Response								

*N = number of system activations/number of trials

6.5.5 Test 4: Warning Based, Dynamic Longitudinal

This grid test assessed the system's longitudinal response envelope, including the maximum longitudinal coverage zone, for dynamically acting features (e.g., Backing Warning and Automatic Braking functions). As illustrated in Figure 47, a trained driver backed the vehicle (equipped with the backing countermeasures) towards five different static test objects (a PVC pole, and 4 surrogate test mannequins, including 2-year-old standing, 5-year-old standing and prone, and hybrid sitting) under three different backing speed profiles (4, 8, and 15 mph). The high-speed approach was used as a boundary value in order to determine the maximum longitudinal range of the system (i.e., the earliest possible point that the system would respond). In all, 15 individual tests were completed, derived from the combination of five test objects across three backing speeds. Each test was repeated a total of three times. Data captured during these tests helped to define the longitudinal range of the response envelope for the countermeasures.

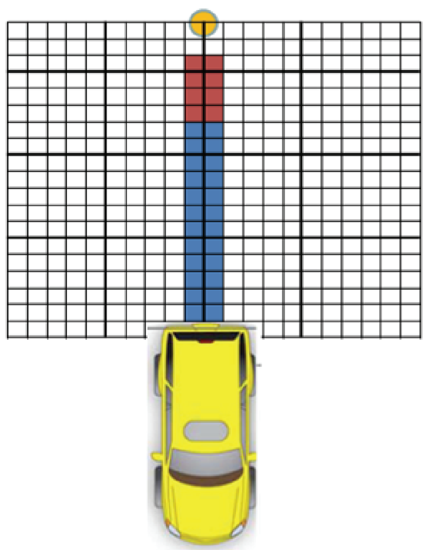


Figure 47. Illustration of the set-up for the dynamic longitudinal test

Analysts used the captured video to code distance from the vehicle to the test object at the onset of each countermeasure feature, including Park Aid, Cautionary Backing Warning (initial audible & visual indication), Imminent Backing Warning (including additional audible tones and a brake pulse), and Automatic Braking. Results, presented below, detail the activation rates for each countermeasure (percentage of trials in which the countermeasure triggered in response to the test object), and the distance measures associated with the onset of activations.

This test was designed to allow the SIM to map a system's longitudinal response envelope – the range at which a given countermeasure responds to a fixed (stationary) object, and to determine how these distances vary as a function of object type and vehicle backing speed. Data are mapped to represent the longitudinal distance at the system's first response (onset of response). The likelihood that a given countermeasure will respond to a given test object under varying approach speeds is also modeled into the SIM.

Data clearly map the progression across countermeasures at response onset while backing, with maximum distances at response onset as follows (values are collapsed across test object type and backing speeds):

- 20.0 ft for the cautionary stage of Backing Warning response,
- 15.1 ft for imminent stage of Backing Warning (including Brake Pulse),
- 6.5 ft for Park Aid, and
- 5.9 ft for Automatic Braking.

Sections that follow present these data as a function of object type and vehicle backing speeds for each individual countermeasure.

6.5.5.1 System Response Probabilities

Activation rates are used by the SIM to estimate the likelihood that a given countermeasure feature will respond to a given test object under the approach conditions tested (backing speeds). This section presents the activation rates for each countermeasure across the assessed test object and speed ranges. Figure 48 presents the activation rates for the Park Aid feature across each of the test objects. The graph only plots data for the 4 mph backing speed profile since this feature is designed to activate at speeds below 5 mph. Results found that the Park Aid system responded to each of the five test objects across the three trials; there were no instances where the feature did not respond when backing at 4 mph.

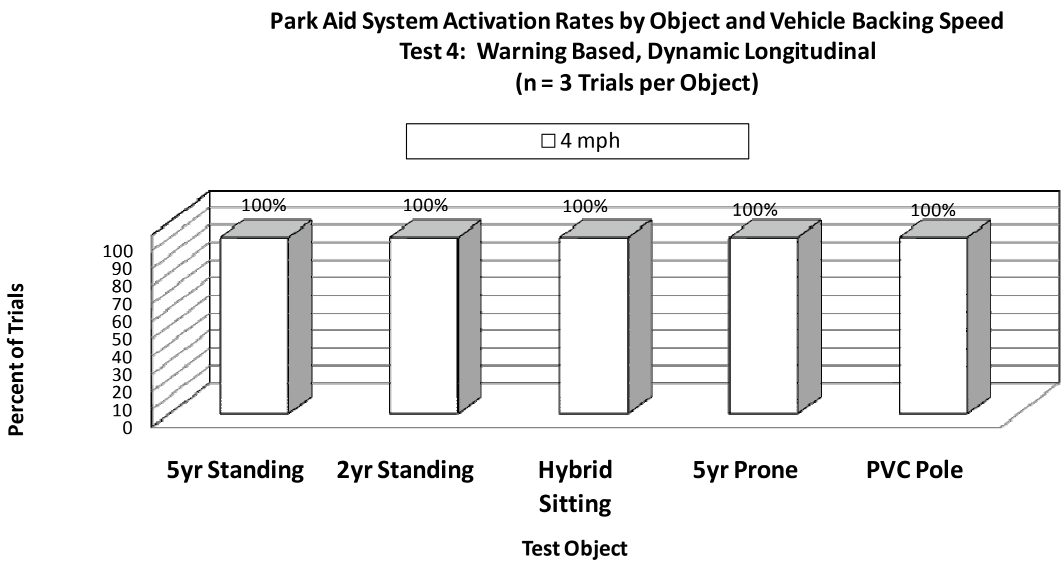


Figure 48. Park Aid activation rates across test objects

Activation rates for the two-staged Backing Warning feature, which included a cautionary warning with a single audible tone and a visual indication, and an imminent warning with audible tones and a brake pulse, are presented in Figure 49 and Figure 50. Note that since these backing warning features are designed to activate at speeds above 5mph, the charts are limited to backing profiles for 8 and 15 mph. Results found that both the cautionary and imminent warning responses activated for each of the test objects under the 8 mph backing profile. At higher backing speeds of 15 mph, imminent warnings (with the brake pulse) appear more sensitive to the object type. Data suggest that imminent warnings (brake pulse activations) are not likely to occur when backing to the 2-year-old standing mannequin at 15 mph, with intermediate levels of performance when backing at 15 mph toward a 5-year-old standing mannequin and a hybrid sitting mannequin.

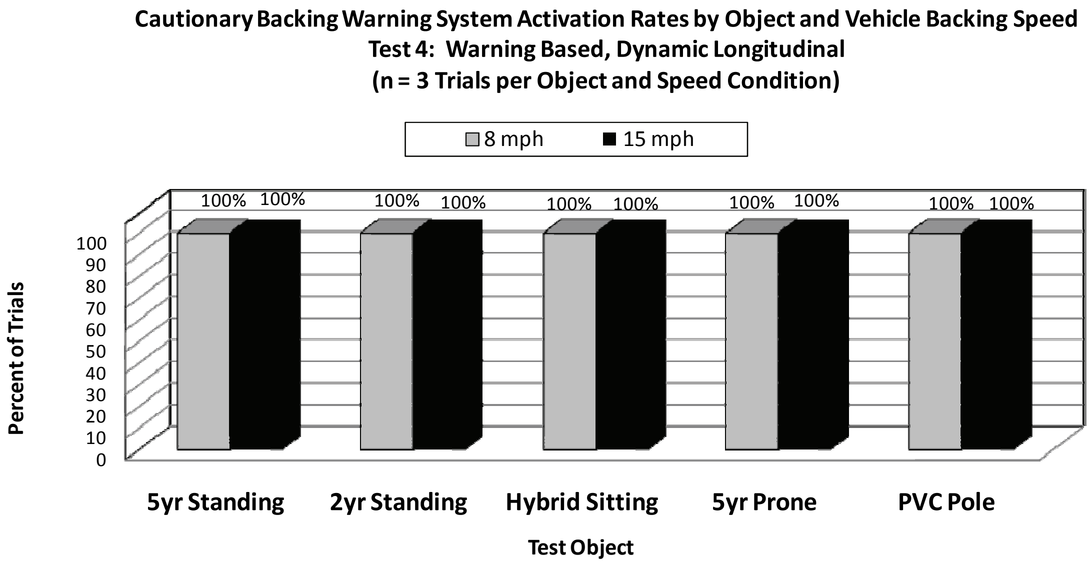


Figure 49. Cautionary backing warning activation rates across test objects and backing speeds

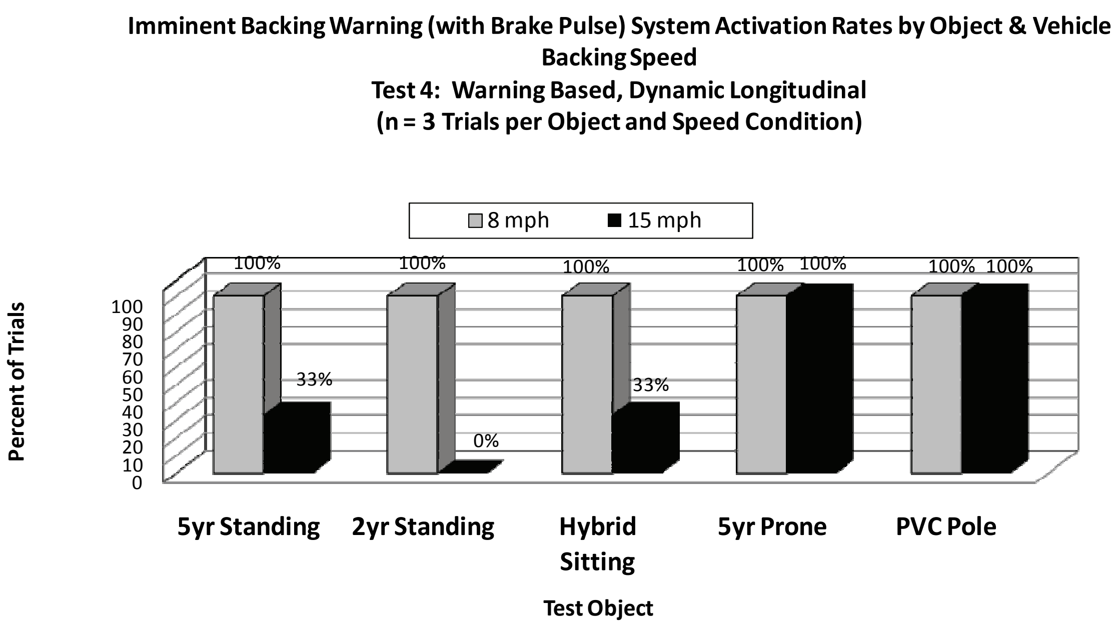


Figure 50. Imminent backing warning activation rates across test objects and backing speeds

Activation rates for Automatic Braking are plotted here across each of the prescribed backing speed profiles. As shown in Figure 51, Automatic Braking was found to trigger across all backing speeds (i.e., 4, 8, and 15 mph) with some variation across test objects. Activation rates for both the 5- and 2-year-old standing mannequins were 100% across each of the three backing speed profiles. Lower levels of performance were observed when backing to the hybrid sitting mannequin (at 4 mph) and the PVC pole (at 15 mph). Low speed approaches to the 5-year-old prone mannequin (at 4 mph) did not trigger any Automatic Braking events.

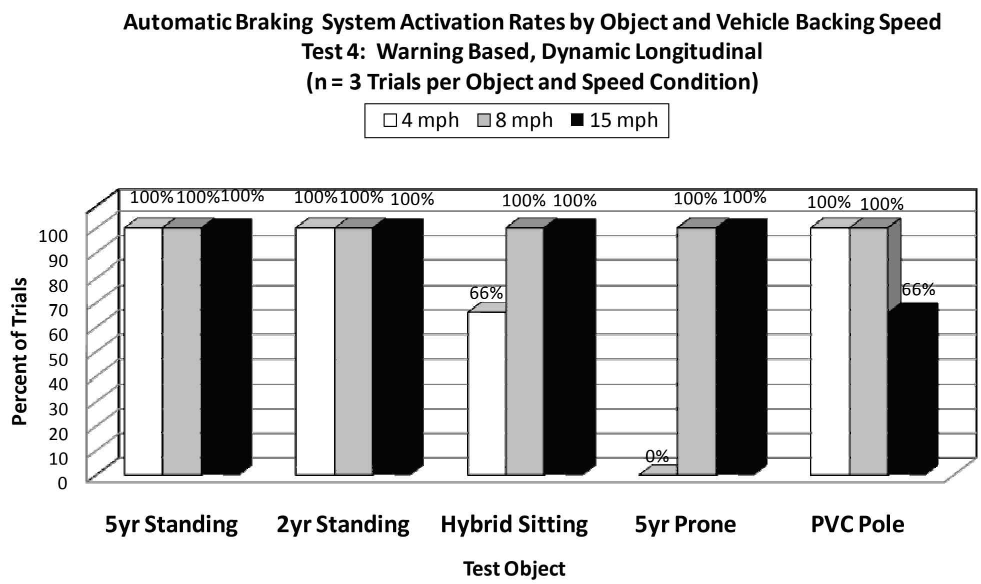


Figure 51. Automatic Braking activation rates across test objects and backing speeds

6.5.5.2 <u>Distances at First Response</u>

Data in the previous section highlighted the activation rates associated with each of the backing countermeasure systems while backing to the test objects under different speed profiles. This section presents data relating to these activations by specifying the distance (in feet) from the vehicle's bumper to the test object at the onset of the response. These data are presented graphically as well as in table form. Graphs depict the observed distance from the object at the countermeasure's first response for each of the three test trials, expressed as a percentage of the trial runs. Note that the percentages depicted in the graphs are based on total number of trials for a given object and backing speed combination (three runs per object at each speed); in some cases the percentage totals may not sum to 100% since the particular countermeasure may not have activated for all three trial runs.

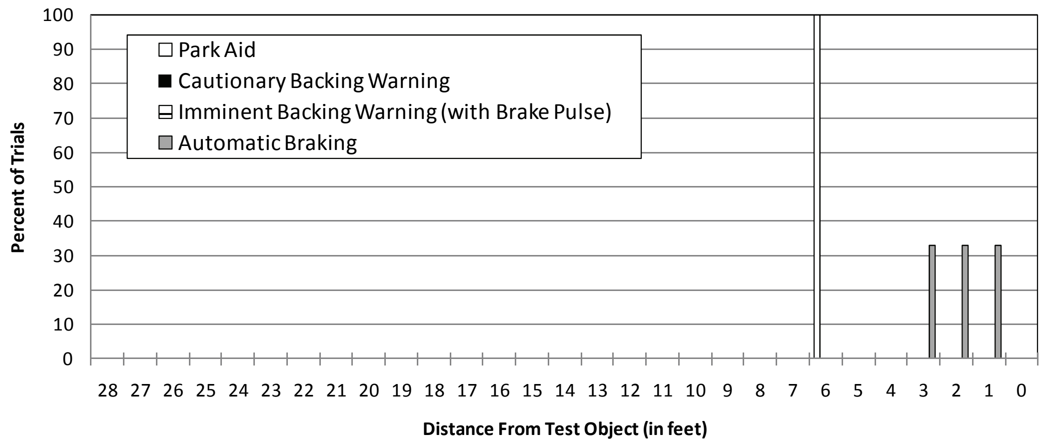
Figure 52 shows the activation distances for the PVC pole under each of the three backing speed profiles. The chart plots distances at the onset of each countermeasure, including Park Aid, Backing Warning (cautionary warning), Backing Warning (imminent warning), and Automatic Braking. As shown, when backing at 4 mph, two countermeasures activated: Park Aid and Automatic Braking. All of the Park Aid cues were initiated at approximately 6 ft from the PVC pole when backing at 4 mph. Onset of the Automatic Braking events were also closely grouped occurring at distances of approximately 3 ft, 2 ft, and 1 ft from the test object. At higher speeds (8 and 15 mph), Park Aid cues were not observed while both stages of Backing Warning and Automatic Braking activations were recorded. For example, at 8 mph audible cues associated with the Cautionary Backing Warning occurred at distances between 27 and 25 ft from the object, with onset of the Imminent Backing Warning at distances between 13 ft and 12 ft. Automatic Braking triggered for all three trials, occurring at distances between 7 ft and 9 ft; two-thirds of these triggers (66%, or 2 out of the 3 trials) were initiated at approximately 7 ft from the PVC pole. Each figure includes the data for a given object across the three backing speed profiles (4, 8, and 15 mph).

Figure 54 - Figure 56 present these data for the remaining test objects, including:

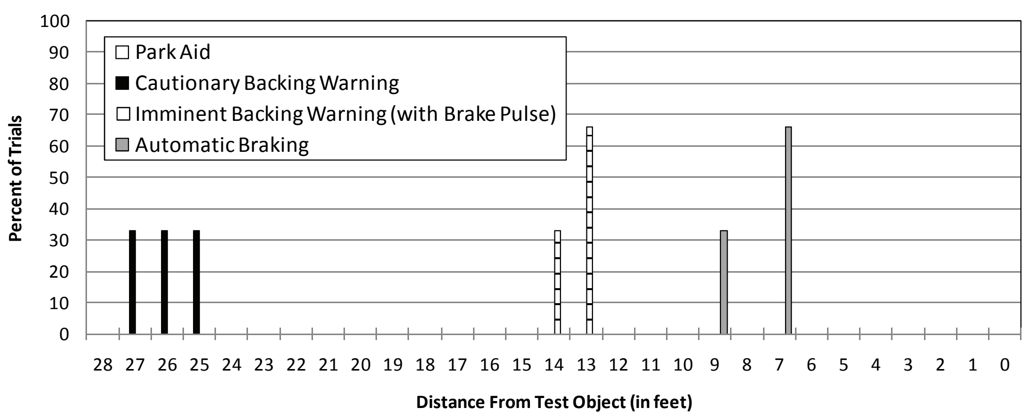
- 5-year-old standing mannequin,
- 2-year-old standing mannequin,
- 5-year-old prone mannequin, and
- Hybrid sitting mannequin.

Table 26 presents a summary of the activation distances for each test object across the three backing speed profiles. The table includes an averaged distance value (representing the arithmetic mean calculated over the observed trials) as well as minimum and maximum distance values. Note that no values were recorded for cases where the countermeasure did not activate; in these cases, the mean was calculated using only the trials where the countermeasure activated.

4 mph: PVC Pole (n = 3 trials)



8 mph: PVC Pole (n = 3 trials)



15 mph: PVC Pole (n = 3 trials)

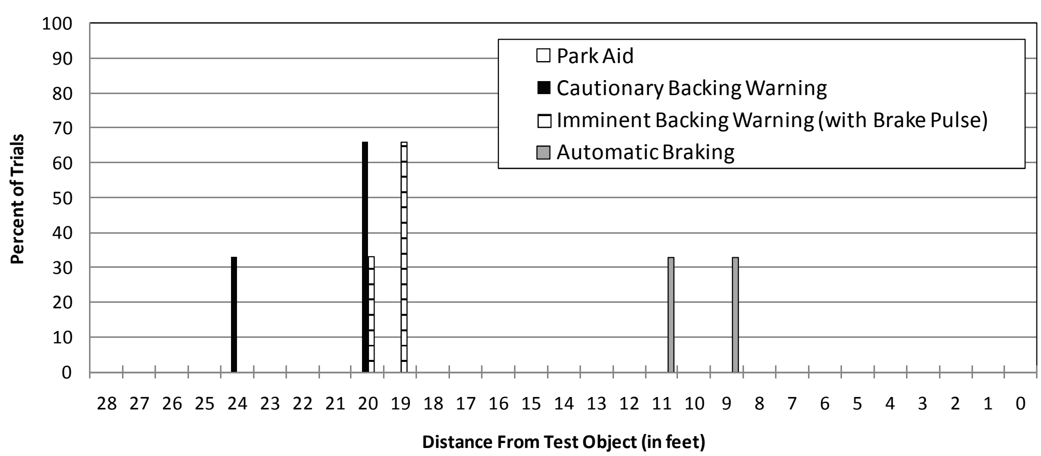


Figure 52. Distance from bumper to object at first response across backing speeds, PVC pole

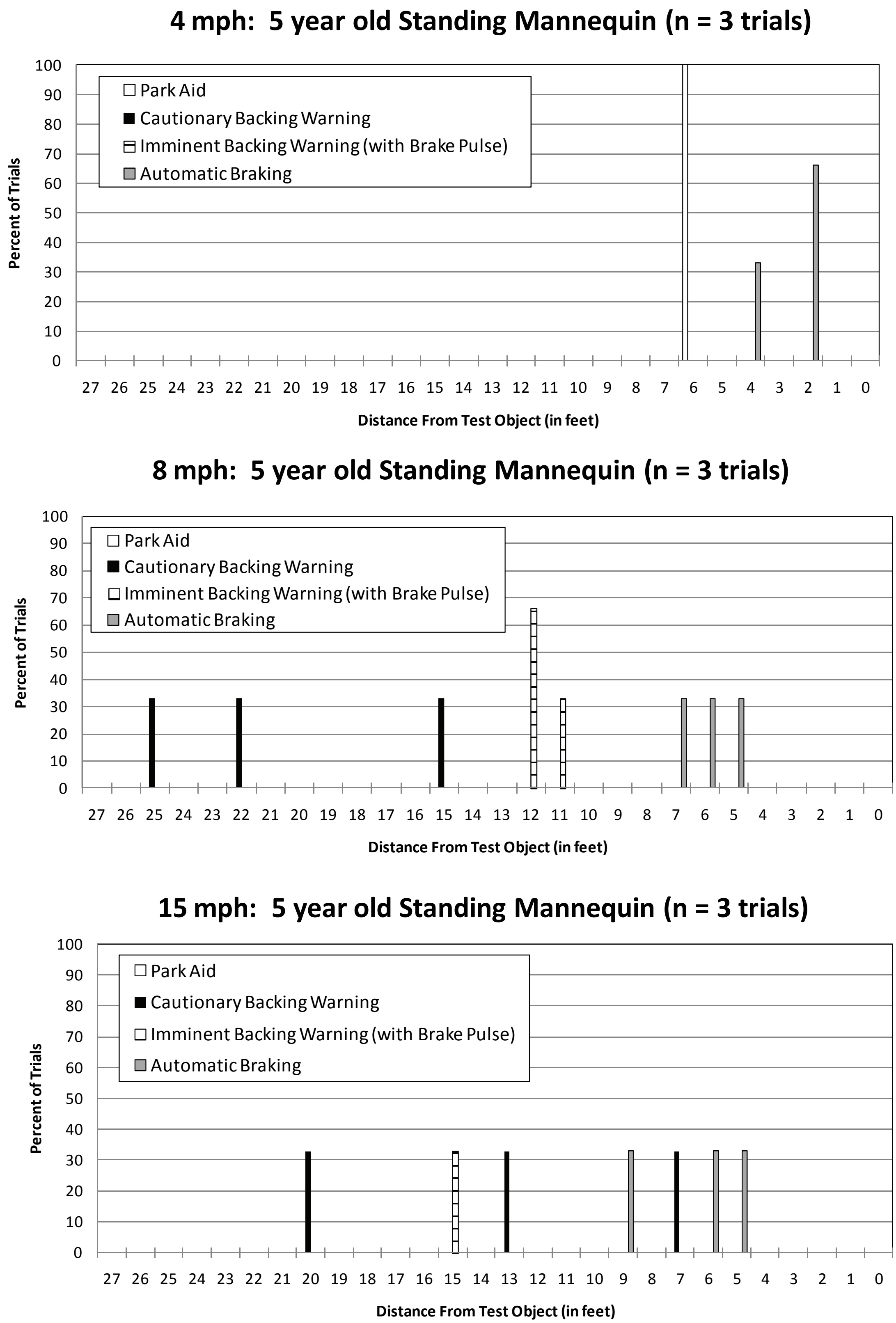


Figure 53. Distance from bumper to object at first response across backing speeds, 5-year-old standing mannequin

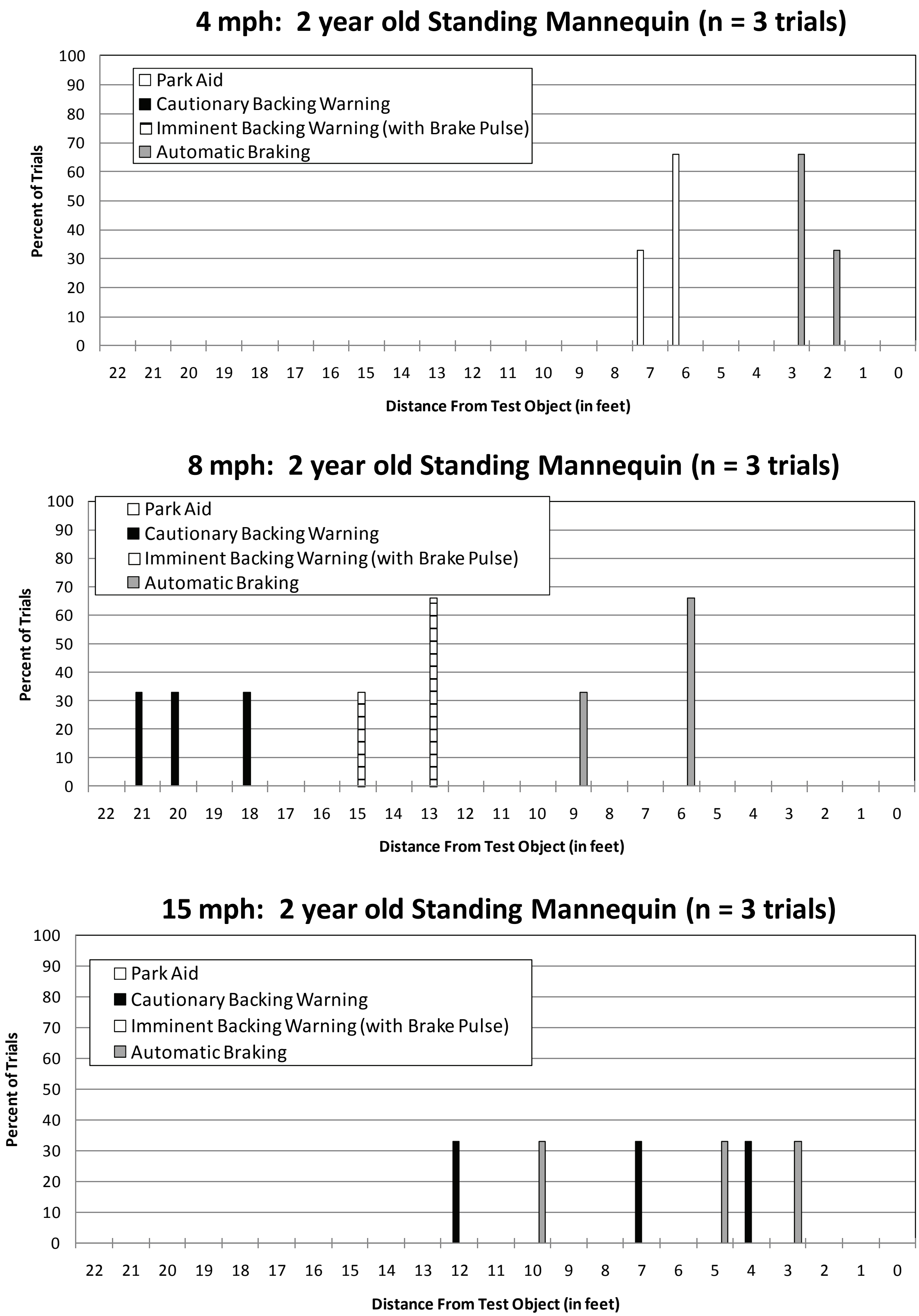


Figure 54. Distance from bumper to object at first response across backing speeds, 2-year-old standing mannequin

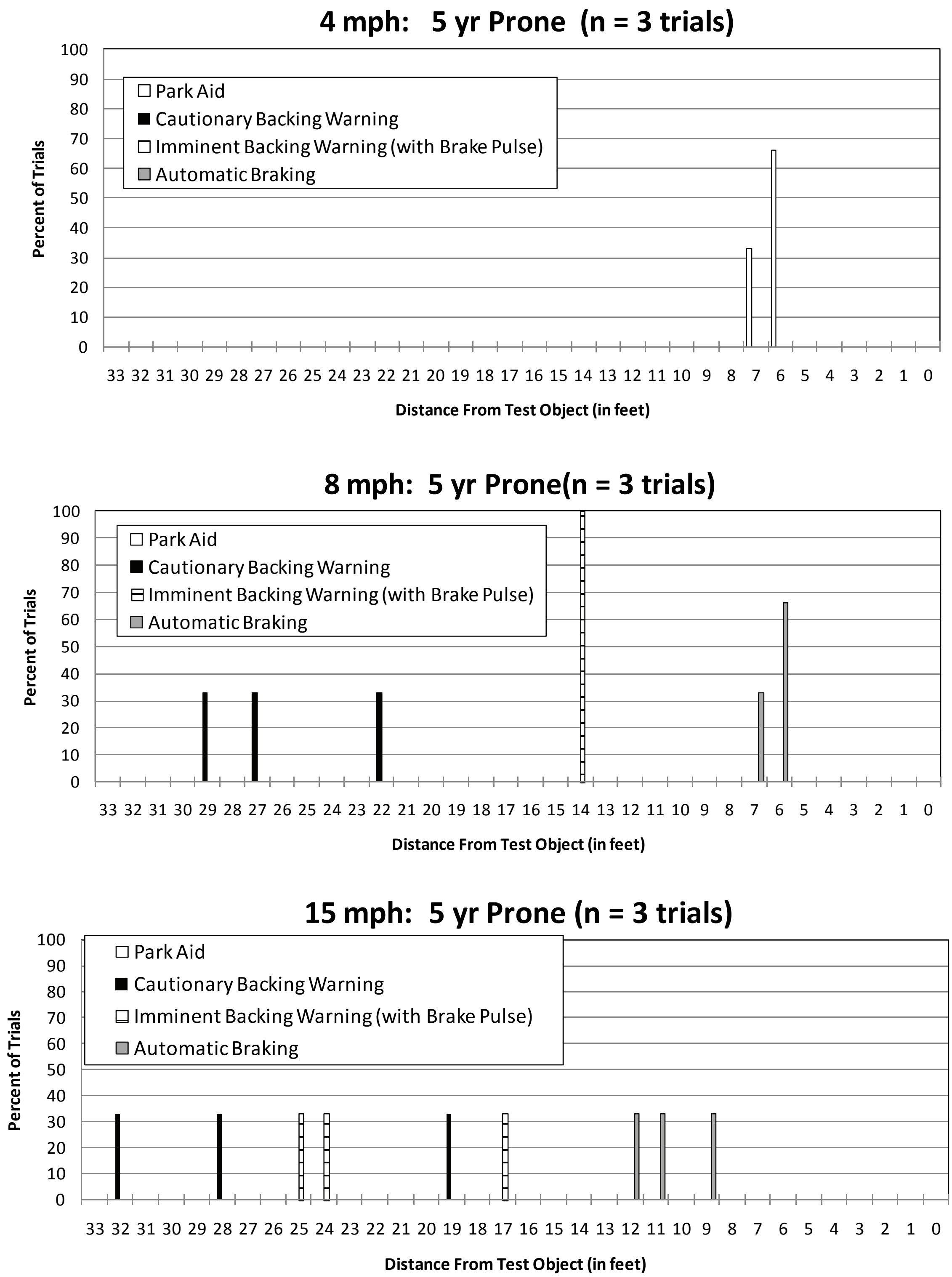


Figure 55. Distance from bumper to object at first response across backing speeds, 5-year-old prone mannequin

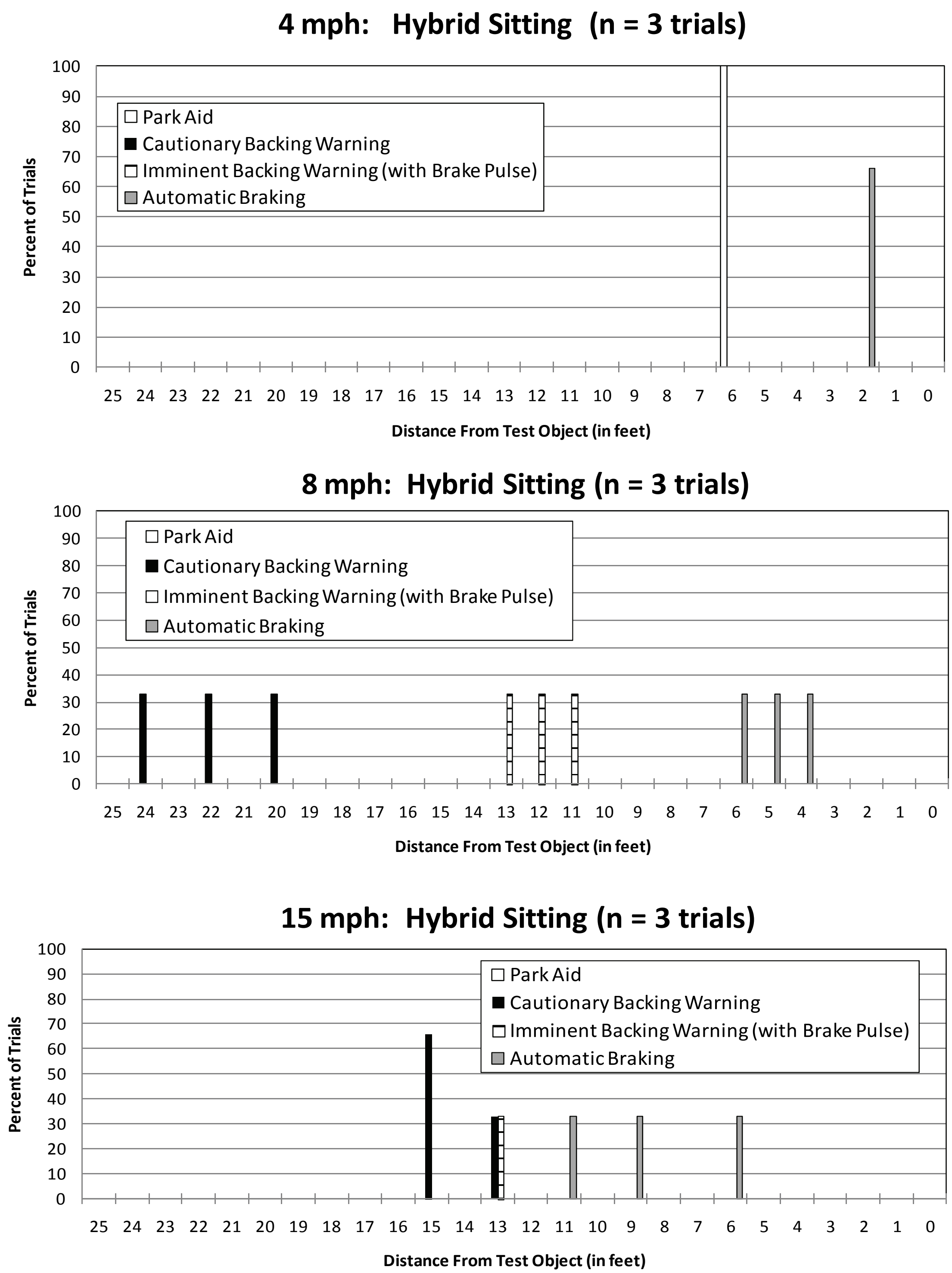


Figure 56. Distance from bumper to object at first response across backing speeds, hybrid sitting mannequin

Table 26. Distance values representing point of first response as a function of object type and backing speed (values in feet, from vehicle bumper to test object). Test 4: warning-based, dynamic longitudinal

	4 mph				8 mph				15 mph			
	Mean	Min	Max	N*	Mean	Min	Max	N*	Mean	Min	Max	N*
Park Aid												
5 yr old standing	6.3	6.3	6.3	3/3	N/A				N/A			
2 yr old standing	6.7	6.3	7.5	3/3								
Sitting	6.3	6.3	6.3	3/3								
5 yr old prone	6.7	6.3	7.4	3/3								
PVC pole	6.3	6.3	6.3	3/3								
Pooled Mean	6.5	6.3	7.5	15/15								
Cautionary Backing Warning												
5 yr old standing	N/A				20.8	15.5	24.7	3/3	13.6	7.5	20.1	3/3
2 yr old standing					19.7	17.8	21.2	3/3	7.8	4.0	12.0	3/3
Sitting					21.9	20.1	23.5	3/3	14.7	13.2	15.5	3/3
5 yr old prone					28.1	27.0	29.3	3/3	26.2	18.9	31.6	3/3
PVC pole					25.8	24.7	27.0	3/3	21.2	20.1	23.5	3/3
Pooled Mean					23.3	15.5	29.3	15/15	16.7	4.0	31.6	15/15
Imminent Backing Warning (with brake pulse)												
5 yr old standing	N/A				11.7	10.9	12.0	3/3	15.5	15.5	15.5	1/3
2 yr old standing					14.0	13.2	15.5	3/3	.	.	.	0/3
Sitting					12.0	10.9	13.2	3/3	13.2	13.2	13.2	3/3
5 yr old prone					14.3	14.3	14.3	3/3	21.6	16.6	24.7	3/3
PVC pole					13.6	13.2	14.3	3/3	19.3	18.9	20.1	3/3
Pooled Mean					13.1	10.9	15.5	15/15	18.9	13.2	24.7	10/15
Automatic Braking												
5 yr old standing	2.5	1.7	4.0	3/3	6.3	5.2	7.5	3/3	6.3	4.0	8.6	3/3
2 yr old standing	2.5	1.7	2.9	3/3	7.0	6.3	8.6	3/3	5.9	2.9	9.7	3/3
Sitting	1.7	1.7	1.7	2/3	5.2	4.0	6.3	3/3	8.6	6.3	10.9	3/3
5 yr old prone	.	.	.	0/3	6.7	6.3	7.5	3/3	10.5	8.6	12.0	3/3
PVC pole	1.7	0.6	2.9	3/3	7.8	7.5	8.6	3/3	9.7	8.6	10.9	2/3
Pooled Mean	2.1	0.6	4.0	14/15	6.6	4.0	8.6	15/15	8.1	2.9	12.0	14/15

*N = number of system activations/number of trials

6.5.6 Test 5: Warning Based, Dynamic Horizontal, Full Lock

This is one of two tests intended to assess the edge of a system's response zone for dynamically acting features (e.g., Backing Warning and Automatic Braking functions). This test specifically identifies the edge of the system's response zone (including any path prediction) by simulating backing along a continuous circular path with static test objects. It captures the system's maximum response range when backing at 5 mph along a curved path. A test driver backed the vehicle (equipped with the backing countermeasures) along a sharp curve (representing the vehicle's maximum turning radius – steering wheel at full lock position) toward five test objects. The diameter of the circle was approximately 30 ft. As shown in Figure 57, the test was performed on a circular path overlaid on the ground used to delineate the vehicle's path and to position test objects; reference marks on the path allowed precise distance measures to be derived, with a resolution of approximately 3 inches. All testing was conducted on a straight, level, dry surface under daytime conditions. Appendix A provides the detailed test procedures for conducting this assessment. Analysts marked the location at which the dynamically acting countermeasure features first responded to the test objects using captured video. Data are presented that summarize the system response probabilities under this scenario, as well as distances from the test object at the onset of the response.

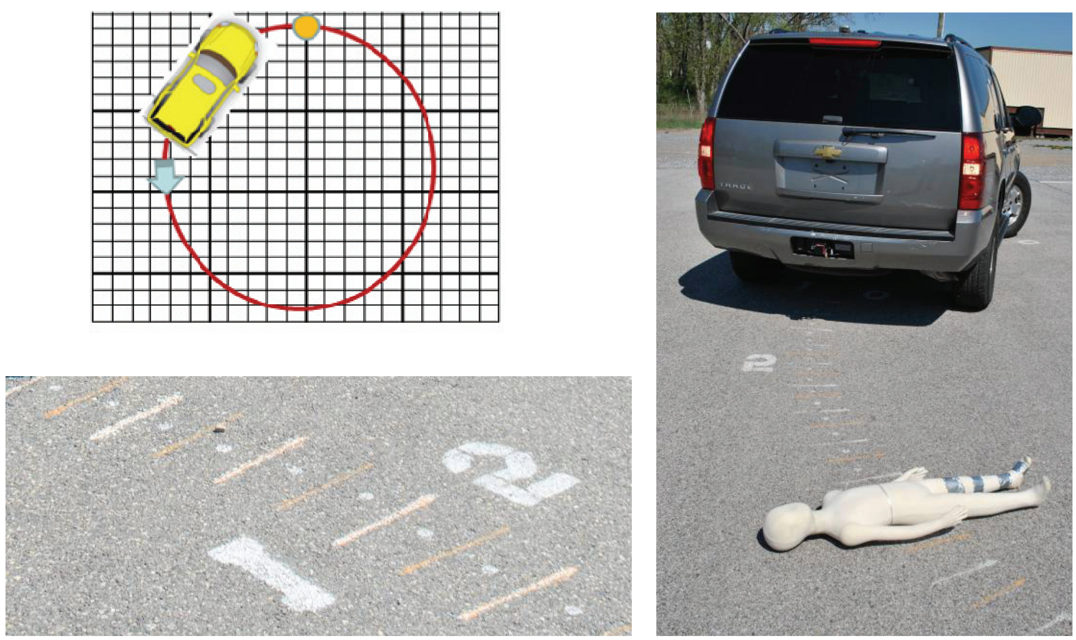


Figure 57. Illustration of the full lock test as conceptualized and implemented

In all, a total of 20 trials were run as specified below:

- 5 test objects (PVC pole, 2-year-old standing mannequin, 5-year-old standing mannequin, hybrid sitting mannequin, and 5-year-old prone mannequin),
- 1 vehicle backing speeds (5 mph, or 8 km/h), and
- 4 repetitions each (counterbalanced with 2 trials in each backing direction; clockwise and counterclockwise).

This test allows the SIM to model the system's ability to respond to test objects when backing along a curved path. Key measures extracted from the tests include the probability that a countermeasure will respond to a particular test object (response probability), as well as the distance associated with the onset of the response. Two distance measures are used to model system performance, including curve distance and straight-line distance.

Response rates were found to vary as a function of test object and countermeasure. Automatic Braking, for example, triggered in response to four out of the five test objects, with no activations for the 5-year-old prone mannequin; this test object also did not induce any system responses for the other countermeasures under these test conditions. On average, distances to test objects for Automatic Braking activation events were approximately 3.3 ft (straight-line distance, collapsed across test objects), with some variation attributable to test object type. Sections that follow provide detailed data for each countermeasure as a function of test object.

6.5.6.1 System Response Probabilities

Figure 58 presents the countermeasure activation rates in response to each test object when backing at 5mph along the curved path. With the exception of the 5-year-old prone mannequin, all test objects elicited some form of system response. The Imminent Backing Warning (with Brake Pulse) was only triggered in response to the 2-year-old standing mannequin, and only on half of the occasions (two out of the four trials). Response to the pole and standing mannequin test objects was consistent across Cautionary Backing Warning and Automatic Braking countermeasures while the hybrid sitting mannequin showed variability and the prone mannequin was not detected by any countermeasure.

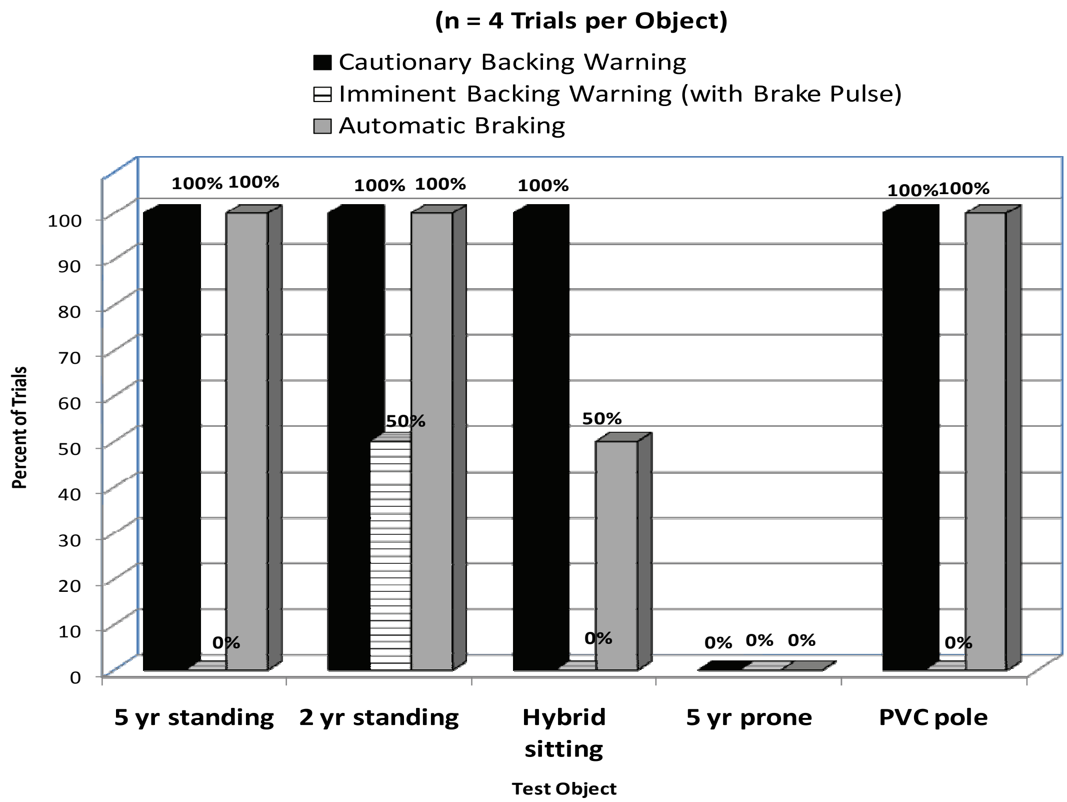


Figure 58. System activation rates under full lock at 5 mph backing speed

6.5.6.2 <u>Distance at First Response</u>

Distances to test objects at system response onset were extracted from the video using the marked points along the path; these allowed measurements to be estimated within approximately 3 inches from the vehicle bumper to the test object. Two types of distance measures were scored and represented in the SIM, and presented here. The first represents the curve distance – the length (in feet) following the perimeter of the curved path at the onset of the countermeasure. The second is the straight-line distance, representing the shortest distance or straight path to the test object from the center of the bumper. **Table 27** presents the summarized distance measurements for all triggered events and test objects showing the mean, minimum, and maximum values for both curve and straight-line measurements.

Figure 59 - Figure 62 illustrate the straight-line distance measures (shortest linear distance from the vehicle to the test object) associated with the countermeasure's first response for each of the test objects for the Full Lock test. Four trials were captured for each object with the vehicle backing at 5mph. Tables plot the response range for countermeasures, showing the percent of trials activated at given distances from the test object.

Table 27. Distance at first response for full lock, test 5. Tabled values represent linear (straight) and curve distance (in feet)

	Vehicle Backing Speed 5 mph							
	Straight Distance				Curve Distance			
	Mean	Min	Max	N*	Mean	Min	Max	N*
Park Aid								
5 yr old standing	N/A				N/A			
2 yr old standing								
Sitting								
5 yr old prone								
PVC pole								
Pooled Mean								
Cautionary Backing Warning								
5 yr old standing	3.9	2.5	5.7	4/4	4.0	2.6	5.8	4/4
2 yr old standing	7.9	4.8	12.9	4/4	8.1	4.9	13.4	4/4
Sitting	4.8	3.2	6.5	4/4	4.9	3.3	6.6	4/4
5 yr old prone	.	.	.	0/4	.	.	.	0/4
PVC pole	4.3	2.2	6.5	4/4	4.4	2.3	6.6	4/4
Pooled Mean	5.2	2.5	12.9	16/20	5.3	2.3	13.4	16/20
Imminent Backing Warning (with brake pulse)								
5 yr old standing	.	.	.	0/4	.	.	.	0/4
2 yr old standing	9.3	7.3	11.3	2/4	9.6	7.6	11.7	2/4
Sitting	.	.	.	0/4	.	.	.	0/4
5 yr old prone	.	.	.	0/4	.	.	.	0/4
PVC pole	.	.	.	0/4	.	.	.	0/4
Pooled Mean	9.3	7.3	11.3	2/20	9.6	7.6	11.7	2/20
Automatic Braking								
5 yr old standing	2.4	1.7	2.8	4/4	2.4	1.7	2.8	4/4
2 yr old standing	3.2	2.0	3.5	4/4	3.2	2.0	3.8	4/4
Sitting	2.6	1.4	3.7	2/4	2.6	1.4	3.8	2/4
5 yr old prone	.	.	.	0/4	.	.	.	0/4
PVC pole	2.6	2.2	3.2	4/4	2.7	2.3	3.3	4/4
Pooled Mean	2.7	1.4	3.7	14/20	2.7	1.4	3.8	14/20

*N = number of system activations/number of trials

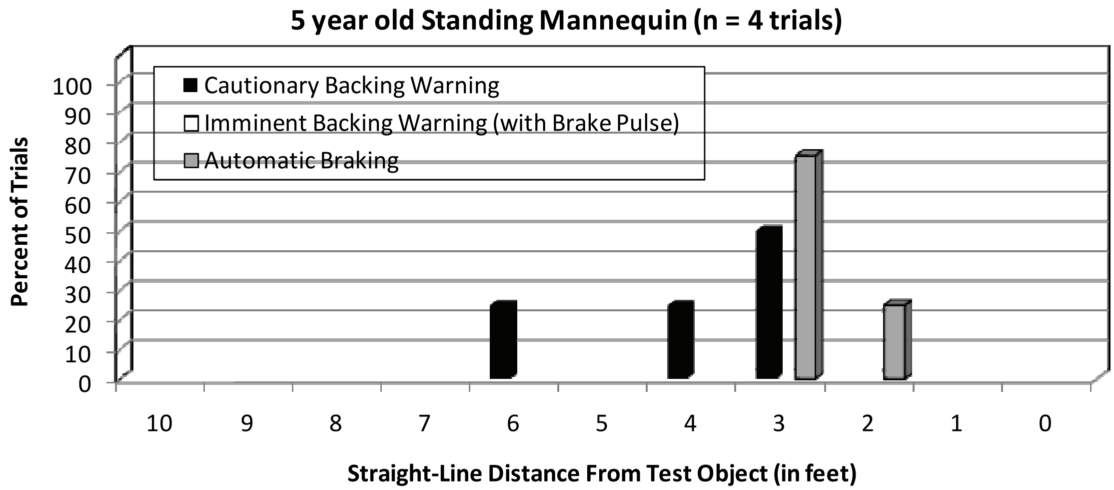


Figure 59. Straight-line distance at countermeasure onset, 5-year-old standing mannequin, full lock

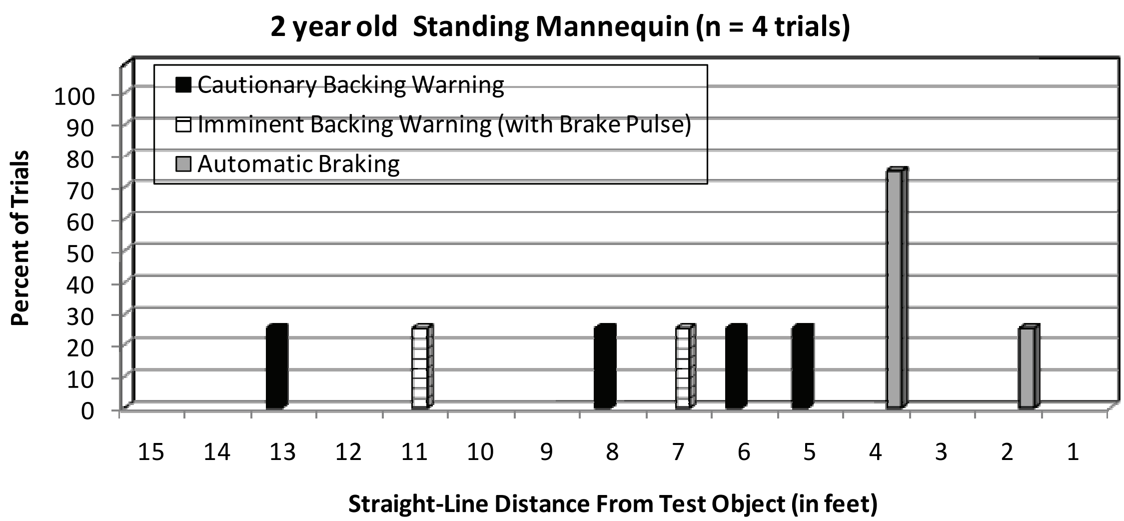


Figure 60. Straight-line distance at countermeasure onset, 2-year-old standing mannequin, full lock

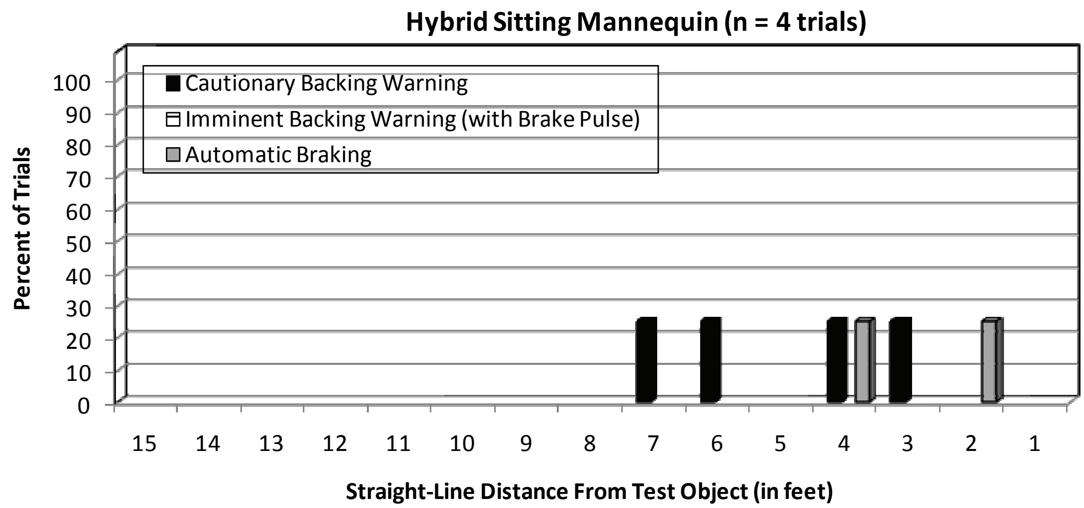


Figure 61. Straight-line distance at countermeasure onset, hybrid sitting mannequin, full lock

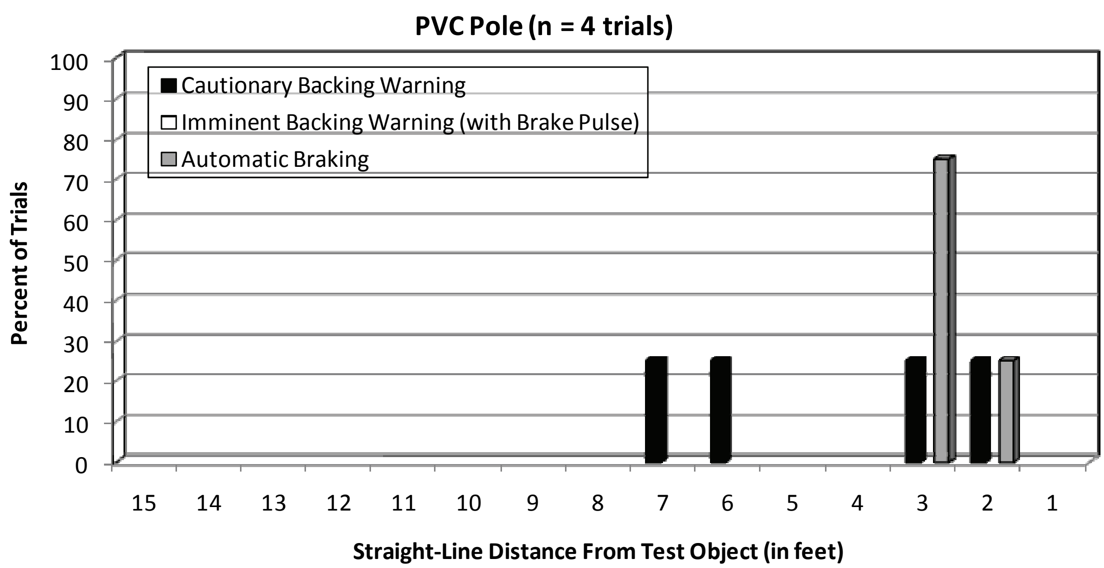


Figure 62. Straight-line distance at countermeasure onset, PVC pole, full lock

6.5.7 Test 6: Warning Based, Dynamic Horizontal, Backing Straight With Incurring Obstacles

This is one of two tests designed to assess the horizontal field of response for dynamically acting features (e.g., Backing Warning and Automatic Braking functions). This test identifies the edge of the system's response zone when backing along a straight path with incurring test objects; measurements are taken using a moving vehicle and test objects. As illustrated in Figure 63, a trained test driver backed the vehicle down an extended path (150-foot test grid) on an intersection path with a series of test objects. The test was run under several conditions including three test objects, two vehicle backing speeds (4 and 8 mph), two test object movement speeds (2 and 4 mph), and two line-of-sight conditions (unobstructed view and obstructed view which partially blocked the sensor's line-of-sight to the incurring test object). In all, a total of 48 trials were run derived from combinations of the following test conditions:

- 3 test objects (PVC pole, 2-year-old standing mannequin, 5-year-old standing mannequin),
- 2 vehicle backing speeds (4 and 8 mph; 6.4 and 12.9 km/h),
- 2 obstacle incurring speeds (2 and 4 mph; 3.2 and 6.4 km/h), and
- 2 line-of-sight conditions (clear and obstructed).

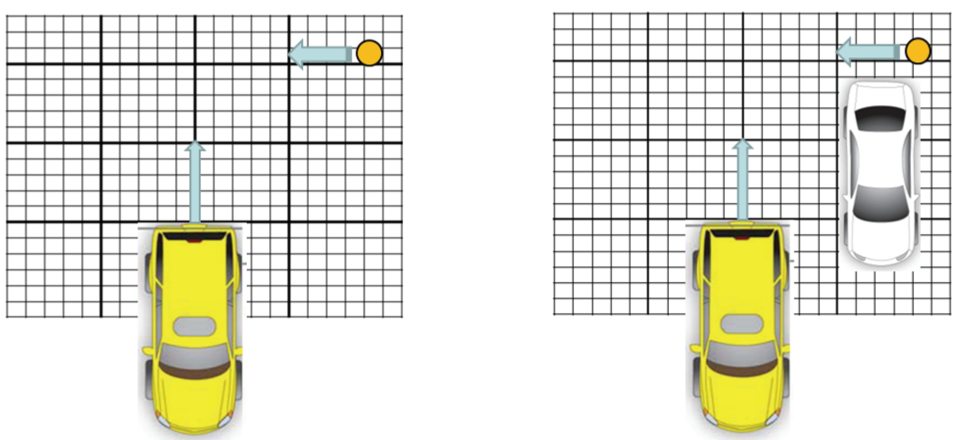


Figure 63. Test configurations illustrating clear (left panel) and obstructed (right panel) line-of-sight conditions

Test trials were staged to allow the intersection of the backing vehicle and test object to occur at the mid-point of the vehicle's bumper, allowing for some variation within a prescribed range. A trial was considered valid if the intersection path was within the vehicle's wheel base; trials outside this area were re-run.

This test is similar in concept to Test 3 (Field of Response for Incurring Obstacles) designed to assess the system's lateral detection zone, except that it uses a dynamic vehicle to map performance associated with the dynamically acting countermeasure functions. Data relating to the countermeasure's ability to respond to laterally incurring objects are mapped as a function of test object, object movement rates, and vehicle backing speeds. Performance is also modeled for two different line-of-sight (preview) conditions: one corresponding to limited preview where the line-of-sight from the vehicle sensors to the test object is obstructed, and another representing a clear, unobstructed line-of-sight. The sections that follow present detailed information relating to each countermeasure's activation rate (response probability), as well as longitudinal and lateral distance measures at the onset of the response. Both metrics are presented as a function of test object, object movement rates, vehicle backing speeds, and preview conditions.

6.5.7.1 System Response Probabilities

Data in this section present the activation rates for each of the countermeasures (Park Aid, Cautionary Backing Warning, Imminent Backing Warning, and Automatic Braking) when backing to the various test objects under different vehicle and object movement speed profiles. Performance with and without preview is also contrasted. System activation rates are illustrated in Figure 64 - Figure 67.

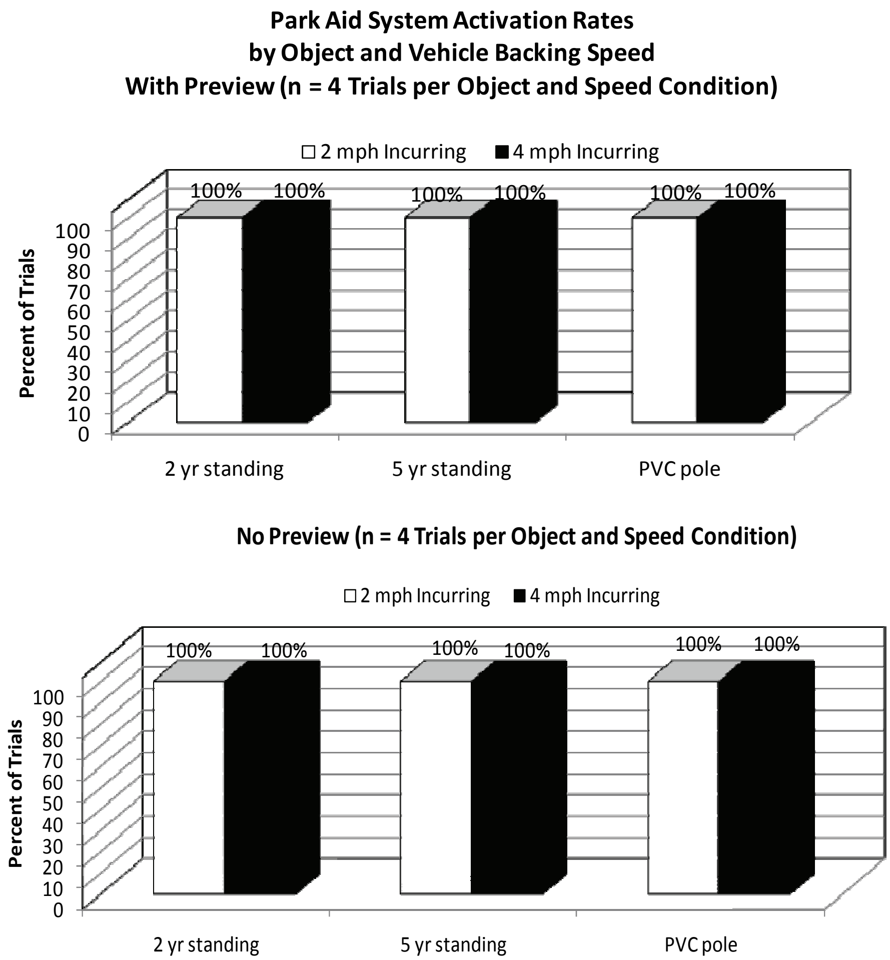
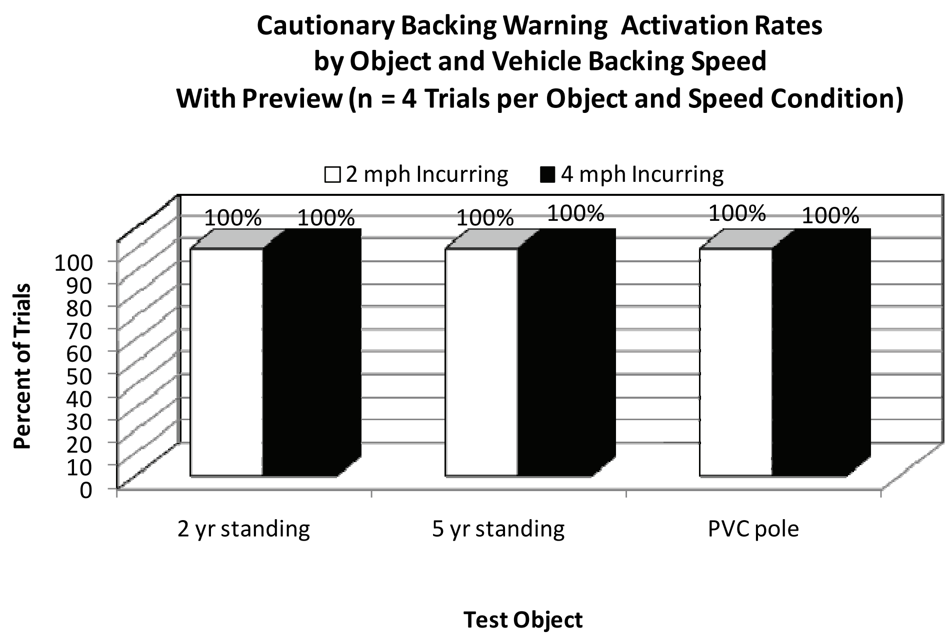


Figure 64. Park Aid activation rates with and without preview for test 6. Vehicle backing speed of 4 mph (Park Aid is not active at 8 mph)



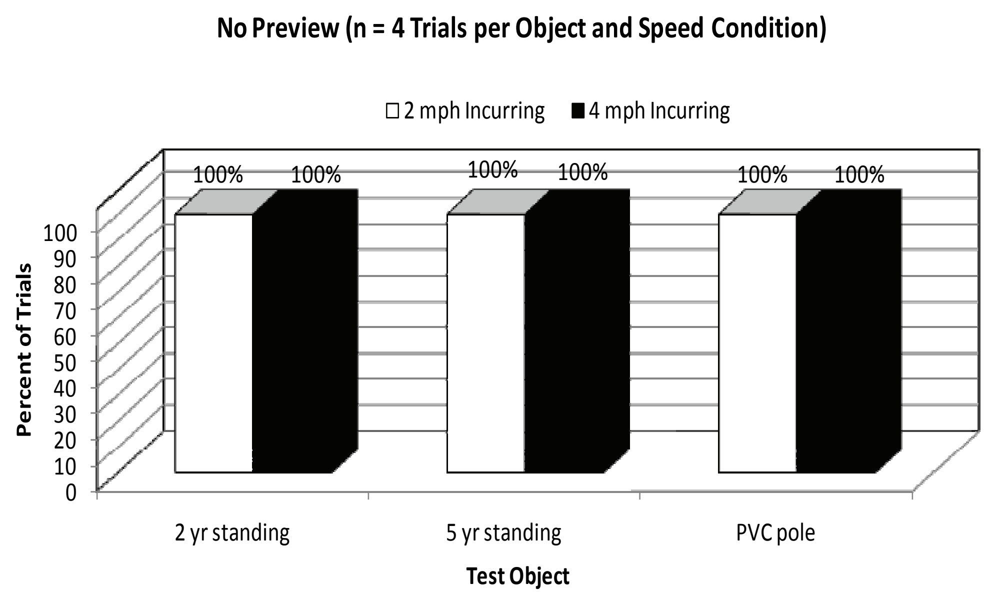
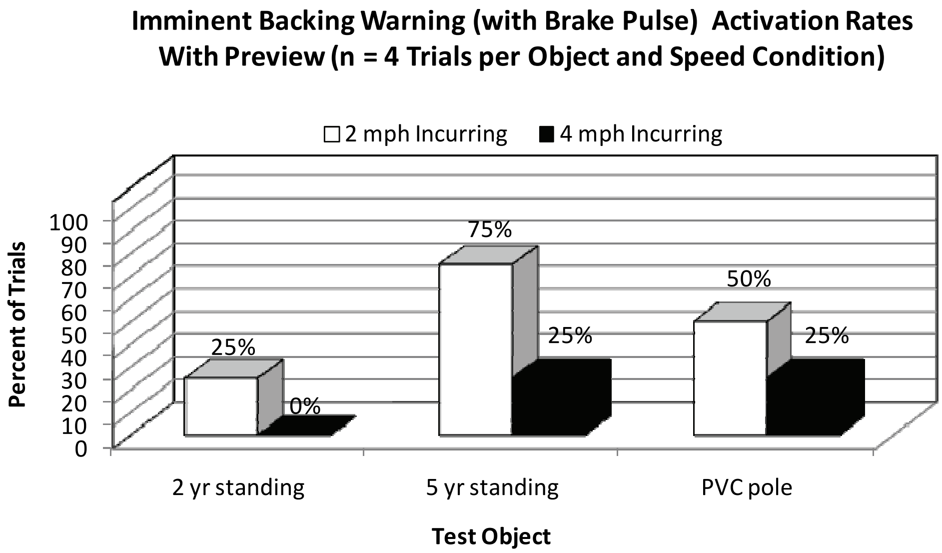


Figure 65. Cautionary backing warning activation rates with and without preview for test 6. Vehicle backing speed of 8 mph (backing warning is not active at 4 mph)



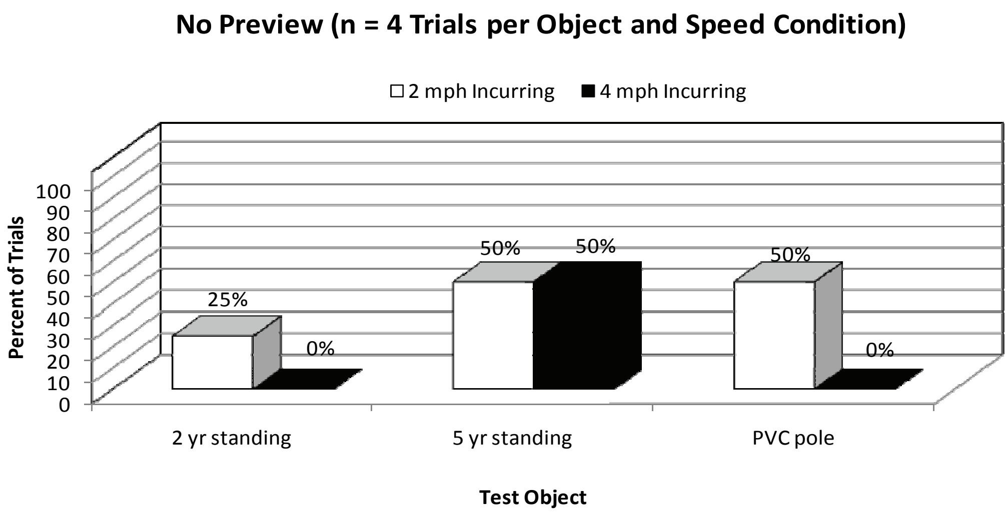
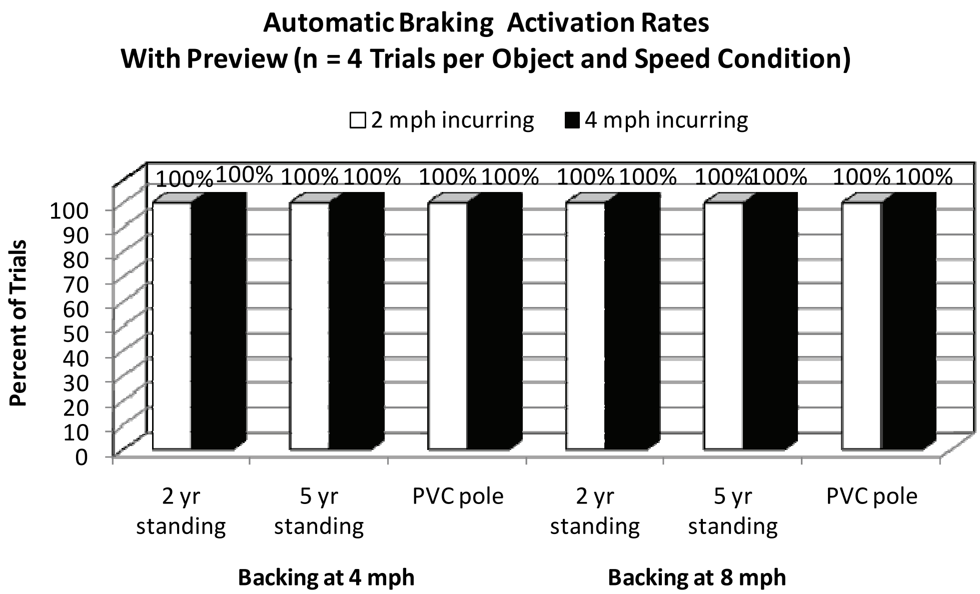


Figure 66. Imminent backing warning activation rates with and without preview for test 6. Vehicle backing speed of 8 mph (backing warning is not active at 4 mph)



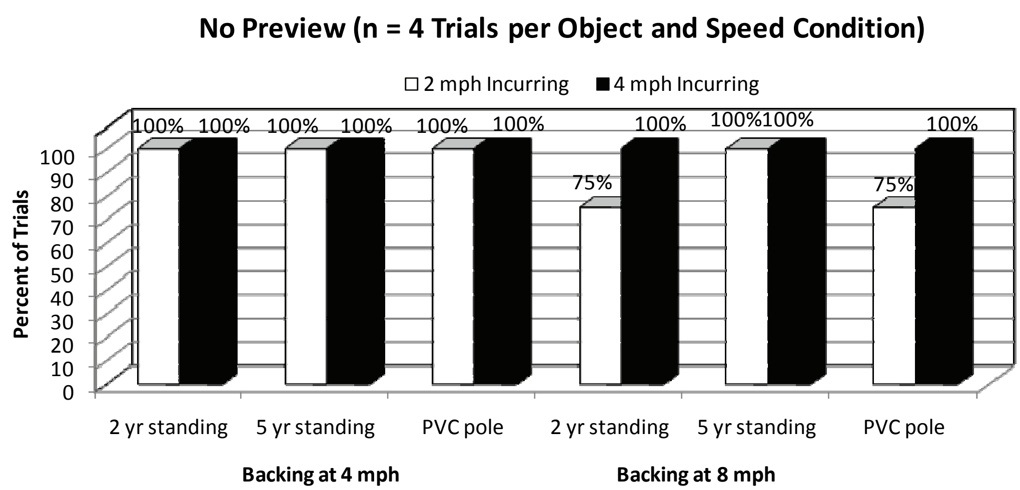


Figure 67. Automatic Braking activation rates with and without preview for test 6

Table 28 and Table 29 summarize the system activation rates for Test 6 (backing straight with incurring obstacles) as a function of test object, vehicle backing speed, and object incurring speed.

Table 28. System Activation Rates as a Function of Test Object and Vehicle Backing Speed: Object Incurring at 2 mph

Objects Incurring at 2 mph		Vehicle Backing Speeds and Object Visibility			
		4 mph		8 mph	
	N	Preview	No Preview	Preview	No Preview
5 yr old Standing					
Park Aid	4	100%	100%	.	.
Cautionary Backing Warning	4	.	.	100%	100%
Imminent Backing Warning	4	.	.	75%	50%
Automatic Braking	4	100%	100%	100%	100%
2 yr old Standing					
Park Aid	4	100%	100%	.	.
Cautionary Backing Warning	4	.	.	100%	100%
Imminent Backing Warning	4	.	.	25%	25%
Automatic Braking	4	100%	100%	100%	75%
PVC Pole					
Park Aid	4	100%	100%	.	.
Cautionary Backing Warning	4	.	.	100%	100%
Imminent Backing Warning	4	.	.	50%	50%
Automatic Braking	4	100%	100%	100%	75%

Cells with a "." denote that the countermeasure is not active under this condition

Table 29. System Activation Rates as a Function of Test Object and Vehicle Backing Speed: Object Incurring at 4 mph

Objects Incurring at 4 mph		Vehicle Backing Speeds and Object Visibility			
		4 mph		8 mph	
	N	Preview	No Preview	Preview	No Preview
5 yr old Standing					
Park Aid	4	100%	100%	.	.
Cautionary Backing Warning	4	.	.	100%	100%
Imminent Backing Warning	4	.	.	25%	50%
Automatic Braking	4	100%	100%	100%	100%
2 yr old Standing					
Park Aid	4	100%*	100%	.	.
Cautionary Backing Warning	4	.	.	100%*	100%
Imminent Backing Warning	4	.	.	0%*	0%
Automatic Braking	4	100%*	100%	100%*	100%
PVC Pole					
Park Aid	4	100%	100%	.	.
Cautionary Backing Warning	4	.	.	100%	100%
Imminent Backing Warning	4	.	.	25%	0%

*Set contained three valid trials. Cells with a "." denote that the countermeasure is not active under this condition

6.5.7.2 Distance at First Response

Two distance measures were reduced and coded for each backing event or trial, mapping the longitudinal and lateral distance from the vehicle's bumper to the test object. Figure 68 illustrates these two distance measures used to represent the 2-dimensional location of the test object relative to the vehicle at the response onset of the countermeasure. Lateral distance measures are coded relative to the leading edge of the vehicle's path, similar to the coding scheme used in Test 3, so that negative values represent lateral distances within the vehicle's path. Results are presented in Table 30 - Table 33, and break down the longitudinal and lateral response distances across test objects by vehicle backing speed, object movement speed, and line-of sight (preview versus no preview).

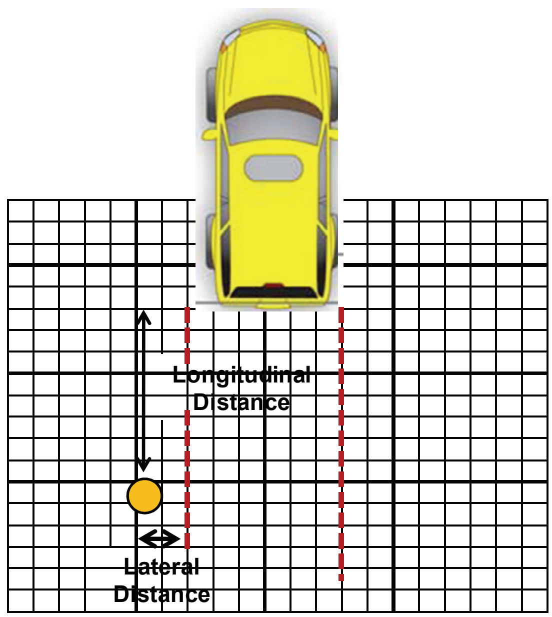


Figure 68. Illustration of Longitudinal and Lateral Distance Measures at Response Onset

Table 30. Longitudinal and Lateral Distance (in feet) at Response Onset for Each Countermeasure By Vehicle Backing Speed. With Preview, Objects Incurring at 2 mph

With Preview, Incurring at 2mph	**4 mph Backing**				**8 mph Backing**			
	Mean	Min	Max	N*	Mean	Min	Max	N*
Park Aid					N/A			
5 yr old standing								
Longitudinal	3.7	1.7	6.3	4/4				
Lateral	-2.0	-3.4	-1.1	4/4				
2 yr old standing								
Longitudinal	6.0	4.0	7.4	4/4				
Lateral	-3.4	-4.6	-1.1	4/4				
PVC pole								
Longitudinal	6.6	6.3	7.4	4/4				
Lateral	-4.0	-4.6	-2.3	4/4				
Cautionary Backing Warning	N/A							
5 yr old standing								
Longitudinal					15.8	7.4	21.2	4/4
Lateral					-2.6	-4.6	-1.1	4/4
2 yr old standing								
Longitudinal					14.9	12.0	21.2	4/4
Lateral					-3.7	-4.6	-2.3	4/4
PVC pole								
Longitudinal					14.9	6.3	23.5	4/4
Lateral					-2.9	-4.6	-1.1	4/4
Imminent Backing Warning (with brake pulse)	N/A							
5 yr old standing								
Longitudinal					15.1	13.2	16.6	3/4
Lateral					-4.6	-5.7	-2.3	3/4
2 yr old standing								
Longitudinal					10.1	9.7	10.9	3/4
Lateral					-2.7	-5.7	0	3/4
PVC pole								
Longitudinal					13.8	13.2	14.3	2/4
Lateral					-6.3	-6.9	-5.7	2/4
Automatic Braking								
5 yr old standing								
Longitudinal	1.4	0.6	1.7	4/4	7.4	6.3	8.6	4/4
Lateral	-3.7	-6.9	-2.3	4/4	-5.5	-8.0	-2.3	4/4
2 yr old standing								
Longitudinal	4.3	4.0	5.2	4/4	6.3	4.0	9.7	4/4
Lateral	-4.0	-4.6	-2.3	4/4	-5.7	-9.2	-3.4	4/4
PVC pole								
Longitudinal	2.9	1.7	4.0	4/4	5.7	4.0	7.4	4/4
Lateral	-6.0	-6.9	-4.6	4/4	-6.0	-9.2	-2.3	4/4

*N = number of system activations/number of trials

Table 31. Longitudinal and Lateral Distance (in feet) at Response Onset for Each Countermeasure By Vehicle Backing Speed. With Preview, Objects Incurring at 4 mph

With Preview, Incurring at 4 mph	**4 mph Backing**				**8 mph Backing**			
	Mean	Min	Max	N*	Mean	Min	Max	N*
Park Aid								
5 yr old standing								
Longitudinal	5.4	5.2	6.3	4/4				
Lateral	-2.6	-3.4	-1.1	4/4				
2 yr old standing								
Longitudinal	5.9	5.2	6.3	3/4				
Lateral	-3.4	-3.4	-3.4	3/4				
PVC pole								
Longitudinal	4.9	4.0	6.3	4/4				
Lateral	-2.3	-3.4	-1.1	4/4				
Cautionary Backing Warning								
5 yr old standing								
Longitudinal					11.5	6.3	18.9	4/4
Lateral					-4.0	-5.7	-2.3	4/4
2 yr old	N/A							
Longitudinal					7.8	5.2	9.7	3/4
Lateral					-4.6	-5.7	-3.4	3/4
PVC pole								
Longitudinal					11.2	7.4	15.5	4/4
Lateral					-2.9	-4.6	-1.1	4/4
Imminent Backing Warning (with brake pulse)								
5 yr old standing								
Longitudinal					15.5	15.5	15.5	1/4
Lateral					-4.6	-4.6	-4.6	1/4
2 yr old standing	N/A							
Longitudinal					.	.	.	0/4
Lateral					.	.	.	0/4
PVC pole								
Longitudinal					14.3	14.3	14.3	1/4
Lateral					-4.6	-4.6	-4.6	1/4
Automatic Braking								
5 yr old standing								
Longitudinal	4.0	2.9	5.2	4/4	6.6	4.0	9.7	4/4
Lateral	-4.3	-4.6	-3.4	4/4	-6.3	-9.2	-4.6	4/4
2 yr old standing								
Longitudinal	4.4	2.9	6.3	3/4	6.7	4.0	9.7	3/4
Lateral	-5.4	-5.7	-4.6	3/4	-5.0	-5.7	-3.4	3/4
PVC pole								
Longitudinal	2.9	1.7	4.0	4/4	8.6	7.3	10.9	4/4
Lateral	-4.0	-4.6	-3.4	4/4	-3.4	-4.6	-1.1	4/4

*N = number of system activations/number of trials

Table 32. Longitudinal and Lateral Distance (in feet) at Response Onset for Each Countermeasure by Vehicle Backing Speed. No Preview, Objects Incurring at 2 mph

No Preview, Incurring at 2 mph	4 mph Backing				8 mph Backing			
	Mean	Min	Max	N*	Mean	Min	Max	N*
Park Aid								
5 yr old standing					N/A			
Longitudinal	5.5	3.4	6.9	4/4				
Lateral	-1.7	-2.9	-1.1	4/4				
2 yr old standing								
Longitudinal	4.6	2.3	5.7	4/4				
Lateral	-3.4	-4.6	-2.3	4/4				
PVC pole								
Longitudinal	5.2	4.6	5.7	4/4				
Lateral	-2.6	-4.6	0	4/4				
Cautionary Backing Warning								
5 yr old standing	N/A							
Longitudinal					11.8	3.4	19.5	4/4
Lateral					-2.9	-3.4	-1.1	4/4
2 yr old standing								
Longitudinal					10.6	3.4	21.8	4/4
Lateral					-2.9	-4.6	-2.3	4/4
PVC pole								
Longitudinal					13.2	2.3	23.0	4/4
Lateral					-2.6	-3.4	-2.3	4/4
Imminent Backing Warning (with brake pulse)								
5 yr old standing	N/A							
Longitudinal					16.7	16.1	17.2	2/4
Lateral					-2.9	-3.4	-2.3	2/4
2 yr old standing								
Longitudinal					14.9	14.9	14.9	1/4
Lateral					-3.4	-3.4	-3.4	1/4
PVC pole								
Longitudinal					13.8	12.6	14.9	2/4
Lateral					-3.4	-4.6	-2.3	2/4
Automatic Braking								
5 yr old standing								
Longitudinal	2.9	1.1	4.6	4/4	5.7	3.4	6.9	4/4
Lateral	-3.4	-4.6	-2.3	4/4	-4.9	-5.7	-3.4	4/4
2 yr old standing								
Longitudinal	2.3	0	3.4	4/4	6.5	4.6	10.3	3/4
Lateral	-4.9	-5.7	-3.4	4/4	-5.0	-6.9	-3.4	3/4
PVC pole								
Longitudinal	2.3	1.1	3.4	4/4	6.9	5.7	8.0	3/4
Lateral	-4.0	-5.7	-1.1	4/4	-4.6	-6.9	-3.4	3/4

*N = number of system activations/number of trials

Table 33. Longitudinal and Lateral Distance (in feet) at Response Onset for Each Countermeasure by Vehicle Backing Speed. No Preview, Objects Incurring at 4mph

No Preview, Incurring at 4 mph	4 mph Backing				8 mph Backing			
	Mean	Min	Max	N*	Mean	Min	Max	N*
Park Aid								
5 yr old standing					N/A			
Longitudinal	4.9	3.4	5.7	4/4				
Lateral	-2.6	-3.4	-1.1	4/4				
2 yr old standing								
Longitudinal	3.7	2.3	5.7	4/4				
Lateral	-3.7	-4.6	-2.3	4/4				
PVC pole								
Longitudinal	2.9	2.3	4.6	4/4				
Lateral	-2.9	-3.4	-2.3	4/4				
Cautionary Backing Warning								
5 yr old standing	N/A							
Longitudinal					12.3	8.0	16.1	4/4
Lateral					-3.4	-4.6	-2.3	4/4
2 yr old standing								
Longitudinal					6.6	2.3	13.8	4/4
Lateral					-5.2	-5.7	-4.6	4/4
PVC pole								
Longitudinal					5.2	3.4	9.2	4/4
Lateral					-3.2	-3.4	-2.3	4/4
Imminent Backing Warning (with brake pulse)								
5 yr old standing	N/A							
Longitudinal					13.2	12.6	13.8	2/4
Lateral					-4.0	-4.6	-3.4	2/4
2 yr old standing								
Longitudinal					.	.	.	0/4
Lateral					.	.	.	0/4
PVC pole								
Longitudinal					.	.	.	0/4
Lateral					.	.	.	0/4
Automatic Braking								
5 yr old standing								
Longitudinal	3.2	2.3	3.4	4/4	7.5	5.7	9.2	4/4
Lateral	-4.3	-4.6	-3.4	4/4	-5.7	-6.9	-4.6	4/4
2 yr old standing								
Longitudinal	2.3	1.1	4.6	4/4	4.9	2.3	9.2	4/4
Lateral	-5.2	-5.7	-4.6	4/4	-6.3	-6.9	-5.7	4/4
PVC pole								
Longitudinal	0.9	0	2.3	4/4	2.9	1.1	5.7	4/4
Lateral	-4.3	-4.6	-3.4	4/4	-3.7	-4.6	-2.3	4/4

*N = number of system activations/number of trials

6.6 False Alarm Performance Tests

This family of tests characterizes false system activations and situations leading to these types of events. Evaluations rely on the development of a standard test course that includes opportunities for occasioning false alarms - an erroneous system activation (e.g., the system issues a backing warning when no in-path obstacle is present). High levels of false alarms may negatively impact driver acceptance and responsiveness to valid system alerts. Although the tests detailed below are intended to examine false activation behavior(s) for a given countermeasure, establishing the level of acceptable rates or the rate of exposure to these situations in real-world driving remains an open question as it will depend on individual behaviors and regional factors.

Assessments were performed by having a single test driver negotiate a “course” comprised of a series of representative backing settings and maneuvers. The procedures for designing and conducting these false alarm tests are presented in Appendix A, and prescribe a set of environmental conditions (including relevant objects and elements common to a setting) and backing maneuvers. Tests may be implemented by using a combination of real-world and artificial testing approaches which require: 1) locating existing real-world environments which adequately capture the elements of interest, as well as 2) constructing an artificial environment (part-task setting) to accurately represent the desired conditions. The goal is to adequately represent and capture system responses to known or expected elements and settings likely to trigger false alarm events.

The elements and environments detailed in these false alarm tests are derived on the basis of the best information currently available, including the SCI cases and operational experience with prototype backing crash countermeasure systems. While efforts were made to draw from a plausible range of environmental characteristics and elements commonly found in these environments, these are by no means exhaustive. The full range of potential situations and objects, as well as the base rate occurrences for these types of scenarios (i.e., the number of times any particular driver may experience these same conditions under normal usage), is unknown. Additional data are needed to understand and map the exposure rates for these specific situations. When interpreting the data, it is important to remember that these tests used a relatively stable and uniform backing speed and steering profile. In practice, drivers may moderate their backing speeds and steering profiles in ways that may increase or reduce the likelihood of false system activation (e.g., quick accelerations, or late braking). Test results are presented in the subsequent sections, and detail countermeasure performance under residential, commercial parking lot, and public street environments and settings.

Data from the False Alarm Performance tests are intended to assess the degree to which backing countermeasures falsely activate under typical operating environments. Each referenced test object or feature, described in subsequent sections, is assigned an incidence rate based on the number of backing trials in which it was observed to trigger a false activation (e.g., number of triggered trials/number of total trials). Aggregating the observed data beyond this level to derive an overall estimate of the false alarm rate for this operating environment, while desirable, may lead to inaccurate and unreliable estimates. This is because additional work is needed to establish exposure rates, including understanding the frequency with which drivers experience various operating environments as well as the range of objects and features encountered when backing. Regional variation in the driving environment and individual driving style are also likely to play a significant role in determining the incidence of false system activations.

6.6.1 Test 7: Residential Driveway

This test assessed the false alarm potential when backing down residential driveway environments in the presence of common roadside and driveway elements (test objects) to include, among other objects: bicycle, mailbox, fence, vehicle, garden hose, basketball pole, watering can, and trash can. Driveway characteristics were also evaluated, including: discontinuities in road surface (joints, cracks, potholes) as well as changes in elevation when transitioning from the driveway to the roadway. Testing was conducted using both real-world driveways which adequately captured the elements of interest, as well as artificial driveway environments to accurately represent the desired conditions (simulated environments). The procedures for staging and performing each of these tests are detailed in Appendix A; tests involve backing the vehicle to defined situations at speeds consistent with these driveway environments.

In all, 17 unique test objects/driveway elements were examined, and are summarized in Table 34. System responses were evaluated when backing in the presence of these test objects/elements under a range of situations including straight and curved driveway profiles. To ensure that evaluations captured a range of objects and elements, testing used parallel forms where feasible (multiple exemplars of a given test object), and repeated measurements over multiple trials.

Table 34. Unique Residential Driveway Objects and Features

False Alarm Test	Objects/Elements	Number Unique Cases/ Objects	Number of Test Conditions (speed, direction, etc)	Number of Repetitions (per test condition)	Number of Total Trials
Residential Driveway	Garden Hose	1	2	2	4
	Parked Car	1	2	2	4
	Adjacent Parked Vehicles	1	2	2	4
	Mail Box	1	4	2	8
	Watering Can	1	4	2	8
	Basketball Pole	1	2	2	4
	Metal Trash Can	1	4	2	8
	Ice/Snow Bank	1	2	2	4
	Bicycle	1	4	2	8
	Steep Grade	3	2	1	6
	Medium Grade	3	2	1	6
	Flat (No grade)	3	2	1	6
	Moderate Alignment Change	3	2	1	6
	Entrance Features	3	4	1	12
	Ruts	3	3	1	9
	Cracks	3	4	1	12
	Puddle	3	4	1	12
Sub Total	N= 17	N=33	N=49	N=26	N=121

6.6.1.1 False System Activations

Analysts noted the incidence of false system activations (False Alarms) for each countermeasure during these staged backing maneuvers. Figure 69 – Figure 71 present the observed False Alarm rates across each of the 17 objects and items; data are plotted across a variety of backing situations, including simulated as well as actual driveway situations. Rates were observed to vary widely from no false activations to 100%, depending on the type of test object or driveway feature, backing speed, and countermeasure. The vast majority of Backing Warnings and Automatic Braking activations occurred when backing along a curved driveway environment; however, backing over a garden hose or simulated ice/snow bank also tended to trigger false system activations.

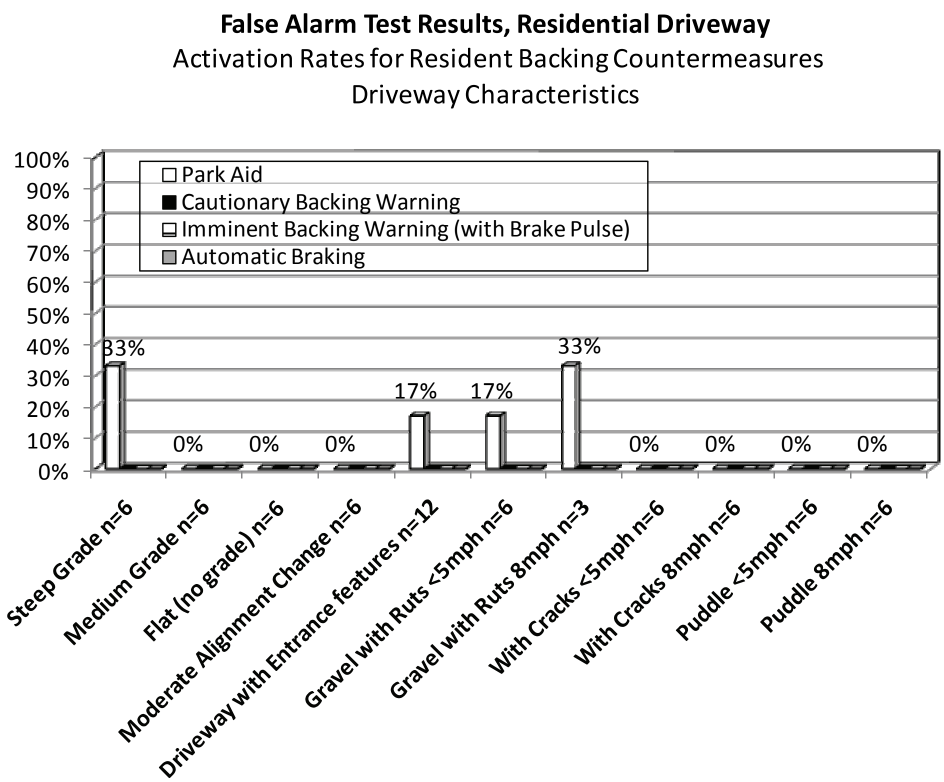
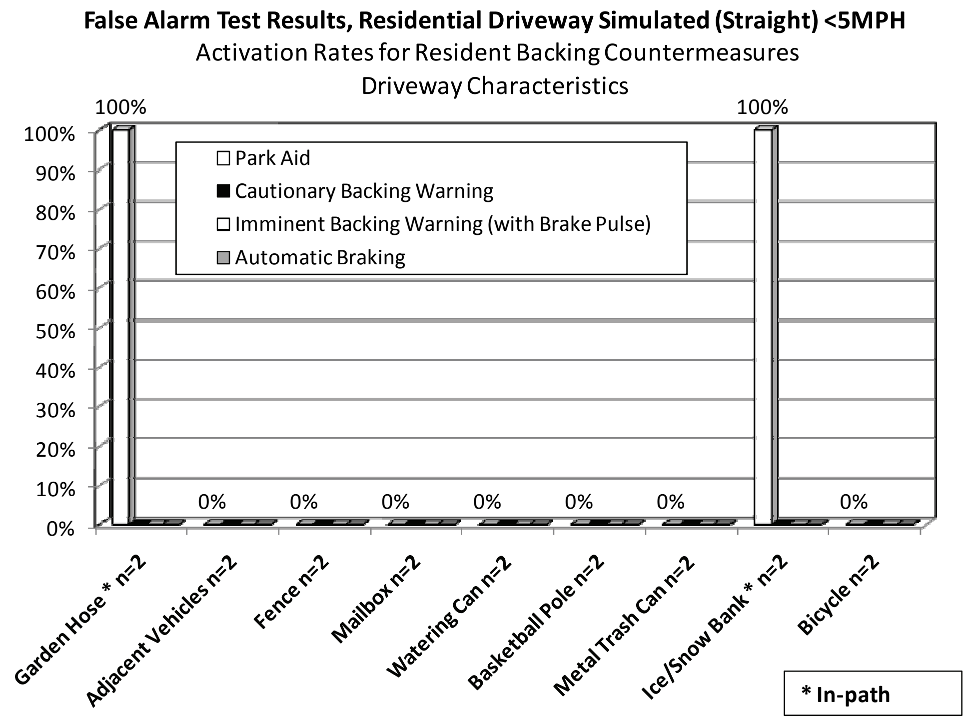


Figure 69. False System Activation Rates for Driveway Features



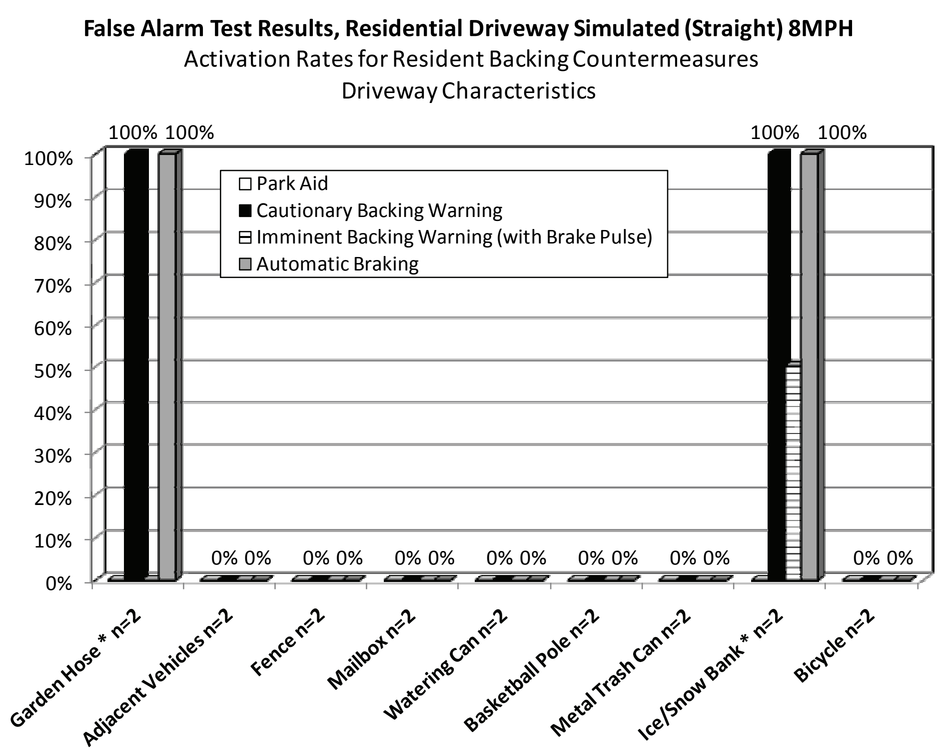
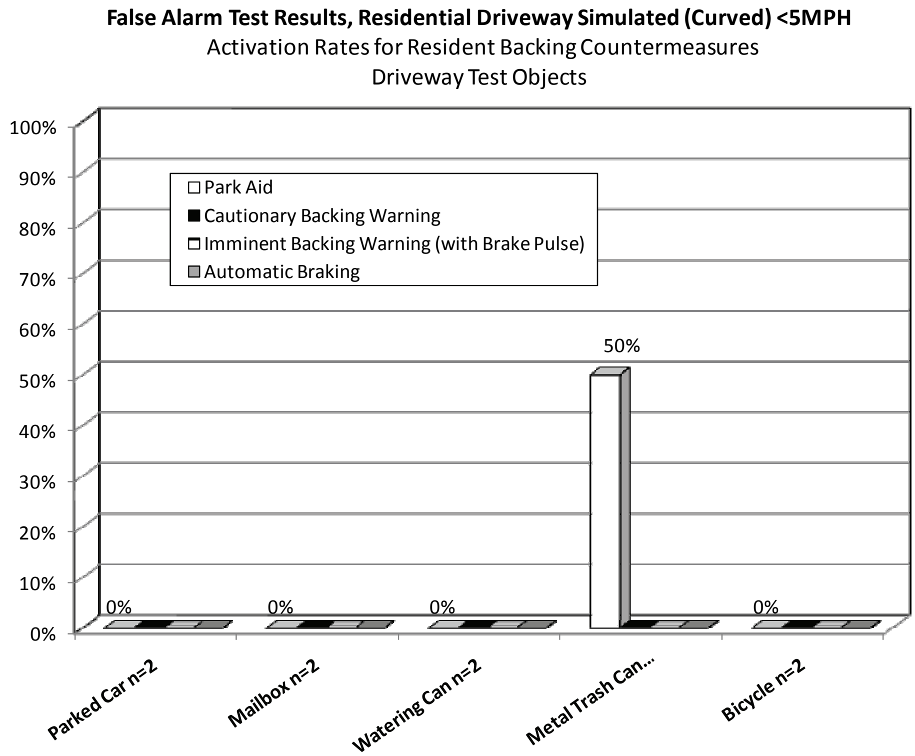


Figure 70. False System Activation Rates for Driveway Test Objects: Backing at 4 mph (top) and 8 mph (bottom) on a Straight Driveway



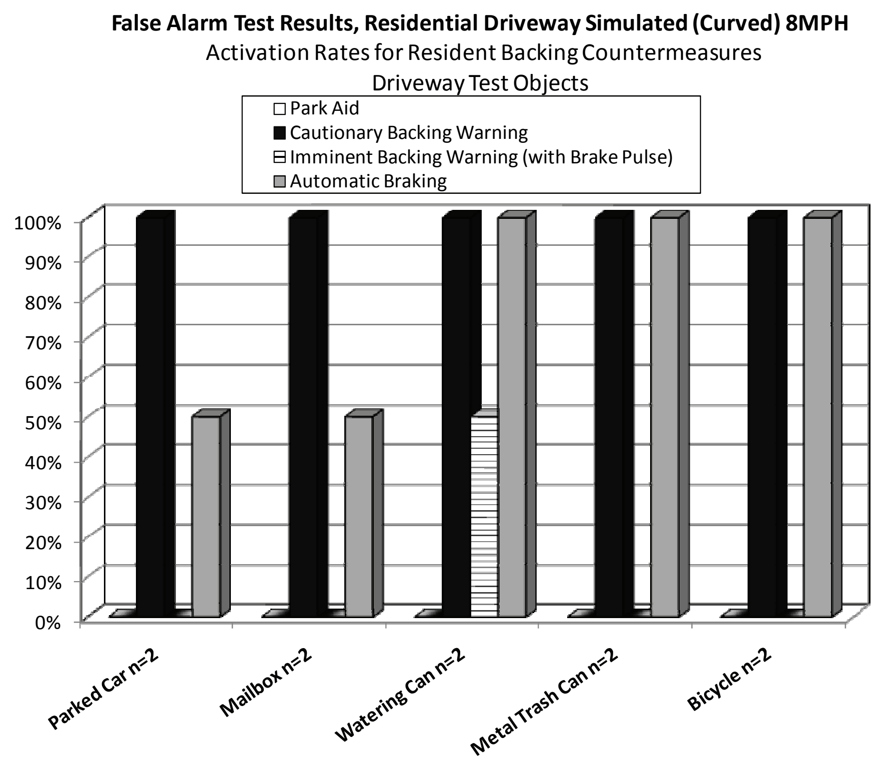


Figure 71. False System Activation Rates for Driveway Test Objects: Backing at 4 mph (top) and 8 mph (bottom) on a Curved Driveway

Table 35 summarizes the false system activation rates for driveway test objects and features as a function of backing speed and driveway environment (straight, curved, etc). These data are consolidated or aggregated across test conditions in Table 36, showing the overall false activation rates for each of the 17 unique test objects and features; these rates are collapsed across other test dimensions including vehicle backing speed and test environment.

Table 35. False System Activation Rates for Residential Driveway Test Objects and Features as a Function of Backing Speed

False Alarm Test Objects & Features	Backing at 4 mph					Backing at 8 mph				
	# of Trials	Park Aid	Cautionary Warning	Imminent Warning	Auto-Brake	# of Trials	Park Aid	Cautionary Warning	Imminent Warning	Auto-Brake
Residential Driveway										
Garden hose	2	100%	0%	0%	0%	2	0%	100%	0%	100%
Adjacent Parked Vehicles	2	0%	0%	0%	0%	2	0%	0%	0%	0%
Fence	2	0%	0%	0%	0%	2	0%	0%	0%	0%
Mail Box Straight	2	0%	0%	0%	0%	2	0%	0%	0%	0%
Mail Box Curved	2	0%	0%	0%	0%	2	0%	100%	0%	50%
Watering Can Straight	2	0%	0%	0%	0%	2	0%	0%	0%	0%
Watering Can Curved	2	0%	0%	0%	0%	2	0%	100%	50%	100%
Basketball Pole	2	0%	0%	0%	0%	2	0%	0%	0%	0%
Metal Trash Can Straight	2	0%	0%	0%	0%	2	0%	0%	0%	0%
Metal Trash Can Curved	2	50%	0%	0%	0%	2	0%	100%	0%	100%
Ice/Snow Bank	2	100%	0%	0%	0%	2	0%	100%	0%	100%
Bicycle Straight	2	0%	0%	0%	0%	2	0%	0%	0%	0%
Bicycle Curved	2	0%	0%	0%	0%	2	0%	100%	0%	100%
Parked Car Curved	2	0%	0%	0%	0%	2	0%	100%	0%	50%
Steep Grade	6	33%	0%	0%	0%	NA	NA	NA	NA	NA
Medium Grade	6	0%	0%	0%	0%	NA	NA	NA	NA	NA
Flat (no Grade)	6	0%	0%	0%	0%	NA	NA	NA	NA	NA
Moderate Alignment Change	6	0%	0%	0%	0%	NA	NA	NA	NA	NA
Entrance Features	12	17%	0%	0%	0%	NA	NA	NA	NA	NA
Gravel with Ruts	6	17%	0%	0%	0%	3	33%	0%	0%	0%
With Cracks	6	0%	0%	0%	0%	6	0%	0%	0%	0%
Puddle	6	0%	0%	0%	0%	6	0%	0%	0%	0%

Table 36. False System Activations for Residential Driveway Features Collapsed Across Backing Speed and Straight and Curved Driveways

False Alarm Test Objects & Features	Collapsed Across All Backing Speeds & Driveways (Straight & Curved)				
	# of Trials	Park Aid	Cautionary Warning	Imminent Warning	Auto-Brake
Residential Driveway					
Garden hose	4	50%	50%	0%	50%
Adjacent Parked Vehicles	8	0%	25%	0%	13%
Fence	4	0%	0%	0%	0%
Mail Box	8	0%	25%	0%	13%
Watering Can	8	0%	25%	13%	25%
Basketball Pole	4	0%	0%	0%	0%
Metal Trash Can	8	13%	25%	0%	25%
Ice/Snow Bank	4	50%	50%	0%	50%
Bicycle	8	0%	25%	0%	25%
Steep Grade	6	33%	0%	0%	0%
Medium Grade	6	0%	0%	0%	0%
Flat (no Grade)	6	0%	0%	0%	0%
Moderate Alignment Change	6	0%	0%	0%	0%
Entrance Features	12	17%	0%	0%	0%
Gravel with Ruts	9	17%	0%	0%	0%
With Cracks	12	0%	0%	0%	0%
Puddle	12	0%	0%	0%	0%

In summary, this test exposed the backing countermeasures to 17 driveway objects and elements, under different residential driveway types (straight and curved driveways) and backing speed profiles. Results found that the incidences of false system activations were sensitive to object and driveway type, including speed. For example, elements placed along the apex of a curved driveway are more likely to trigger a false activation when backing at higher speeds than when placed alongside a straight driveway.

6.6.2 Test 8: Residential Garage

This test assessed the false alarm potential when backing into and out of residential garage environments with associated elements and characteristics, including variations in the width of the opening, presence of a lip or joint at the entrance threshold, presence of a metal drainage grate near the entrance, and presence of metal garage door tracks. All tests used real-world garage environments to capture the elements of interest, with a test driver backing the vehicle into as well as out of the garage. Detailed test protocols and procedures are contained in Appendix A.

Data were collected for five unique residential garage features (listed in Table 37), with backing speeds below 5 mph. As shown in the table below, multiple cases (or exemplars) for a given garage feature or element were measured (e.g., three cases of a narrow garage bay entrance) in an attempt to capture variations within a class of features and a range of environments.

Table 37. Unique Residential Garage Features

False Alarm Test	Object/Features	Number of Unique Cases/ Objects	Number of Test Conditions (speed, direction, etc)	Number of Repetitions (per test condition)	Number of Total Trials
Residential Garage	Narrow Bay Entrance	3	2	1	6
	Wide bay	3	2	1	6
	Transition (lips or joints)	3	1	1	3
	Metal Drainage Grate	3	1	1	3
	Metal Rail Door Tracks	3	1	1	3
Sub Total	N= 5	N=15	N=7	N=5	N=21

6.6.2.1 False System Activations

Results are plotted in Figure 72 (and detailed in Table 38). Data reveal few false system activations under these conditions; only the Park Aid system was shown to trigger when backing in the presence of these objects/features. Both narrow bays (with an opening of 8 ft) and wide bays (with an opening of 10 ft) were found to occasion Park Assist responses. Metal garage door tracks were also somewhat likely to lead to false activation, occurring on approximately 33% of the trials. Backing Warning and Automatic Braking did not exhibit any false system activations under these environments.

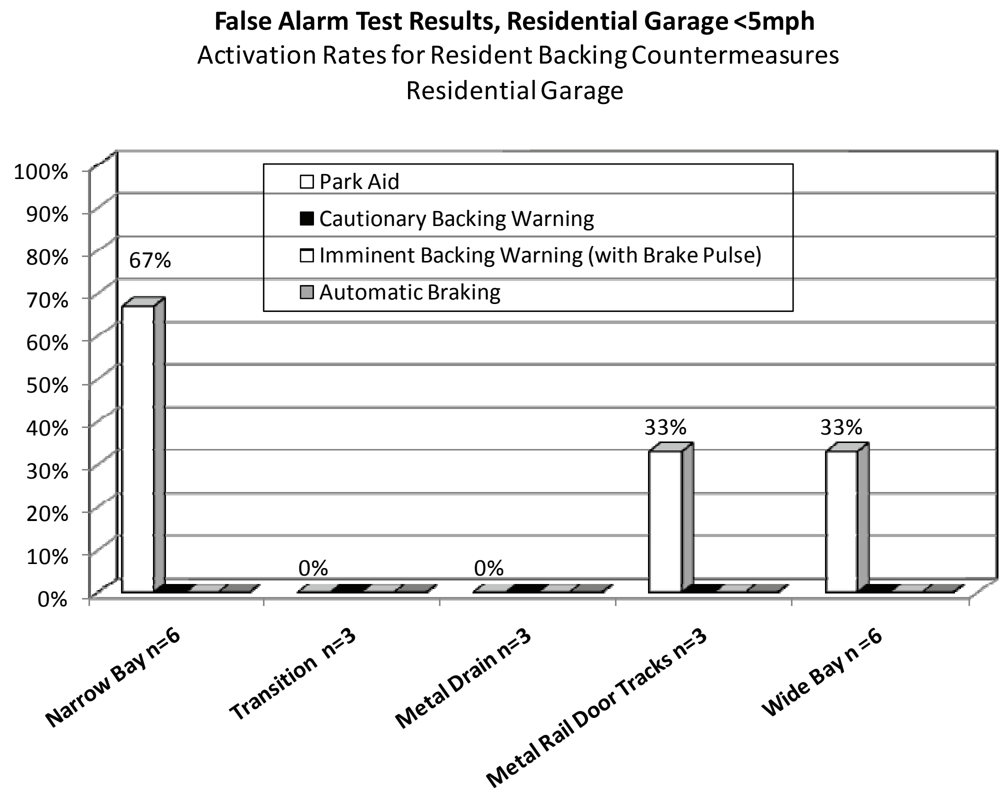


Figure 72. False System Activation Rates for Objects Sampled from Residential Garage Environments

Table 38. Observed False System Activation Rates for Residential Garage Tests

False alarm Test	Backing Speed <5mph				
	# of Trials	Park Aid	Cautionary Warning	Imminent Warning	Auto Brake
Residential Garage					
Narrow Bay	6	67%	.	.	0%
Wide Bay	6	33%	.	.	0%
Transition	3	0%	.	.	0%
Metal Drain	3	0%	.	.	0%
Metal Door Tracks	3	33%	.	.	0%

Cells with a "." denote that the countermeasure is not active under this condition and therefore chance of activation is zero

In summary, this test exposed the backing countermeasures to five unique residential garage environments when backing at speeds under 5 mph. Results found that the incidence of false system activations were limited to proximity-based (Park Aid) alert activations.

6.6.3 Test 9: Commercial Parking Lot

This test evaluates the false alarm potential when backing within a commercial parking lot environment (e.g., shopping center, mall, etc.) with elements (test objects) common to these types of situations, including: narrow parking aisles with parked vehicles, pavement markings, signs, parking barriers, metal shopping carts, cart racks, lamp posts, and speed humps. Assessments were performed using real-world parking lot environments which adequately captured the elements of interest; multiple test sites were used in order to capture the full range of test features and objects.

The vehicle was exposed to six unique features within real-world commercial parking lot environments (see Table 39); each required a trained test driver to back toward or over the object/feature noting system responses. Backing speeds were consistent with backing maneuvers typical in these environments, and were executed under 5 mph. As indicated in the table, several parallel forms of a given object/feature were selected with multiple trials to ensure reliable results. Detailed test protocols and procedures for administering these tests are contained in Appendix A.

Table 39. Unique Commercial Parking Lot Objects and Features

False Alarm Test	**Object/Features**	**Number of Unique Objects/ Cases**	**Number of Test Conditions (speed, direction, etc)**	**Number of Repetitions (per test condition)**	**Number of Total Trials**
Commercial Parking Lot	Concrete Wheel Stop	3	3*	1	8
	Vehicles in Adjacent Bay	3	4	1	12
	Speed Hump	3	1	1	3
	Painted Reflective Markings	3	1	1	3
	Shopping Cart Return (Angled and Perpendicular)	6	3*	1	15
	Sign Post	3	2	1	6
Sub Total	N= 6	N=21	N=14	N=6	N=47

* Only a subset of test conditions were feasible to run for some cases

6.6.3.1 <u>False System Activations</u>

As shown in Figure 73, results found no Backing Warning or Automatic Braking events. Park Aid was found to trigger in response to several features, including sign posts, concrete wheel stops, parked vehicles in adjacent bays, and shopping cart returns. Table 40 details the observed False Alarm rate by individual feature.

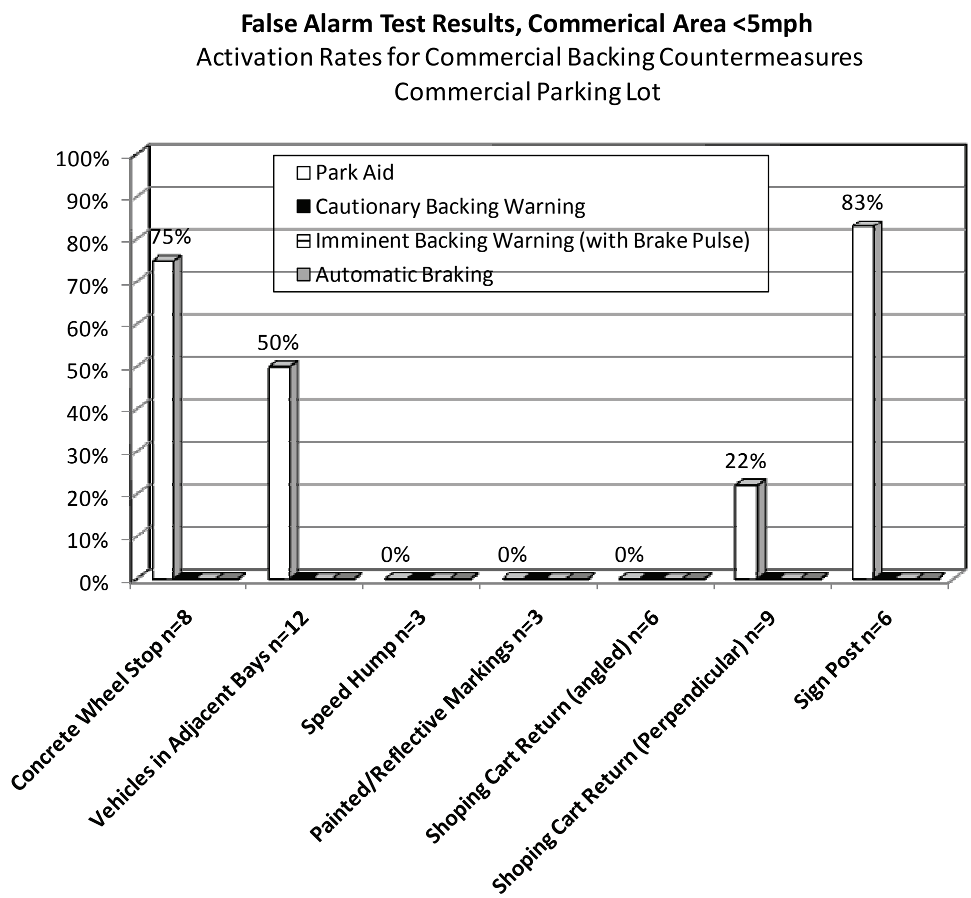


Figure 73. False System Activation Rates for Objects Sampled from Commercial Parking Lots

Table 40. Observed False System Activation Rates for Commercial Parking Lot Tests

False Alarm Test	<5mph				
	# of Trials	Park Aid	Cautionary Warning	Imminent Warning	Auto Brake
Commercial Parking Lot					
Concrete Wheel Stop	8	75%	0%	0%	0%
Vehicles in Adjacent Bay	12	50%	0%	0%	0%
Speed Hump	3	0%	0%	0%	0%
Painted Reflective Markings	3	0%	0%	0%	0%
Shopping Cart Return (angled)	6	0%	0%	0%	0%
Shopping Cart Return (Perpendicular)	9	22%	0%	0%	0%
Sign Post	6	83%	0%	0%	0%

In summary, this test exposed the backing countermeasures to six unique commercial parking lot environments when backing at speeds under 5 mph. Results found that the incidence of false system activations were limited to proximity-based (Park Aid) alert activations.

6.6.4 Test 10: Public City Street

This test assessed the false alarm potential when parking and backing in public street environments in the presence of common roadway elements (test objects) found in these settings to include: parking meters, curbs, guardrails, fire-hydrant, potholes, railroad tracks, embedded retro reflective lane markers, manhole covers, and road debris (crushed aluminum can). The approach involved locating existing real-world street settings which adequately capture the elements of interest. Test maneuvers were completed using a trained driver who parked as well as backed the vehicle in the presence of these elements. Table 41 contains a breakdown of the 12 test objects and features used to assess false alarm activations under the public city street environment. Multiple exemplars or parallel forms of a given object were used in the assessments which were executed under a variety of backing conditions (e.g., variation in vehicle backing speed, approach direction, object orientation, etc.), resulting in multiple trials for each test object/feature. Refer to Appendix A for the detailed test procedures.

Table 41. Unique Public City Street Objects and Features

False Alarm Test	Objects/Features	Number of Unique Objects/ Cases	Number of Test Conditions (speed, direction, etc)	Number of Repetitions (per test condition)	Number of Total Trials
Public City Streets	Backing to Curb	3	2	1	6
	Parking Meter	3	2*	1	5
	Fire Hydrant	2	2*	1	3
	Guardrail	2	3*	1	4
	Man Hole Cover	3	2	1	6
	Pot Hole	3	2	1	6
	Road Debris	3	6	1	18
	Overhead Sign	3	2	1	6
	Rail Road Tracks	3	2	1	6
	Narrow Alleyway	3	4	1	12
	Parking Garage Joint	3	2	1	6
	Fence	3	3*	1	7
Sub Total	N= 12	N=34	N=32	N=12	N=85

* Only a subset of test conditions were feasible to run for some cases

6.6.4.1 <u>False System Activations</u>

Observed false system activation rates for each countermeasure are plotted in Figure 74; the figure shows the variation in performance across each of the individual testing conditions. Results found that false alarm rates for Backing Warning and Automatic Braking functions were limited to higher speed situations when backing to road debris (which included backing to empty aluminum cans). The remaining activation events resulted from the Park Aid system which was found to respond to six unique test objects with false alarms rates ranging from 11% to 100% for test objects. These data are presented in Table 42 which shows the individual speeds' test conditions across test objects. Table 43 summarizes these data by collapsing across testing conditions and presents a single false alarm rate by test object.

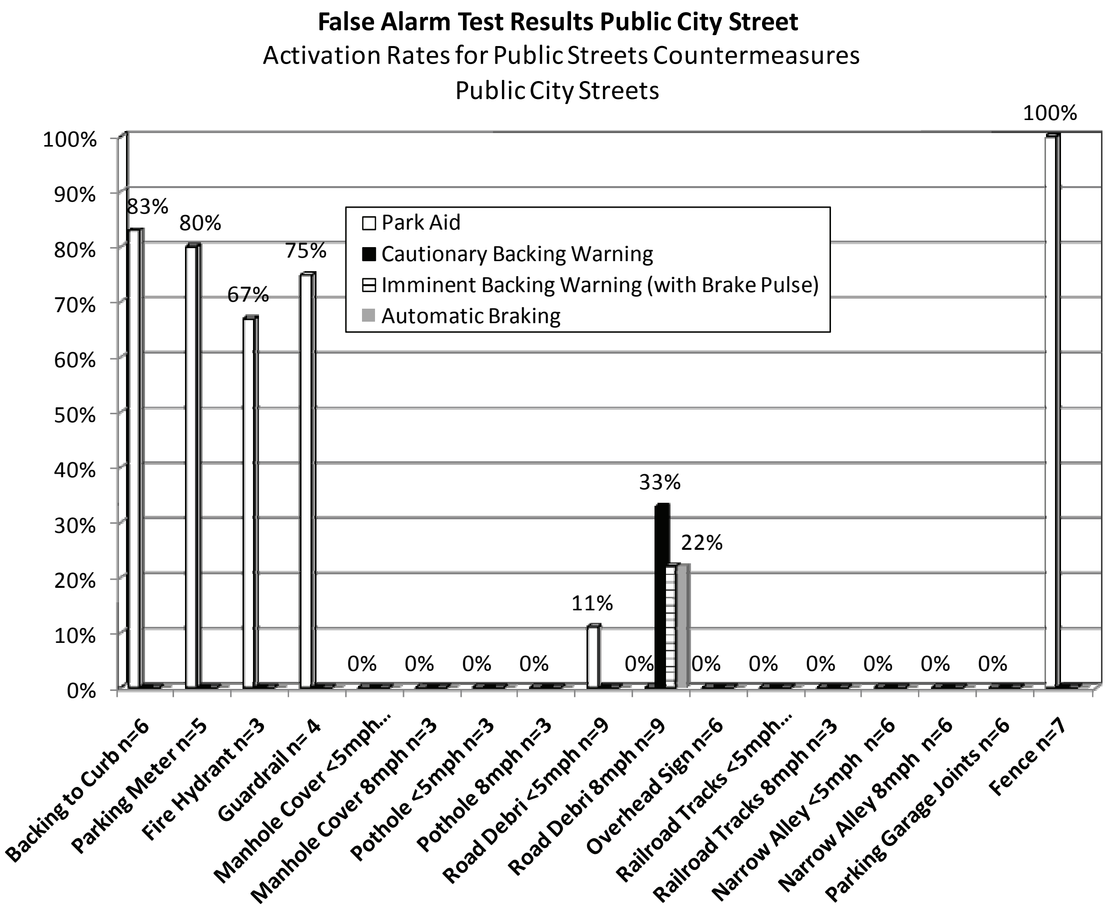


Figure 74. False System Activation Rates for Objects Sampled from Public City Street Environments

Table 42. System False Activation Rates for Sample of Objects Present in Public City Streets as a Function of Vehicle Backing Speed

False Alarm Test	<5 mph					8 mph				
	# of Trials	Park Aid	Cautionary and Imminent Warning		Auto Brake	# of Trials	Park Aid	Cautionary Warning	Imminent Warning	Auto Brake
Public City Street										
Backing to Curb	6	83%	.	.	0%	NA		NA	NA	NA
Parking Meter	5	80%	.	.	0%	NA	.	NA	NA	NA
Fire Hydrant	3	67%	.	.	0%	NA	.	NA	NA	NA
Guardrail	4	75%	.	.	0%	NA	.	NA	NA	NA
Manhole Cover	3	0%	.	.	0%	3	.	0%	0%	0%
Pothole	3	0%	.	.	0%	3	.	0%	0%	0%
Road Debris	9	11%	.	.	0%	9	.	33%	22%	22%
Overhead Sign	6	0%	.	.	0%	NA	.	NA	NA	NA
Railroad Tracks	3	0%	.	.	0%	3	.	0%	0%	0%
Narrow Alley	6	0%	.	.	0%	6	.	0%	0%	0%
Parking Garage Joints	6	0%	.	.	0%	NA	.	NA	NA	NA
Fence	7	100%	.	.	0%	NA	.	NA	NA	NA

Table 43. System False Activation Rates For Public City Street Features Collapsed Across Vehicle Backing Speeds

False Alarm Test	Collapsed Across All Backing Speeds				
	# of Trials	Park Aid	Cautionary Warning	Imminent Warning	Auto Brake
Public City Street					
Backing to Curb	6	83%	0%	0%	0%
Parking Meter	5	80%	0%	0%	0%
Fire Hydrant	3	67%	0%	0%	0%
Guardrail	4	75%	0%	0%	0%
Manhole Cover	6	0%	0%	0%	0%
Pothole	6	0%	0%	0%	0%
Road Debris	18	6%	17%	11%	11%
Overhead Sign	6	0%	0%	0%	0%
Railroad Tracks	6	0%	0%	0%	0%
Narrow Alley	12	0%	0%	0%	0%
Parking Garage Joints	6	0%	0%	0%	0%
Fence	7	100%	0%	0%	0%

In summary, this test exposed the backing countermeasures to 12 unique public city street environments when backing at various speeds. Results found that the incidence of false system activations were primarily limited to proximity-based (Park Aid) alert activations, with the exception of backing to road debris which also triggered dynamically acting countermeasures (i.e., Backing Warning and Automatic Braking).

6.7 Driver-In-The-Loop Performance

Driver-in-the-Loop tests characterize the performance of the driver when interacting with the system across a variety of conflict situations. Unlike the Grid tests, Driver-in-the-Loop tests are not meant to assess the system's response performance. Rather, these tests yield measures of driver responsiveness to the information, warnings, and control assistance provided by the backing countermeasures. These tests characterize driver performance with the system.

Tests were administered in five different scenarios encompassing pedestrian, vehicle, and fixed-object crash scenarios, and were derived from the set of 10 ACAT crash scenarios. As shown in Figure 75, three of the scenarios involve a stationary test object, and two involve a moving or incurring pedestrian. The Driver-in-the-Loop tests emphasize pedestrian-related crashes (with three represented scenarios), including the most frequently occurring pedestrian crash scenarios as revealed by the SCI cases (e.g., Pedestrian 3).

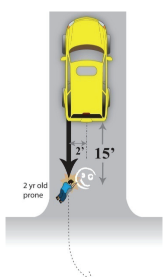
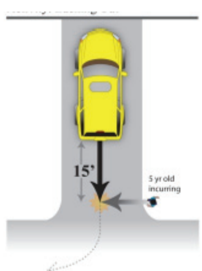
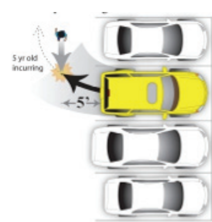
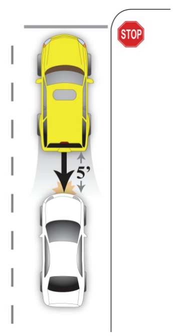
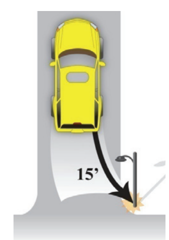
				
Scenario 3 (Pedestrian 3)	**Scenario 4 (Pedestrian 4)**	**Scenario 5 (Pedestrian 5)**	**Scenario 7 (Vehicle 1)**	**Scenario 10 (Fixed Object)**

Figure 75. Illustration of Driver-in-the-Loop Test Scenarios

Unlike the other testing approaches, Driver-in-the-Loop tests require the use of individuals recruited from the larger population of drivers. Special considerations were required for staging and executing these types of tests, including delineating specifications for the amount of practice or exposure each driver is to have with the countermeasures, driver demographics (age, gender, driving history, etc.), experience and familiarity with production backing aids and associated countermeasures, as well as setting the stage for the level of driver expectancy and the predictability of events. Levels and ranges of these participant factors are detailed below as executed during the Driver-in-the-Loop tests:

- Participants ranged in age from 30 to 65 years based on driver demographics associated with backing crashes.
- Participants had no prior experience with warning-based backing countermeasures, or rear vision systems, in order to allow for uniform levels of training and experience to be achieved

across drivers during the testing sessions. Practice opportunities were provided to allow drivers to access and use the Park Aid and Rear Vision Systems during 12 backing tasks prior to the Driver-in-the-Loop test.

- Participants recruited for these tests were informed about the Rear Vision and Park Aid backing countermeasures, but not the Backing Warning or Automatic Braking features. This strategy was presumed to result in a "worst case" scenario, allowing initial responses and behaviors of relatively unfamiliar users to be modeled. This approach is expected to provide relatively conservative estimates of system effectiveness. Future testing protocols can expand upon this work and contribute to the database and SIM by generating performance models representative of more experienced system users.

6.7.1 Test 11: Intermediate, Static Pedestrian (Scenario 3)

This Driver-in-the-Loop test simulated a backing crash scenario wherein a driver backs the vehicle in the presence of an unknown small child who is prone 4.5 meters (15 ft) behind the vehicle (Pedestrian Scenario 3). Testing was performed with a group of nine drivers (ages 32 to 64 years) recruited from the general driving public; each owned a large SUV, comparable in size to the test vehicle (a 2008 Chevrolet Tahoe), and had no previous experience with Park Aid or Rear Vision features. Drivers were provided opportunities to experience the Park Aid and Rear Vision system features during a series of 12 backing and parking practice trials performed as part of a vehicle familiarization phase preceding the surprise conflict scenario. Drivers were not informed of the existence of the Backing Warning or Automatic Braking features of the vehicle, nor did they experience these features during practice. This section summarizes the scenario-specific protocols used to stage and execute this conflict situation and the test results, highlighting key performance measures of relevance to the SIM. The prescriptive, standardized objective test protocols for this scenario are presented in Appendix A.

6.7.1.1 Scenario Site Characteristics

Test conditions were mapped to the Pedestrian Scenario 3 conflict situation in which a test object (representative of a 2-yr old child) was placed 15 ft behind the vehicle (located 2 ft off-center towards the driver's side) in a driveway-like environment requiring drivers to back down a designated path. As shown in Figure 76, the actual staged environment was comparable to the target conflict scenario. Note that use of a standing 2-year-old mannequin was substituted for the prone 2-year-old child. In this case, the standing 2-year-old served as a functionally similar surrogate to the prone child since both were not visible to drivers at this location either in the mirrors or via direct glances.

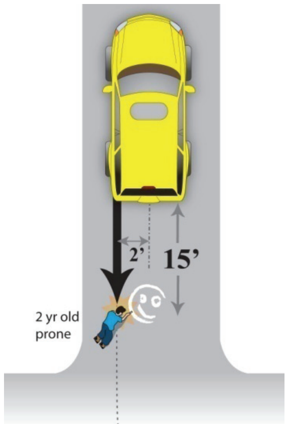


Figure 76. Pedestrian Scenario 3: Intermediate, Static Pedestrian, as Conceptualized (Left) and Realized (Right)

Several strategies were used to promote and reinforce the expectation for pedestrian traffic, including parking the vehicle in front of the main entrance to VTTI, a location with moderate pedestrian traffic, and exposing all drivers to a staged pedestrian who walked by the driver's side of the vehicle and entered the building just as they were preparing to back the vehicle.

6.7.1.2 Scenario Staging and Driver Instructions

As specified in the test protocols, all testing was conducted on a straight, level, dry surface under daytime conditions. Test conditions were designed to capture and elicit representative driver behaviors without necessarily focusing on the vehicle's backing countermeasures. It was necessary to enhance the object's sensor signature to allow more reliable performance and ensure that the full range of countermeasure features would be activated by the test object (note that the Grid tests provide an accurate measure of countermeasure sensor performance). Participants were instructed that the purpose of the study was to solicit impressions and comments regarding a variety of vehicle features, convenience devices, and aids. Although Park Aid and Rear Vision were among these aids, drivers were initially introduced to a variety of devices including advanced radio features, OnStar, and Adaptive Cruise Control (ACC), among others. Drivers were first provided opportunities to experience and comment on the parking features (Park Aid and Rear Vision) during 12 practice trials, with the expectation that they would undergo similar opportunities to experience and evaluate the other previously described devices and aids. Pilot testing found that some limited exposure to Park Aid and Rear Vision features is important in order to eliminate and/or reduce potential novelty effects which may otherwise lead drivers to artificially focus or overly rely on these new features.

The session was interrupted immediately following assessments of the backing aids by injecting a ruse which necessitated participants to drive back to the main entrance (where they initially accessed the vehicle), park, and exit the vehicle in order to complete a "previously neglected" questionnaire; this was in fact a deliberate oversight intended to get drivers to exit the vehicle and allow experimenters to set up the surprise event conflict scenario. Drivers were led to believe they would be heading out to a local area highway to experience the ACC system once they returned to the vehicle. As participants exited the building and approached the vehicle, accompanied by the experimenter, they were instructed to back the vehicle to an open parking space so they could leave the complex in preparation to test the ACC system. It is important to note that drivers had already backed down this same driveway at the beginning of the session with no incident. The surprise event conflict scenario was injected during this second backing event using this “get in and go” approach which had drivers walk to the vehicle (approaching from the front) and back down the driveway much as they would in a typical driveway setting. As drivers entered the vehicle, a research assistant surreptitiously placed the 2-year old mannequin in the appropriately marked location 15 ft behind the vehicle’s bumper. Driver interactions with the backing countermeasures were video recorded as they backed the vehicle under this staged conflict scenario. Once the conflict scenario was completed, drivers were immediately de-briefed following the procedures and question paths detailed in Appendix C in order to attempt to gauge their understanding of the event and reliance on the backing countermeasures.

6.7.1.3 Participants

This Driver-in-the-Loop test recruited nine drivers ranging from 32 to 64 years of age. All were licensed drivers who owned and routinely drove a large SUV comparable in size to the test vehicle; drivers also had no previous exposure to Park Aid or Rear Vision systems. Sample characteristics are detailed in Table 44.

Table 44. Driver Age and Gender Characteristics for Pedestrian Scenario 3

Driver Gender	N	Mean Age	Min Age	Max Age
Males	5	50	38	63
Females	4	50	32	64
Total	**9**	**50**	**32**	**64**

6.7.1.4 Results

Overall Avoidance & Detection

Results of the Pedestrian 3 conflict scenario found that all drivers (100%, or 9 out of 9) were able to successfully avoid the in-path obstacle; as described in subsequent sections, data suggest that this result is due to the availability of backing countermeasure features, including automatic braking. Detection rates (using analyst coding judgments) also suggest that while the vast majority of drivers were able to spot the in-path hazard in the Rear Vision system, some drivers never actually detected the obstacle, yet they remained stopped. This suggests that drivers who did not detect the obstacle exercised some level of trust in the system by remaining stopped without necessarily confirming the existence of an obstacle. As illustrated in Figure 77, while 78% of drivers (7 out of 9) managed to detect the obstacle during the course of the scenario, approximately 22% of drivers (2 out of 9) did not detect or confirm the presence of the hazard. Nevertheless, these two drivers remained stopped rather than continue backing.

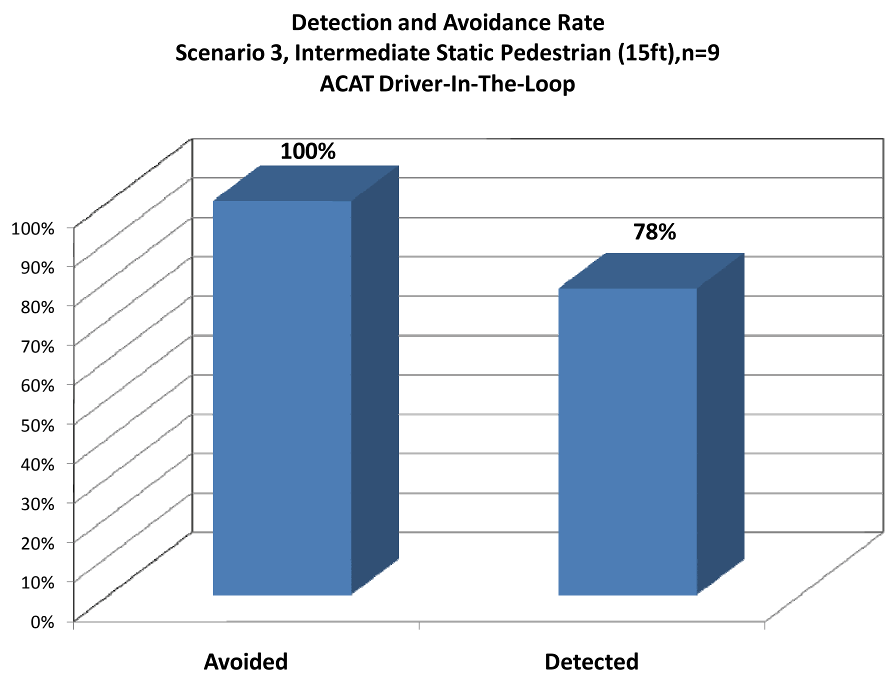


Figure 77 Avoidance and Detection Rates for Pedestrian Scenario 3

As presented above, nearly 78% of drivers (7 out of 9) in this scenario detected the rear pedestrian object at some point during the conflict. The time-course of detection is illustrated in Figure 78, and indicates that approximately 22% of drivers were judged to have spotted the hazard before backing (via the Rear Vision system), with an additional 11% detecting the pedestrian object in the Rear Vision display while backing. Approximately 45% of drivers (4 out of 9) detected the hazard after receiving the Automatic Braking countermeasure. This countermeasure generally cued drivers to search the Rear Vision display. As revealed in subsequent discussions, obstacle detection did not always result in a disruption of the backing sequence (an aborted backing maneuver); one driver continued backing despite having detected something before backing.

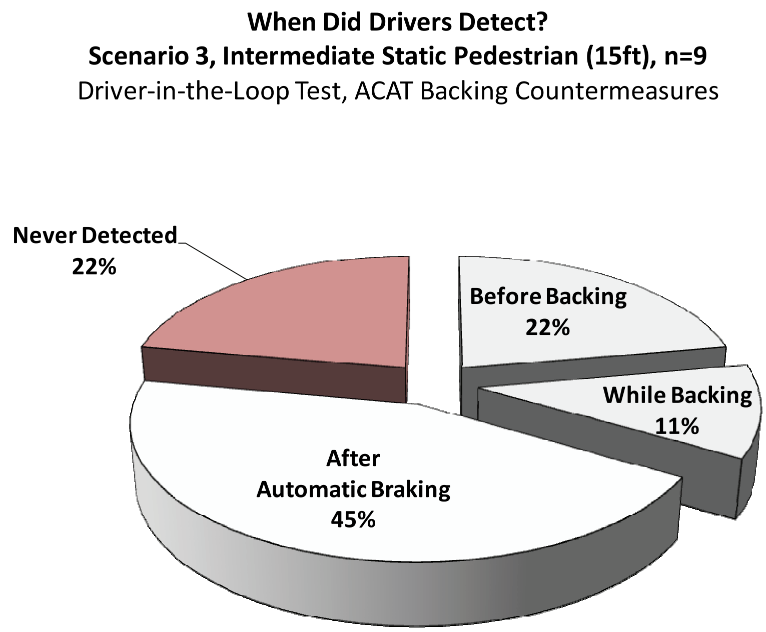


Figure 78. Detection Rates as a Function of Backing Phase

Countermeasure Activations

The test-bed vehicle afforded drivers an integrated suite of backing countermeasures comprised of Rear Vision, Park Assist, Backing Warning, and Automatic Braking. As a group, drivers were observed to exercise nearly all of these features under this backing scenario with the exception of Backing Warning which was never activated (the backing warning feature is only active at backing speeds above 4mph). Data are presented here which show the extent to which features were exercised by plotting the "highest" countermeasure received by drivers as a group. As described in Appendix B (Variable Coding Data Dictionary) the "highest" countermeasure represents the most intrusive or urgent level of intervention received by drivers (information, alert, warning, or active control assist); the approach views the available countermeasures along a continuum with Rear Vision representing the lowest form of intervention and Automatic Braking offering the highest level of intervention. This chart shows the progression through the backing countermeasures hierarchy (but does not necessarily assume drivers received each feature). As depicted in Figure 79, one driver (11%, or 1 out of 9) stopped in response to information gathered from the Rear Vision system alone. However, the vast majority of drivers (78%, or 7 out of 9) backed until the Automatic Braking feature was triggered. Activation of Automatic Braking also suggests that, in many cases, drivers did not access or act on information provided by the Rear Vision and/or Park Aid systems.

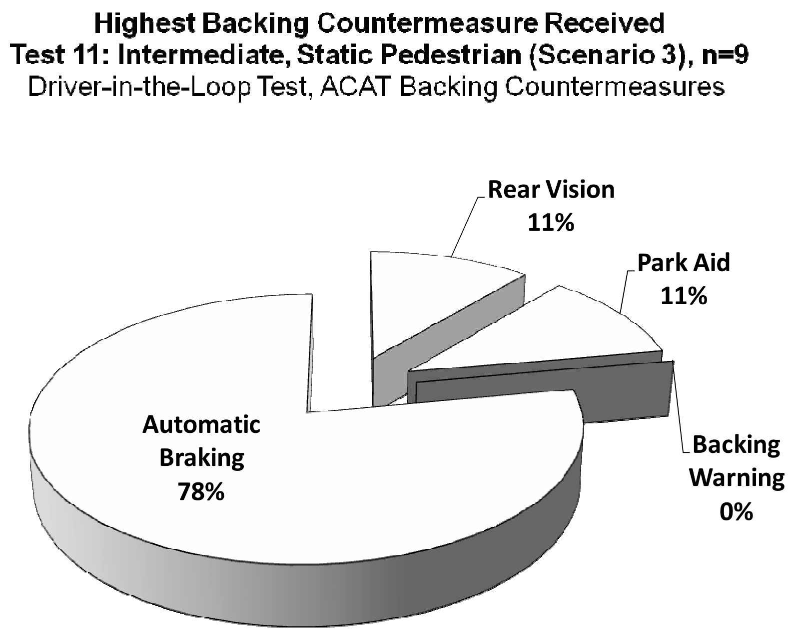


Figure 79. Highest Backing Countermeasure Received, Pedestrian Scenario 3

Search Behavior & Glances to Rear Vision System

Analysts reviewed and scored the video to determine driver glance patterns during this conflict scenario, including the incidence of glances to the Rear Vision system display located on the dash above the center console area. In all, over the course of the backing event, 78% of drivers (7 out of 9) were observed to make at least one glance to the Rear Vision system; 2 drivers (22%, or 2 out of 9) did not glance to the Rear Vision system during the event (these are the same two drivers noted previously who were judged as failing to detect the obstacle). Figure 80 breaks down the incidence of glances to the Rear Vision display as a function of maneuver phase – before backing, during backing, or following Automatic Braking. Relatively few drivers (33%, or 3 out of 9) scanned the Rear Vision display before the onset of the Automatic Braking: 22% of drivers scanned the Rear Vision Display before backing (2 out of 9), and 13% (1 out of 8) while backing. Half of drivers tested (50%, or 4 out of 8) glanced to the Rear Vision system following activation of the Automatic Braking feature, enabling the cause of the braking to be identified and/or confirmed.

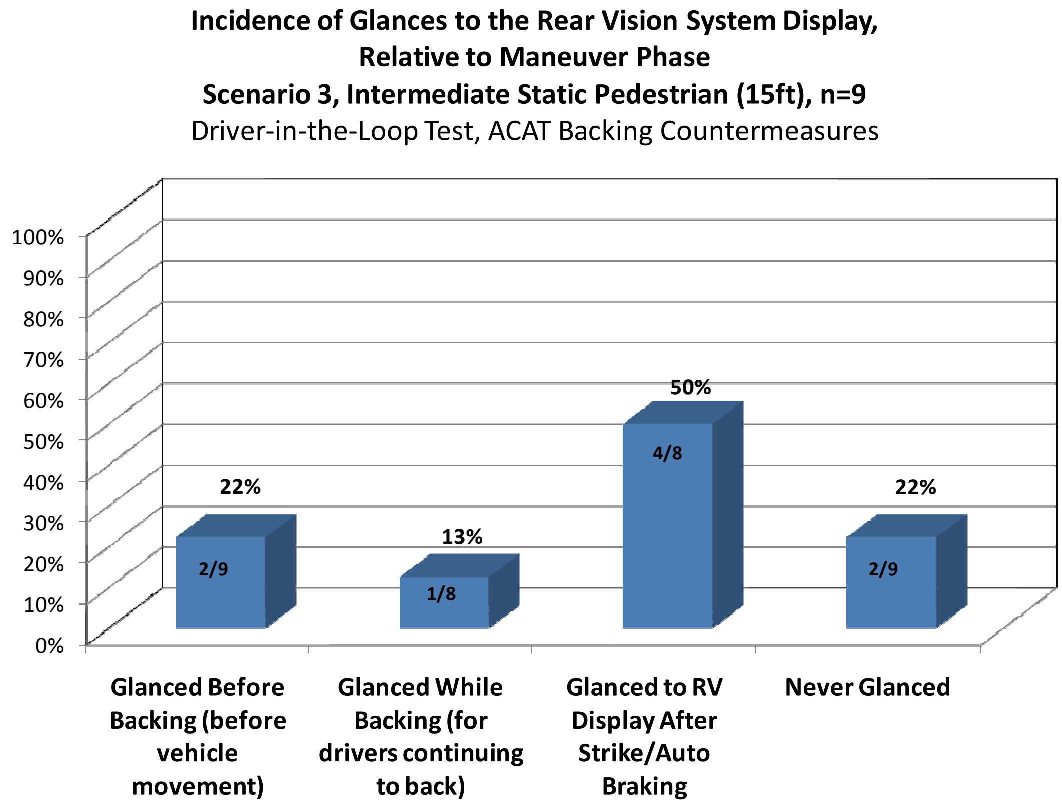


Figure 80. Incidence of Glances to the Rear Vision System Display as a Function of Backing Phase, Pedestrian Scenario 3

Reliance on the Rear Vision system was found to moderate performance as measured by the incidence of automatic braking events (in this scenario a surrogate for pedestrian strikes). Drivers who did not search the Rear Vision display at least once before and/or while backing tended to trigger the Automatic Braking feature – indicative of a failure to detect and respond to the hazard. As shown in Figure 81, all six of the drivers who did not search the Rear Vision system display activated the emergency braking feature. In contrast, drivers who were observed to search the Rear Vision display at least once (either before or while backing) tended as a group to have fewer Automatic Braking system activations.

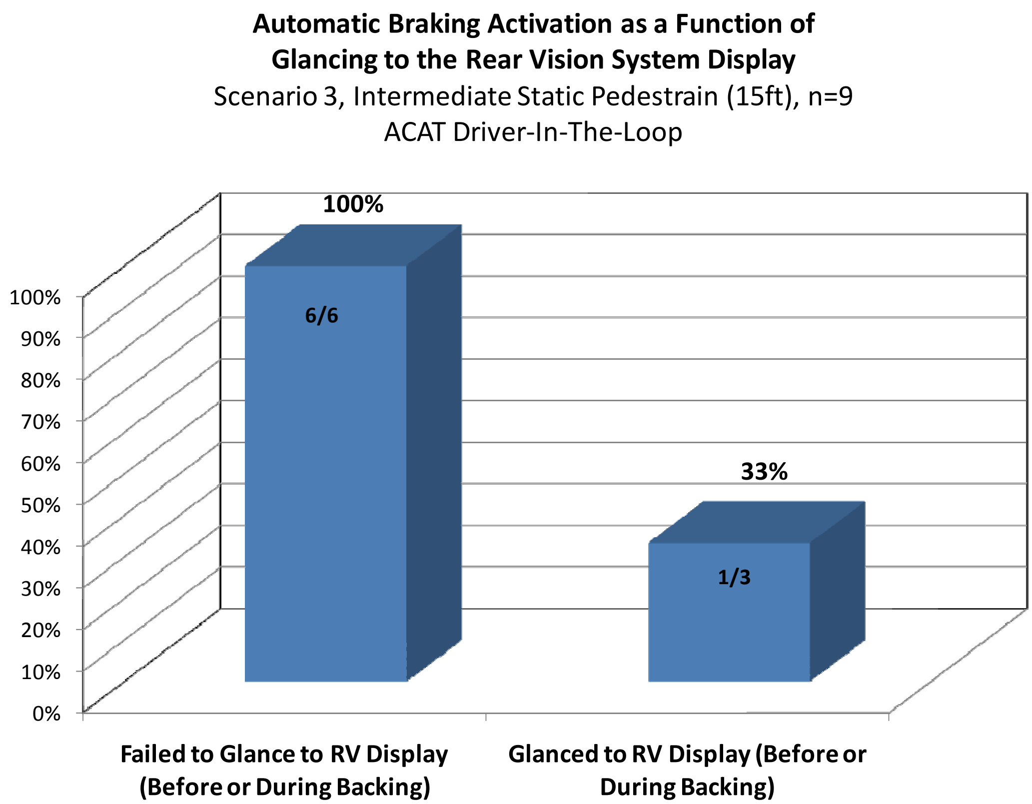


Figure 81. Automatic Braking System Activation Rates as a Function

Table 45 presents the glance frequencies and mean single glance durations to the Rear Vision system display during the surprise event trial.

Table 45. Frequency and Duration of Glances to the Rear Vision System Display Over the Course of the Pedestrian 3 Scenario Conflict Event

Reliance on RV System Display	Mean	Min	Max
Frequency of Glances to Display (number)	1.44	0	3
Duration of Single Glance to Display (seconds)	2.17	0.3	6.0

Summary of Driver Interactions with Countermeasures

This section summarizes driver interactions with the integrated backing countermeasure suite over the course of the conflict scenario. It is important to recognize that the test-bed vehicle was equipped with a collection of inter-related backing countermeasures (Rear Vision, Park Aid, Backing Warning, and Automatic Braking) and drivers generally experienced several during the course of the conflict scenario (e.g., Park Aid alert and Automatic Braking in the presence of Rear Vision). As a result, assessments of direct cause and effect relationships between individual feature outputs and driver responses are extremely difficult to determine. Nevertheless, this section makes an attempt to lay out driver responses to features, or more appropriately, feature combinations, by delineating the time-course of events identifying which countermeasure features were activated at the onset of the behavior.

A wide range of behaviors were observed as this conflict scenario unfolded and drivers backed toward the surrogate pedestrian located 15 ft behind the vehicle. The backing event averaged 25 seconds in duration, ranging from 7 to 73 seconds. Some drivers were judged to have ignored system alerts (Park Aid audible and visual indications) and continued to back, while others responded to system outputs by searching and/or braking to a stop, then attempting to verify or confirm the presence of an obstacle. Drivers were also observed to pull forward in response to the Automatic Braking and attempt backing a second time. The availability of the Rear Vision feature led some drivers to detect the hazard before backing, however, a majority of the drives even though they glanced at the Rear Vision backed the vehicle until they triggered the Automatic Braking feature suggesting that they looked but did not see the obstacle." A detailed analysis of Looking and Not Seeing Probabilities can be found in appendix F page 53.

Figure 82 maps the interactions between each driver and the backing countermeasure suite during the pedestrian conflict scenario. The chart details the frequency with which each countermeasure was activated or accessed, and classifies drivers' responses and subsequent performance outcomes. The top row delineates each of the countermeasures, indicating the percentage of drivers who received or accessed the feature (note that these categories are not mutually exclusive since drivers may have received multiple countermeasures). For example, results show that 22% of the drivers accessed the Rear Vision display and detected the hazard before backing, while 89% of the sample received Park Aid alerts, and 78% of drivers triggered the Automatic Braking feature. Driver responses to these countermeasures are specified in the body of the chart, with the bottom-most row showing the overall outcome indicating whether the pedestrian was struck or avoided. The chart traces the interactions for a given driver (subject identification numbers are annotated within each major cell), showing which countermeasures were accessed and the behavioral responses and outcomes tied to the highest countermeasure received. Organizing the data in this form helps identify behavioral patterns and characteristics associated with countermeasure systems.

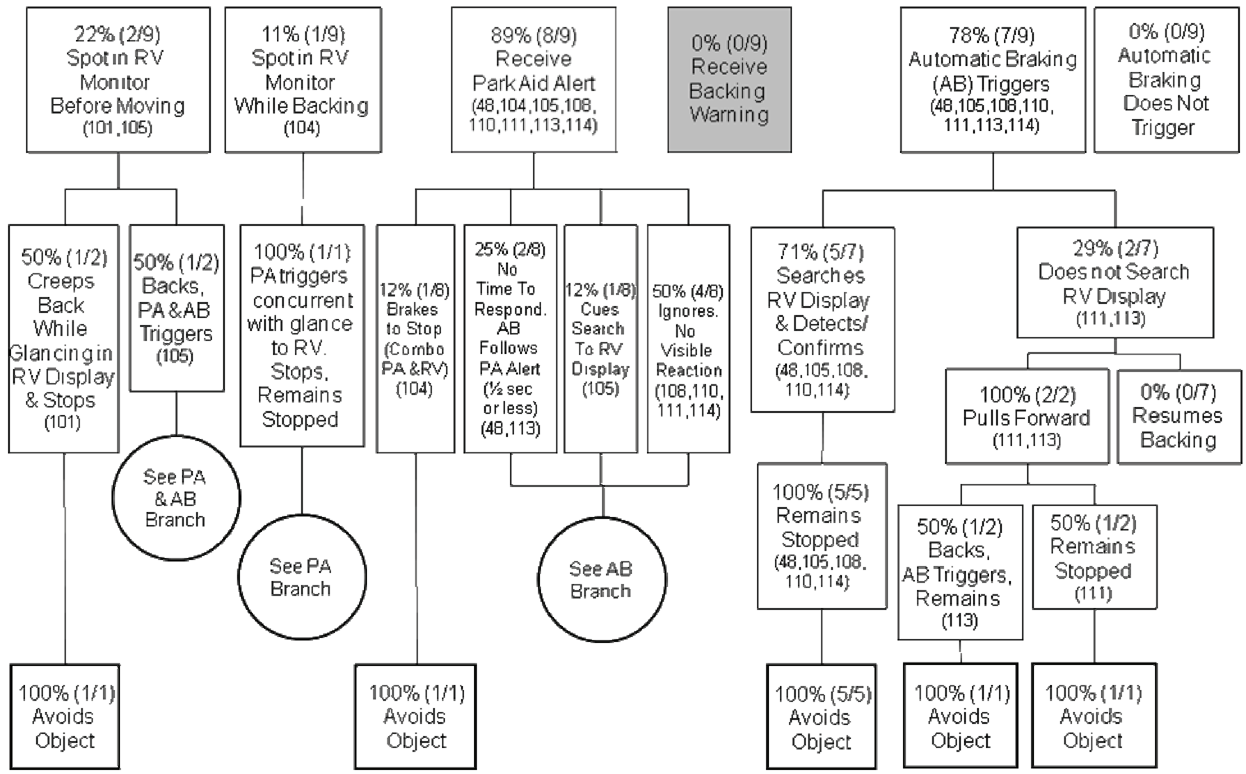


Figure 82. Driver Interactions and Responses to the Backing Countermeasures, Pedestrian Scenario 3, Intermediate Static Pedestrian

As illustrated in the above figure, several aspects related to driver interactions under this particular scenario are noteworthy:

- Less than one-third of drivers accessed the information available to them in the Rear Vision system before Automatic Braking stopped the vehicle. If accessed, data suggest that some drivers (33%, or 1 out of 3) may not act on the information gathered from the display, particularly if it appears to contradict information from other sources (direct glances, mirror checks); this may result from a basic misunderstanding or misconception of the rear blind spot or the representation of the displayed area (recall that drivers had no prior personal experience with Rear Vision, except for the 12 familiarization trials performed in advance of the conflict event).
- Although 8 out the 9 drivers in this scenario received Park Aid alerts (89% in this sample), none of the drivers were observed to brake to a stop as a direct result of these audible and visual Park Aid cues. Only 2 of the 8 drivers (25%) were noted to have any observable response to Park Aid alerts – in one case the alert served to cue the driver to search the Rear Vision display, and in the other the driver stopped but the response was likely a result of the combination of the Park Aid and Rear Vision system. 75% of the drivers (6 out of 8) did not exhibit any discernable behavioral response to Park Aid alerts; and in many cases Park Aid alerts provided drivers with insufficient time to respond (alerts were tightly coupled with last second Automatic Braking).
    - Park Aid cues may have played a role following activation of the Automatic Braking feature, allowing some drivers to interpret the automatic stop (recall drivers were not informed about the presence of the Automatic Braking feature).

- The activation rate for Automatic Braking under this particular scenario was 78% (7 out of 9 drivers received this intervention) and contributed to the overall 100% avoidance rate.
- Drivers who searched the Rear Vision system following an Automatic Braking event tended to remain stopped. 71% of drivers (5 out of 7) were observed to search the Rear Vision display following the braking and all who searched remained stopped.
- Drivers who did not search the Rear Vision system display following an Automatic Braking event (equivalent to 29%, or 2 out of 7 drivers) tended to pull forward; data show that some drivers will re-engage and attempt to back after having pulled forward.
- None of the drivers were observed to override the Automatic Braking system and resume backing directly without first pulling forward.

Detection Failures: "Looked But Did Not See"

Glances to the Rear Vision system display (as with glances to vehicle mirrors) may not always be accompanied by a detection response; it is possible for drivers to scan the display with the hazard present, yet fail to detect and/or recognize the obstacle. As shown in Figure 83, the incidence of these types of "looked but did not see" events (as judged) were not uncommon, as this phenomenon appears to have occurred for approximately 22% of the sample (2 out of 9 drivers). In these cases, drivers were observed to make a glance to the display, yet did not have any discernable detection response. The incidence of these "looked but did not see" events may vary widely based on the scenario and conspicuity of the hazard – in this case the clothed pedestrian object was located some distance (15 ft) behind the vehicle.

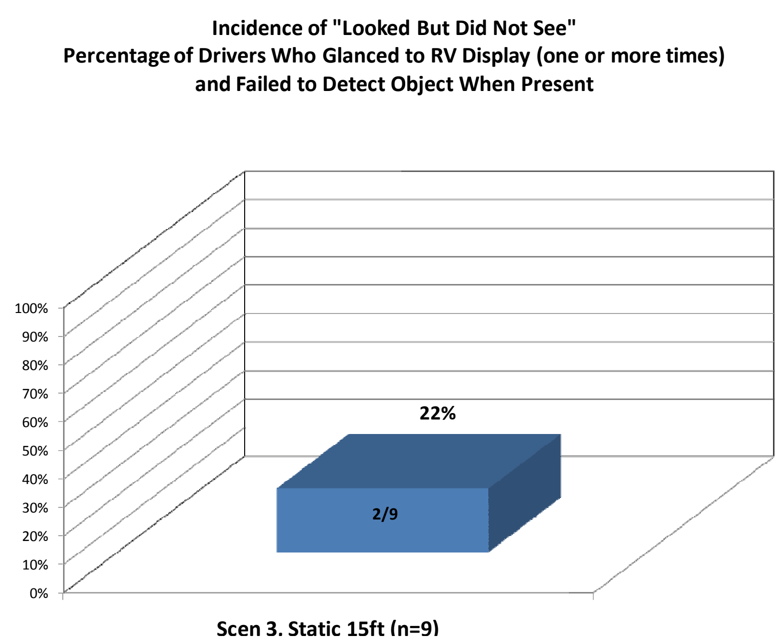


Figure 83. Incidence of "looked but did not see" cases under Pedestrian Scenario 3

6.7.2 Test 12: Near, Incurring Pedestrian (Scenario 5)

This Driver-in-the-Loop test simulated a backing crash scenario wherein a small child enters into the path of a vehicle that is backing out of a parking space; the child encroaches from the driver's side and is in close proximity (5 ft) to the vehicle (Pedestrian Scenario 5). Testing was performed with a group of 8 drivers (ages 31 to 65 years) recruited from the general driving public; each owned a large SUV, comparable in size to the test vehicle (a 2008 Chevrolet Tahoe), and had no previous experience with Park Aid or Rear Vision features. Drivers were provided opportunities to experience the Park Aid and Rear Vision system features during a series of 12 backing and parking practice trials performed as part of a vehicle familiarization phase preceding the surprise conflict scenario. Drivers were not informed of the existence of the Backing Warning or Automatic Braking features of the vehicle, nor did they experience these features during practice. This section summarizes the scenario-specific protocols used to stage and execute this conflict situation and the test results, highlighting key performance measures of relevance to the SIM. The prescriptive, standardized objective test protocols for this scenario are presented in Appendix A.

6.7.2.1 <u>Scenario Site Characteristics</u>

Test conditions were mapped to the Pedestrian Scenario 5 conflict situation in which a test object (representative of a child) incurred from the driver's side of the vehicle within a parking lot setting. The equipment used allowed an experimenter to release the object at the first sign of vehicle movement, thereafter coming to rest at an approximate distance of 5 ft from the rear bumper centerline (the distance is relative to the original parked position). As shown in the figures below (Figure 84 and Figure 85), the actual staged environment was functionally similar to the target conflict scenario. Note that a standing 2-year-old mannequin was substituted for the 5-year-old child since the taller mannequin would have been visible through direct or rearview mirror glances through the rear window. It should also be noted that the mannequin traveled at an approximate speed of 4 mph as opposed to the originally proposed speed of 2 mph. This higher speed was necessary to ensure that the mannequin would be positioned behind the vehicle in time for the event to unfold as intended, and that the pedestrian would not be visible prior to backing.

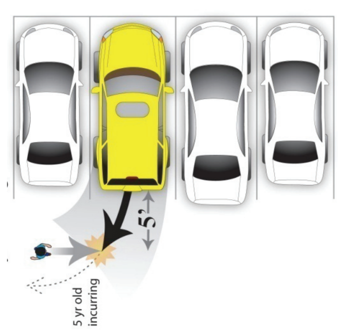


Figure 84. Pedestrian Scenario 5: Near Incurring Pedestrian as Conceptualized

Figure 85. Pedestrian Scenario 5: Near Incurring Pedestrian as Realized

Scenario Staging and Driver Instructions

As specified in the test protocols, all testing was conducted on a dry and level surface under daytime conditions. Test conditions were designed to capture and elicit representative driver behaviors without necessarily focusing on the vehicle's backing countermeasures. Participants were instructed that the purpose of the study was to solicit impressions and comments regarding a variety of vehicle features, convenience devices, and aids. Although Park Aid and Rear Vision were among these aids, drivers were initially made aware of a variety of devices (including advanced radio features, OnStar, and ACC, among others) under the guise that they would be using these later during the study. Drivers were first provided opportunities to experience and comment on the parking features (Park Aid and Rear Vision) during 12 practice trials, with the expectation they would undergo similar opportunities to experience and evaluate the other previously described devices and aids. Pilot testing found that some limited exposure to Park Aid and Rear Vision features is important in order to eliminate and/or reduce potential novelty effects which may otherwise lead drivers to artificially focus or overly rely on these new features.

The session was interrupted immediately following assessments of the backing aids by injecting a ruse which necessitated participants to drive back to the main entrance (where they initially accessed the vehicle), park, and exit the vehicle in order to complete a "previously neglected" questionnaire; this was in fact a deliberate oversight intended to get drivers to exit the vehicle and allow experimenters to set up the surprise event conflict scenario. Drivers were led to believe they would be heading out to a local area highway to experience the ACC system. They were also led to believe that a second Tahoe would be used as it was equipped with the ACC system. In fact, this second Tahoe was identical to the first, but in order to have the vehicle and mannequin precisely positioned it was necessary to pre-stage this event. As participants exited the building and approached the second vehicle, accompanied by the experimenter, they were instructed to back the vehicle out of the perpendicular parking spot so they could leave the complex and head out to a local highway to test the ACC system. The surprise event conflict scenario was injected during this backing event using this "get in and go" approach which had drivers walk to the vehicle (approaching from the front) and back out of the parking spot much as they would in a typical parking lot setting. As drivers began to back, a research assistant released the mannequin down a ramp where it rolled to a stop behind the test vehicle. Driver interactions with the backing countermeasures were video recorded as they backed the vehicle under this staged conflict scenario. Once the conflict scenario was completed, drivers were immediately de-briefed following the procedures and question paths detailed in Appendix C in order to gauge their understanding of the event and reliance on the backing countermeasures.

6.7.2.2 Participants

This Driver-in-the-Loop test recruited eight drivers ranging from 31 to 65 years of age. All were licensed drivers who owned and routinely drove a large SUV comparable in size to the test vehicle; drivers also had no previous exposure to Park Aid or Rear Vision systems. Sample characteristics are detailed in Table 46.

Table 46. Driver Age and Gender Characteristics for Pedestrian Scenario 3

Driver Gender	N	Mean Age	Min Age	Max Age
Males	4	48	31	62
Females	4	50	33	65
Total	**8**	**49**	**31**	**65**

6.7.2.3 Results

Overall Avoidance & Detection

Results of the Pedestrian 5 conflict scenario found that half of the drivers (50%, or 4 out of 8) were able to successfully avoid the in-path obstacle. Unlike the other Driver-in-the-Loop scenarios, the pairing of short distance (5 ft) with an incurring obstacle provided a very short window of opportunity within which the driver and also the vehicle countermeasures could respond. Many drivers were observed to trigger the vehicle's Automatic Braking function even after receiving Park Aid alerts. It should also be noted that unlike in Pedestrian Scenario 3 (Intermediate Static Pedestrian) the Auto Braking did not always prevent a strike with the object; this will be discussed later within this scenario summary. As illustrated in Figure 86, 88% of drivers (7 out of 8) were observed to detect the mannequin; the driver who did not detect the mannequin was instructed to stop by the experimenter after striking it. This scenario yielded high detection rates despite the fact that the mannequin was not visible before backing.

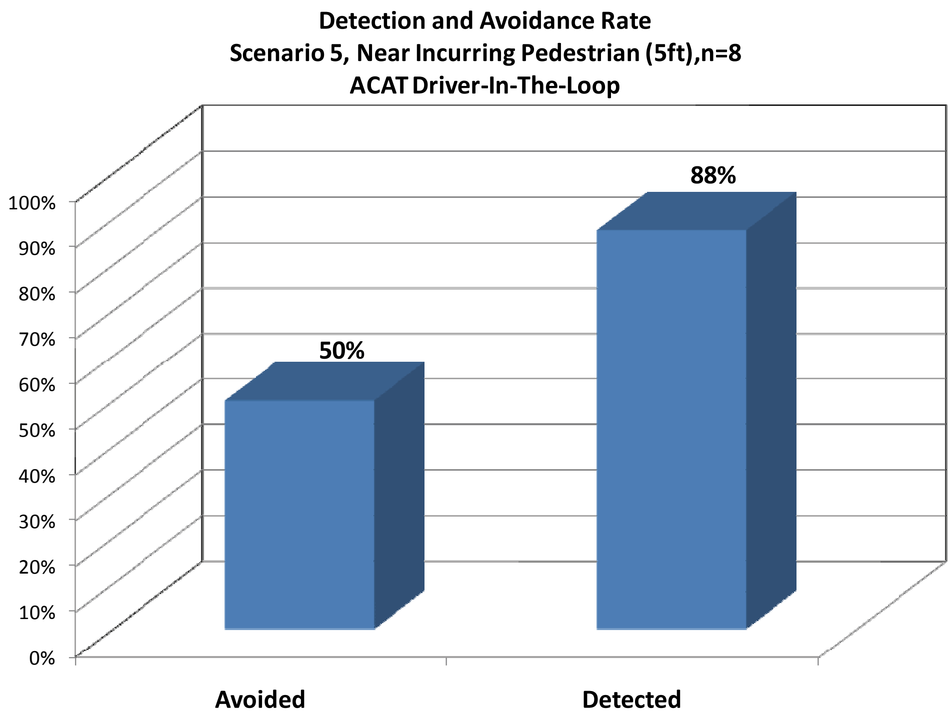


Figure 86. Avoidance and Detection Rates for Pedestrian Scenario 5

As presented above, nearly 88% of drivers (7 out of 8) in this scenario detected the rear pedestrian at some point during the conflict. The time-course of detection is illustrated in Figure 87, and indicates that approximately 25% of drivers spotted the hazard in the Rear Vision display while backing. Note that the object would not have been visible before backing. Approximately 62% of drivers (5 out of 8) detected the hazard following the vehicle coming to rest through response to Park Aid and/or Automatic Braking which generally cued drivers to search the Rear Vision display.

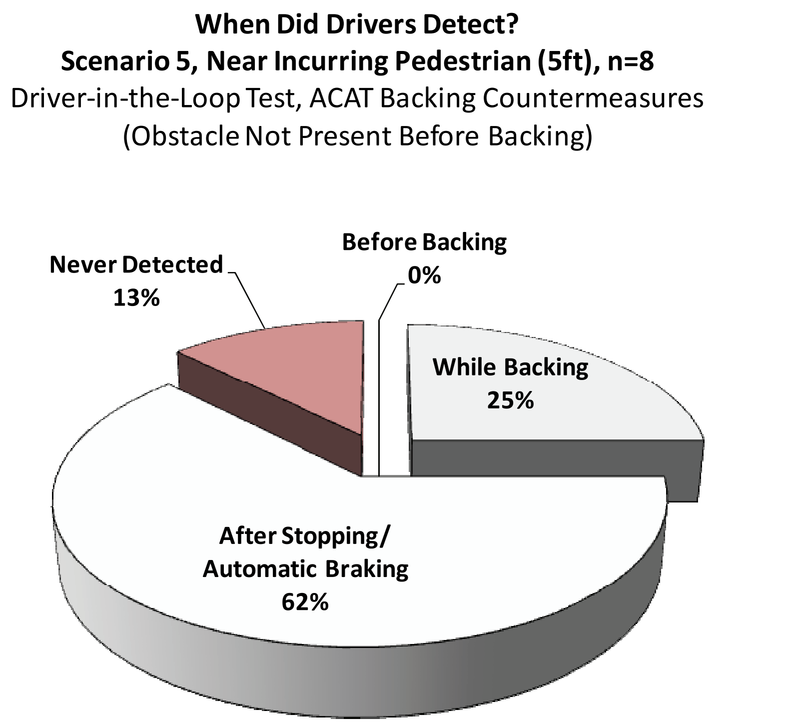


Figure 87. Detection Rates as a Function of Backing Phase

Countermeasure Activations

The test-bed vehicle afforded drivers an integrated suite of backing countermeasures comprised of Rear Vision, Park Assist, Backing Warning, and Automatic Braking. As a group, drivers were observed to exercise nearly all of these features under this backing scenario with the exception of Backing Warning which was never activated (the backing warning feature is only active at backing speeds above 4 mph). Data are presented here which show the extent to which features were exercised by plotting the "highest" countermeasure received by drivers as a group. As described in Appendix B (Variable Coding Data Dictionary) the "highest" countermeasure represents the most intrusive or urgent level of intervention received by drivers (information, alert, warning, or active control assist); the approach views the available countermeasures along a continuum with Rear Vision representing the lowest form of intervention and Automatic Braking offering the highest level of intervention. Data show the progression through the backing countermeasures hierarchy (but does not necessarily assume drivers received each feature).

As depicted in Figure 88, one driver (13%, or 1 out of 8) remained stopped in response to information gathered from the Rear Vision system alone. Half of the drivers (50%, or 4 out of 8) either brought the vehicle to a stop or were already stopped when the initial Park Aid alert was issued. All but one of those drivers remained stopped following detection of the mannequin. The remaining three drivers (38%, or 3 out of 8) backed until the Automatic Braking feature was triggered. Note that one driver did strike the mannequin during the Automatic Braking. Activation of Automatic Braking also suggests that, in these cases, drivers did not access or act on information provided by the Rear Vision and/or Park Aid systems.

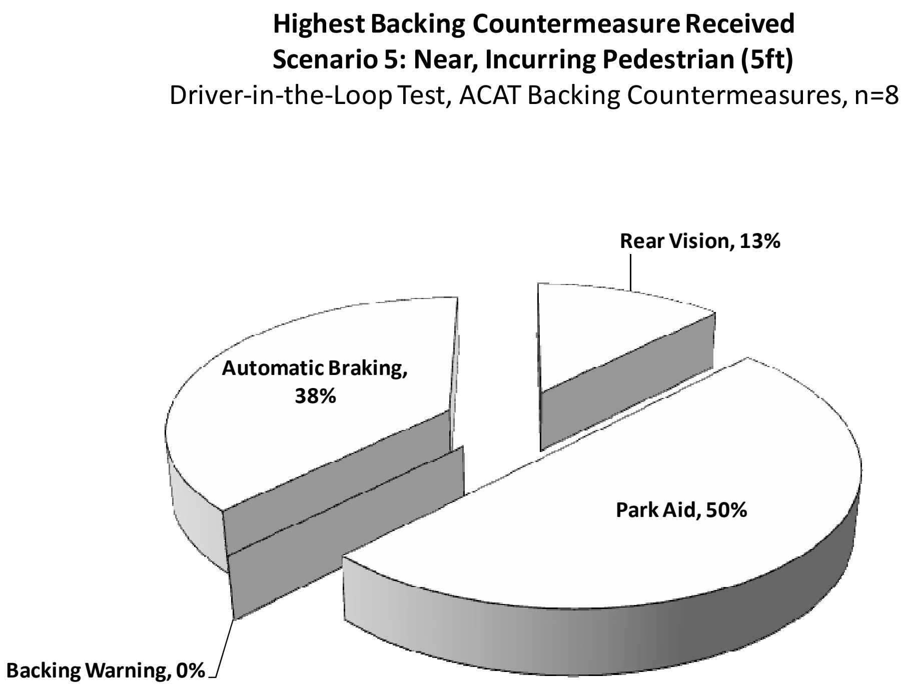


Figure 88. Highest Backing Countermeasure Received, Pedestrian Scenario 5

Search Behavior & Glances to Rear Vision System

Analysts reviewed and scored the video to determine driver glance patterns during this conflict scenario, including the incidence of glances to the Rear Vision system display located on the dash above the center console area. In all, over the course of the backing event, 88% of drivers (7 out of 8) were observed to make at least one glance to the Rear Vision system; only one driver (13%, or 1 out of 8) did not glance to the Rear Vision system during the event (this is the same driver noted previously who did not detect the obstacle). Figure 89 breaks down the incidence of glances to the Rear Vision display as a function of maneuver phase – before backing, during backing, or after stopping or striking the obstacle (note that these phases are not mutually exclusive). One driver was observed to check the Rear Vision system before backing, but as the path was clear s/he proceeded to back but continued to scan the display while backing. Half of the drivers (50%, or 4 out of 8) first glanced to the display after coming to a stop, or impact with the obstacle.

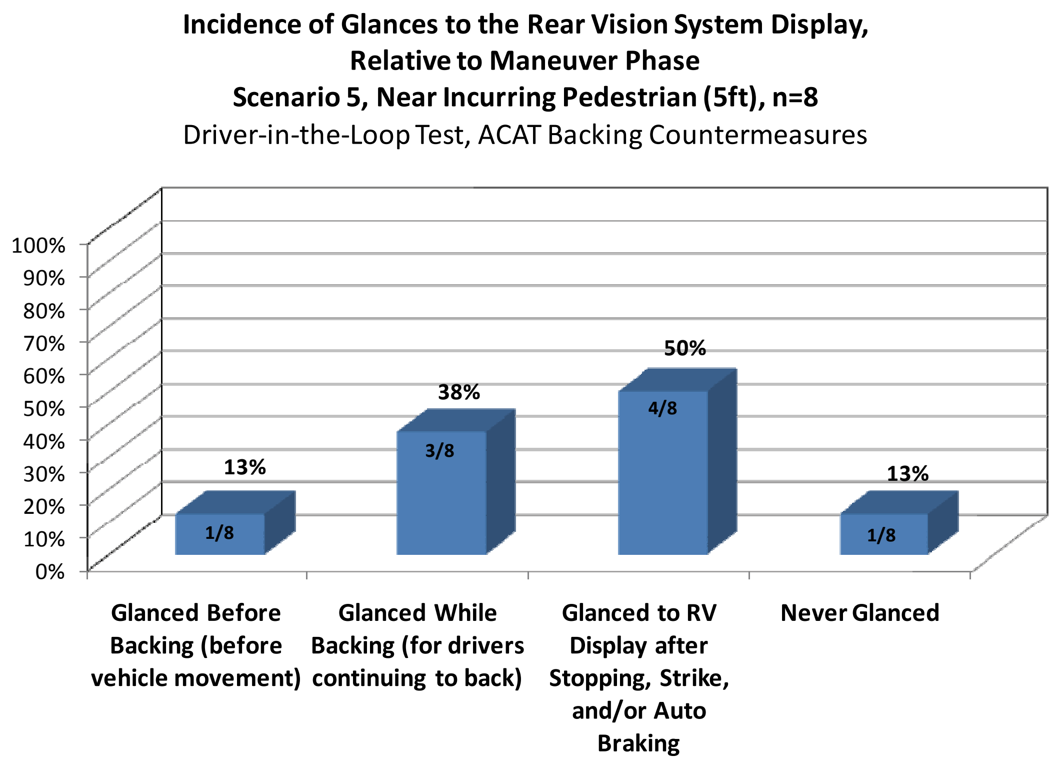


Figure 89. Incidence of Glances to the Rear Vision System Display as a Function of Backing Phase, Pedestrian Scenario 5

Reliance on the Rear Vision system was found to moderate performance as measured by the incidence of automatic braking events (in this scenario a surrogate for pedestrian strikes). Drivers who did not search the Rear Vision display at least once before and/or while backing tended to trigger the Automatic Braking feature – indicative of a failure to detect and respond to the hazard. As shown in Figure 90, 80% (or 4 out of 5) of the drivers who did not search the Rear Vision system display activated the automatic braking feature. In contrast, the three drivers who were observed to search the Rear Vision display at least once (either before or while backing) experienced no Automatic Braking system activations.

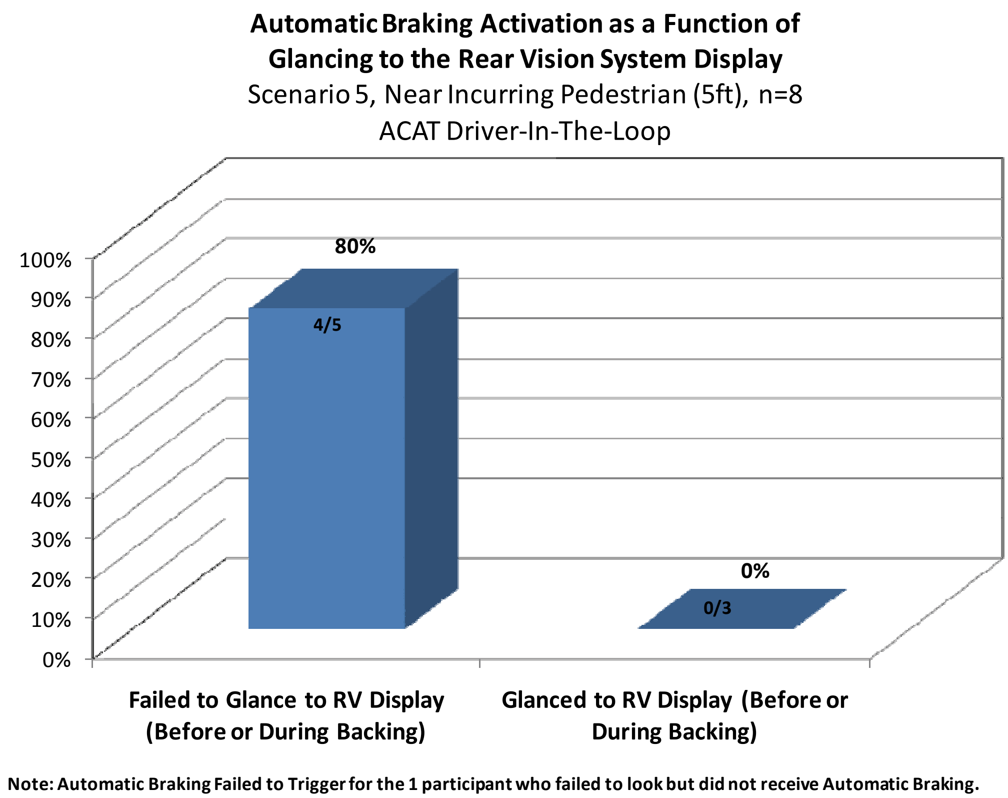


Figure 90. Automatic Braking System Activation Rates as a Function Glancing to the Rear Vision Display

Table 47 presents the glance frequencies and mean single glance durations to the Rear Vision system display during the surprise event trial.

Table 47. Frequency and Duration of Glances to the Rear Vision System Display Over the Course of the Pedestrian 5 Scenario Conflict Event

Reliance on RV System Display	Mean	Min	Max
Frequency of Glances to Display (number)	1.25	0	2
Duration of Single Glance to Display (seconds)	1.62	0.9	3.6

Summary of Driver Interactions with Countermeasures

This section summarizes driver interactions with the integrated backing countermeasure suite. It is important to recognize that the test-bed vehicle was equipped with a collection of inter-related backing countermeasures (Rear Vision, Park Aid, Backing Warning, and Automatic Braking) and drivers generally experienced several during the course of the conflict scenario (e.g., Park Aid alert and Automatic Braking). As a result, assessments of direct cause and effect relationships between individual feature outputs and driver responses are extremely difficult to determine. Nevertheless, this section makes an attempt to lay out driver responses to features, or more appropriately feature combinations, by delineating the time-course of events identifying which countermeasure features were activated at the onset of the behavior.

A wide range of behaviors were observed as this conflict scenario unfolded and drivers backed toward the incurring pedestrian located 5 ft behind the vehicle. The backing event averaged 23 s in duration, ranging from 9 to 56 s. Some ignored system alerts and continued to back, while others responded to system outputs by searching and/or braking to a stop then attempting to verify or confirm the presence of an obstacle. Drivers were even observed to pull forward in response to the Automatic Braking and attempt backing a second time.

Figure 91 maps out the interactions between each driver and the backing countermeasure suite during the pedestrian conflict scenario. The chart details the frequency with which each countermeasure was activated or accessed, and classifies drivers' responses and subsequent performance outcomes. The top row delineates each of the countermeasures, indicating the percentage of drivers who received or accessed the feature (note that these categories are not mutually exclusive since drivers may have received multiple countermeasures). Due to the nature of the scenario, the obstacle was not visible in the Rear Vision Monitor prior to backing. Results show that 88% of the sample received Park Aid alerts, and 38% of drivers triggered the Automatic Braking feature. Driver responses to these countermeasures are specified in the body of the chart, with the bottom-most row showing the overall outcome indicating whether the driver struck or avoided the pedestrian. The chart traces the interactions for a given driver (subject identification numbers are annotated within each major cell), showing which countermeasures were accessed and the behavioral responses and outcomes tied to the highest countermeasure received. Organizing the data in this form helps identify behavioral patterns and characteristics associated with countermeasure systems.

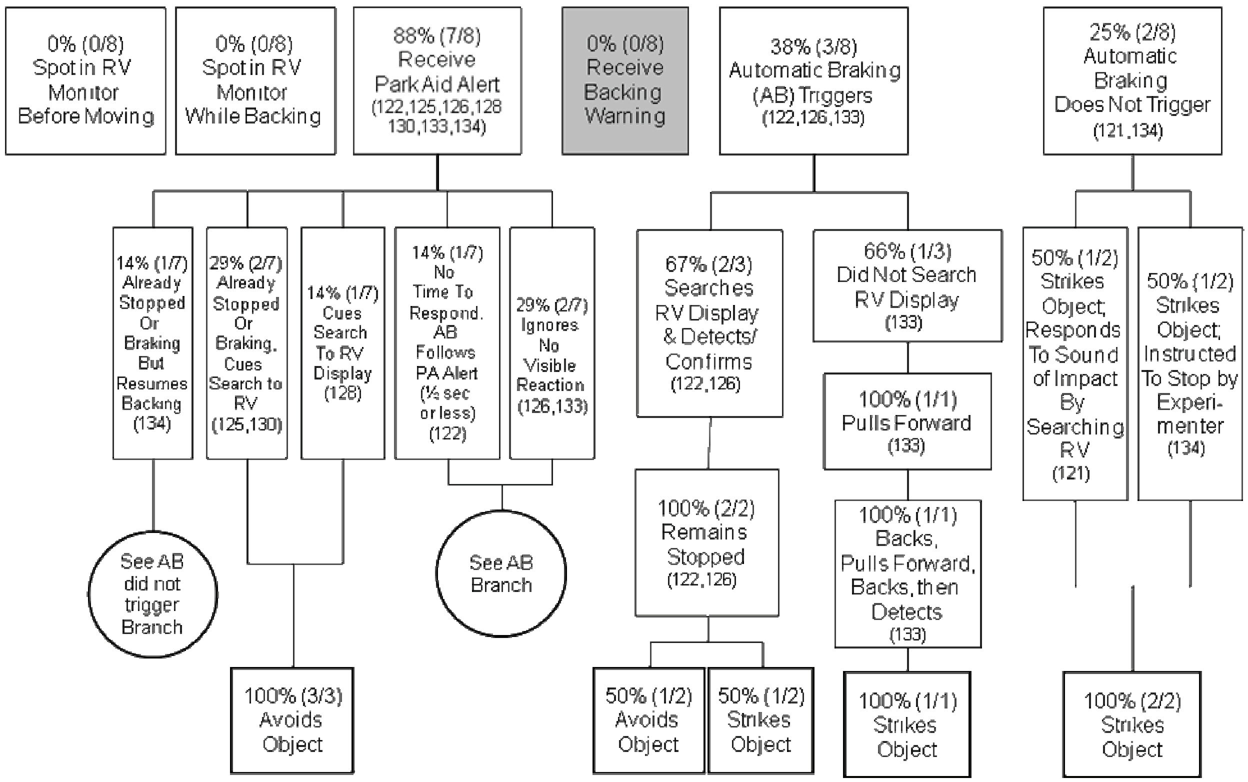


Figure 91. Driver Interactions and Responses to the Backing Countermeasures, Pedestrian Scenario 5, Near Incurring Pedestrian

As illustrated in Figure 91, several aspects related to driver interactions under this particular scenario are noteworthy:

- Most drivers who receive Park Aid alerts under this scenario (88% in this sample) do not respond to these cues; only one of the drivers was observed to brake to a stop as a direct result of these audible and visual Park Aid cues. Two of the eight drivers (25%) were in the process of stopping when Park Aid was issued, and thereafter searched the Rear Vision display (Park Aid possibly cued drivers to search). 38% of the drivers (3 out of 8) did not exhibit any discernable behavioral response to Park Aid alerts; it should be noted that in one case Park Aid alerts provided the driver with insufficient time to respond (alerts were tightly coupled with last second Automatic Braking).
- Automatic Braking contributed to the 50% avoidance rate in this scenario. 66%, of drivers (2 out of 3) who searched the Rear Vision system following an Automatic Braking event remain stopped due to detection of the hazard.
- Drivers who did not search the Rear Vision system display following an Automatic Braking event (equivalent to 33%, or 1 out of 3 drivers) pulled forward. None of the drivers were observed to override the Automatic Braking system and resume backing directly without first pulling forward.

Detection Failures: "Looked But Did Not See"

Glances to the Rear Vision system display (as with glances to vehicle mirrors) may not always be accompanied by a detection response; it is possible for drivers to scan the display with the hazard present, yet did not detect and/or recognize the obstacle. The incidence of these types of "looked but did not see" events were uncommon in this scenario, as this phenomenon did not occur for any of the drivers within this sample (of the 7 drivers who looked to the Rear Vision display).

6.7.3 Test 13: Intermediate, Incurring Pedestrian (Scenario 4)

This crash scenario parallels the scenario detailed in Test 11 (Pedestrian Scenario 3), except the child, in this case a 5-year-old, encroaches into the path of the moving vehicle as it backs down a driveway. Testing was performed with a group of eight drivers (ages 31 to 65 years) recruited from the general driving public; each owned a large SUV, comparable in size to the test vehicle (a 2008 Chevrolet Tahoe), and had no previous experience with Park Aid or Rear Vision features. Drivers were provided opportunities to experience the Park Aid and Rear Vision system features during a series of 12 backing and parking practice trials performed as part of a vehicle familiarization phase preceding the surprise conflict scenario. Drivers were not informed of the existence of the Backing Warning or Automatic Braking features of the vehicle, nor did they experience these features during practice. This section summarizes the scenario-specific protocols used to stage and execute this conflict situation and the test results, highlighting key performance measures of relevance to the SIM. The standardized objective test protocols for this scenario are presented in Appendix A.

6.7.3.1 Scenario Site Characteristics

As shown in Figure 92, test conditions were mapped to the Pedestrian Scenario 4 conflict situation in which a test object (representative of a child) encroaches into the moving vehicle's path, approximately 15 ft behind the vehicle, as it backs down a driveway-like environment. Since this scenario was staged using an actual incurring test object, as opposed to a pop-up object, it was possible for drivers to detect the object in the mirrors or via direct over-the-shoulder glances for a short interval before it entered into the vehicle's blind spot area. In order to reduce the likelihood that drivers would detect the incurring obstacle, a 2-year-old test mannequin was used. Despite use of the smaller test mannequin, approximately 43% of drivers (6 out of 14) were able to detect the child mannequin (in the mirrors or via direct glances) before it entered into the vehicle's path. These "busted" trials serve to illustrate the base unassisted detection rates under this scenario.

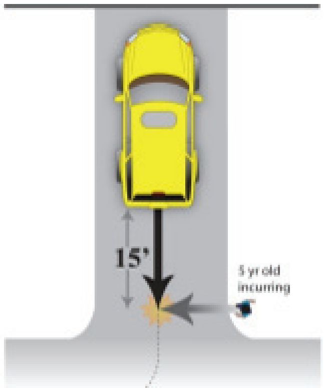


Figure 92. Pedestrian Scenario 4: Intermediate, Incurring Pedestrian, as Conceptualized (Left) and Realized (Right)

6.7.3.2 <u>Scenario Staging and Driver Instructions</u>

As specified in the test protocols, all testing was conducted on a straight, level, dry surface under daytime conditions. Test conditions were designed to capture and elicit representative driver behaviors without necessarily focusing on the vehicle's backing countermeasures; it was necessary to enhance the object's sensor signature to allow more reliable performance and ensure that the full range of countermeasure features would be activated by the test object (note that the Grid tests provide an accurate measure of countermeasure sensor performance). Participants were instructed that the purpose of the study was to solicit impressions and comments regarding a variety of vehicle features, convenience devices, and aids. Although Park Aid and Rear Vision were among these aids, drivers were initially introduced to a variety of devices including advanced radio features, OnStar, and ACC, among others. Drivers were first provided opportunities to experience and comment on the parking features (Park Aid and Rear Vision) during 12 practice trials, with the expectation that they would undergo similar opportunities to experience and evaluate the other previously described devices and aids. Pilot testing found that some limited exposure to Park Aid and Rear Vision features is important in order to eliminate and/or reduce potential novelty effects which may otherwise lead drivers to artificially focus or overly rely on these new features.

The session was interrupted immediately following assessments of the backing aids by injecting a ruse which necessitated participants to drive back to the main entrance (where they initially accessed the vehicle), park, and exit the vehicle in order to complete a "previously neglected" questionnaire; this was in fact a deliberate oversight intended to get drivers to exit the vehicle and allow experimenters to set up the surprise event conflict scenario. Drivers were led to believe they would be heading out to a local area highway to experience the ACC system once they returned to the vehicle. As participants exited the building and approached the vehicle, accompanied by the experimenter, they were instructed to back the vehicle to an open parking space so they could leave the complex in preparation to test the ACC system. It is important to note that drivers had already backed down this same driveway at the beginning of the session with no incident. The surprise event conflict scenario was injected during this second backing event using this "get in and go" approach which had drivers walk to the vehicle (approaching from the front) and back down the driveway much as they would in a typical driveway setting. When the vehicle first started to move, the 2-year-old mannequin was propelled at a rate of 2 mph into the path of the backing vehicle. Driver interactions with the backing countermeasures were video recorded as they backed the vehicle under this staged conflict scenario. Once the conflict scenario was completed, drivers were immediately de-briefed following the procedures and question paths detailed in Appendix C in order to attempt to gauge their understanding of the event and reliance on the backing countermeasures.

6.7.3.3 Participants

This Driver-in-the-Loop test recruited eight drivers ranging from 32 to 64 years of age. All were licensed drivers who owned and routinely drove a large SUV comparable in size to the test vehicle; drivers also had no previous exposure to Park Aid or Rear Vision systems. Sample characteristics are detailed in Table 48.

Table 48. Driver Age and Gender Characteristics for Pedestrian Scenario 4

Driver Gender	N	Mean Age	Min Age	Max Age
Males	4	46	31	60
Females	4	50	37	65
Total	**8**	**48**	**31**	**65**

6.7.3.4 Results

Overall Avoidance & Detection

As illustrated in Figure 93, results of the Pedestrian 4 conflict scenario found that 38% of drivers (or 3 out of 8) were able to successfully avoid the in-path obstacle; as described in subsequent sections, this result is due, in part, to the availability of backing countermeasure features, including Automatic Braking. Detection rates (using analysts' judgments) also suggest that the majority of drivers (63%, or 5 out of 8) were able to spot the in-path hazard in the Rear Vision system during the course of the scenario. Approximately 37% of drivers (3 out of 8) did not detect or confirm the presence of the hazard.

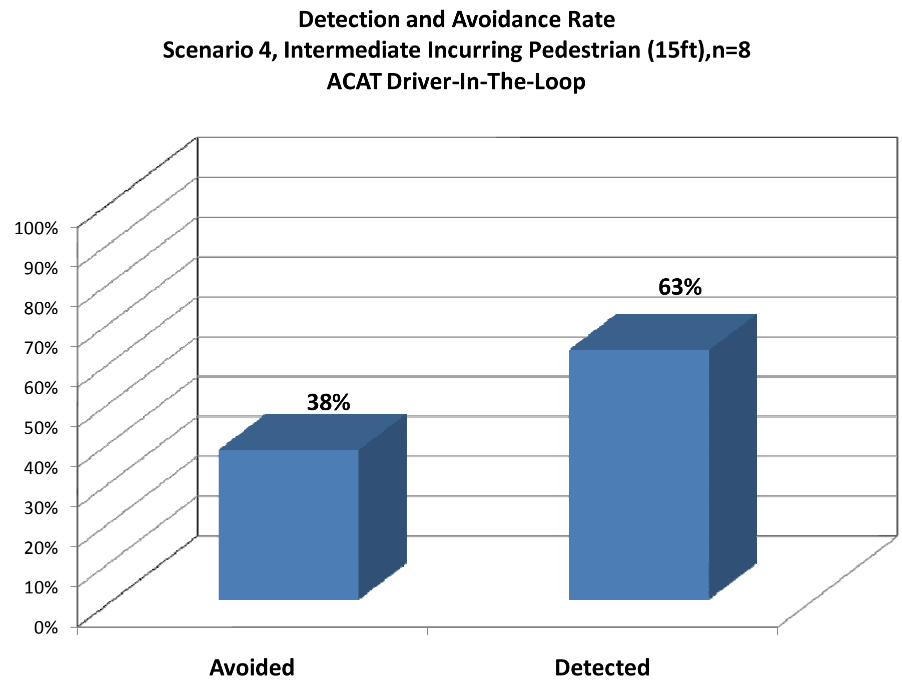


Figure 93. Avoidance and Detection Rates for Pedestrian Scenario 4

As presented above, nearly 63% of drivers (5 out of 8) in this scenario detected the rear pedestrian object at some point during the conflict. The time-course of detection is illustrated in Figure 94, and indicates that approximately 38% of drivers were judged to have spotted the hazard while backing (via the Rear Vision system); the obstacle was not yet present before backing. Approximately 25% of drivers (2 out of 8) detected the hazard following Automatic Braking, which generally cued drivers to search the Rear Vision display, and nearly 38% of drivers (3 out of 8) never detected the child mannequin.

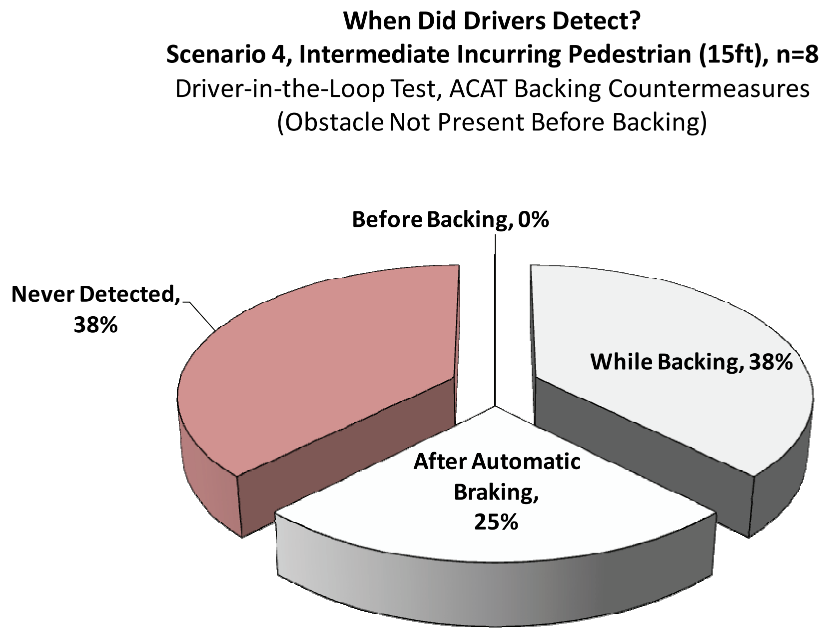


Figure 94. Detection Rates as a Function of Backing Phase

Countermeasure Activations

As a group, drivers were observed to exercise all of the countermeasure types under this backing scenario, although only the cautionary component of Backing Warning was observed. Data are presented here which show the extent to which features were exercised by plotting the "highest" countermeasure received by drivers as a group. As described in Appendix B (Variable Coding Data Dictionary) the "highest" countermeasure represents the most intrusive or urgent level of intervention received by drivers (information, alert, warning, or active control assist); the approach views the available countermeasures along a continuum with Rear Vision representing the lowest form of intervention and Automatic Braking offering the highest level of intervention. This chart shows the progression through the backing countermeasures hierarchy (but does not necessarily assume drivers received each feature). As depicted in Figure 95, several drivers (38% or 3 out of 8) stopped in response to information gathered from the Rear Vision system alone. An equal number (38%, or 3 out of 8) backed until the Automatic Braking feature was triggered. Activation of Automatic Braking suggests that, in these cases, drivers largely failed to access or act on information provided by the Rear Vision and/or Park Aid systems. In this sample, the audible warning cue and Park Aid were also shown to be the highest countermeasure received for some drivers; in both cases drivers continued to back and the automatic braking feature did not trigger, resulting in a collision. In these cases, the Automatic Braking did not trigger due to the design of the backing safety system. Automatic Braking will trigger when speed is greater than 4 mph concurrent with backing warning or if an object suddenly appears in the vehicles path. Since the drivers triggered the Park Aid feature indicating the driver was traveling at a speed less than 4 mph and the object was intermediately encroaching within 2.5 m of the path of the vehicle (not suddenly appearing) the conditions to trigger the Automatic Braking were not present.

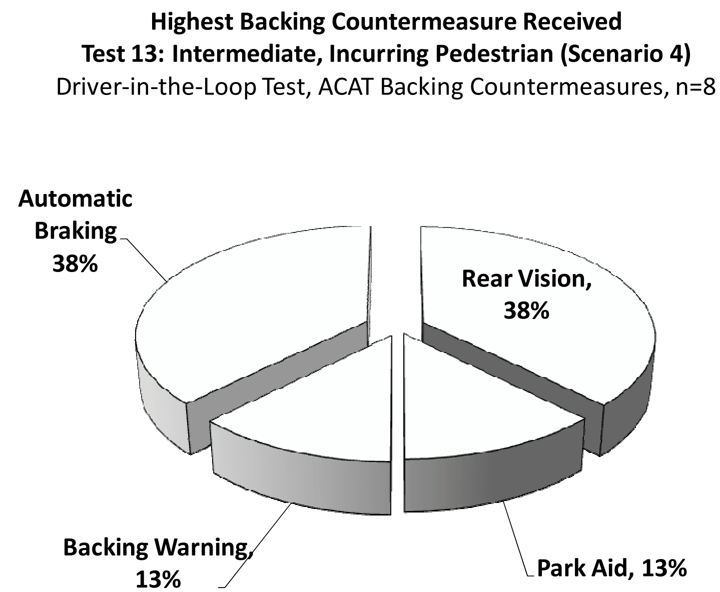


Figure 95. Highest Backing Countermeasure Received, Pedestrian Scenario 3

Search Behavior & Glances to Rear Vision System

Analysts reviewed and scored the video to determine driver glance patterns during this conflict scenario, including the incidence of glances to the Rear Vision system display located on the dash above the center console area. In all, over the course of the backing event, 75% of drivers (6 out of 8) were observed to make at least one glance to the Rear Vision system; 25% of drivers (2 out of 8) did not glance to the Rear Vision system during the event. Figure 96 breaks down the incidence of glances to the Rear Vision display as a function of maneuver phase – before backing, during backing, or following Automatic Braking/collision with obstacle. Approximately 25% of drivers (2 out of 8) scanned the Rear Vision display before backing (note that the obstacle was not yet visible), with 50% of drivers (4 out of 8) referencing the Rear Vision Display while backing. Nearly all of the drivers were observed to glance to the Rear Vision display following Automatic Braking and/or colliding with the mannequin.

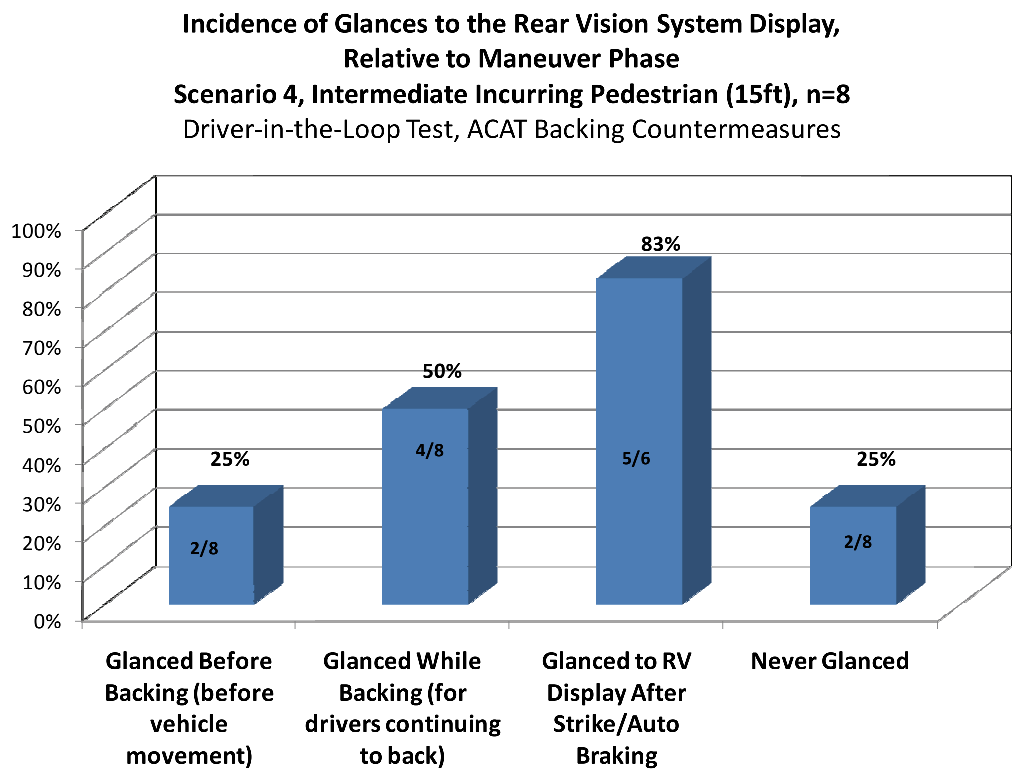


Figure 96. Incidence of Glances to the Rear Vision System Display as a Function of Backing Phase, Pedestrian Scenario 3

Reliance on the Rear Vision system was found to moderate performance as measured by the incidence of automatic braking events (in this scenario a surrogate for pedestrian strikes) and collisions with the test mannequin. Drivers who did not search the Rear Vision display at least once before and/or while backing tended to trigger the Automatic Braking feature (or collide with the test mannequin). As shown in Figure 97, all of the four drivers who did not search the Rear Vision system display activated the emergency braking feature and/or struck the test object (in some cases, the Automatic Braking feature did not activate). In contrast, drivers who were observed to search the Rear Vision display at least once (either before or while backing) tended as a group to have fewer Automatic Braking system activations.

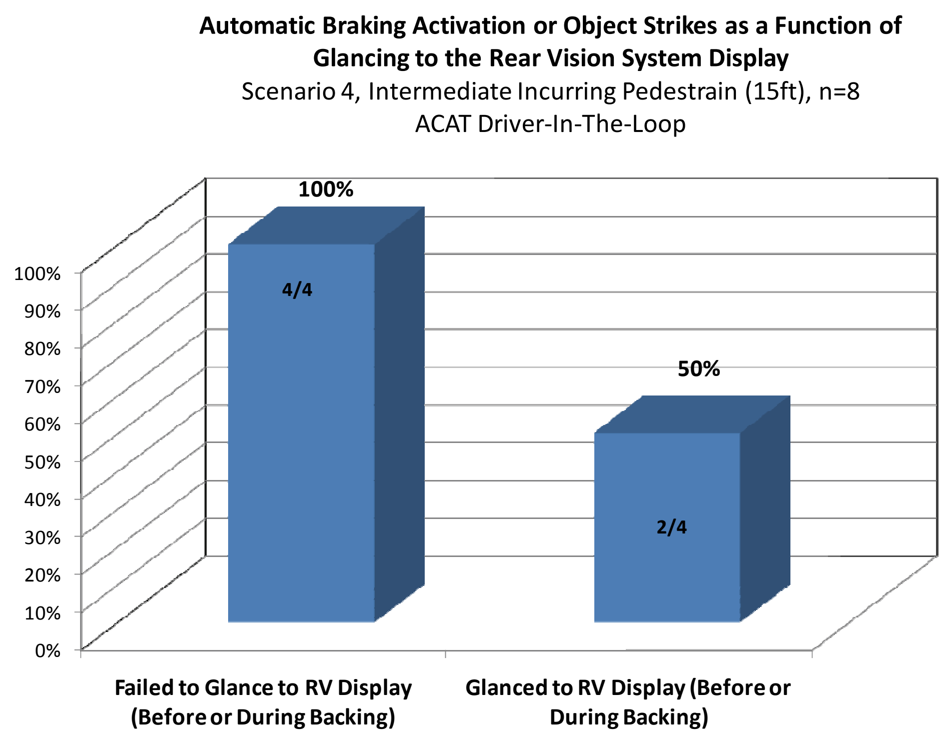


Figure 97. Automatic Braking System Activation and Collision Rates as a Function of Access to Rear Vision Display

Table 49 presents the glance frequencies and mean single glance durations to the Rear Vision system display during the surprise event trial.

Table 49. Frequency and Duration of Glances to the Rear Vision System Display Over the Course of the Pedestrian 4 Scenario Conflict Event

Reliance on RV System Display	Mean	Min	Max
Frequency of Glances to Display (number)	1.90	0	4
Duration of Single Glance to Display (seconds)	1.99	0.2	5.7

Summary of Driver Interactions with Countermeasures

This section summarizes driver interactions with the integrated backing countermeasure suite over the course of the conflict scenario. It is important to recognize that the test-bed vehicle was equipped with a collection of inter-related backing countermeasures (Rear Vision, Park Aid, Backing Warning, and Automatic Braking) and drivers generally experienced several during the course of the conflict scenario (e.g., Park Aid alert and Automatic Braking in the presence of Rear Vision). As a result, assessments of direct cause and effect relationships between individual feature outputs and driver responses are extremely difficult to determine. Nevertheless, this section makes an attempt to lay out driver responses to features, or more appropriately feature combinations, by delineating the time-course of events identifying which countermeasure features were activated at the onset of the behavior.

Figure 98 maps out the interactions between each driver and the backing countermeasure suite during this incurring pedestrian conflict scenario. The backing event averaged 18 seconds in duration, ranging from 8 to 44 seconds. The chart details the frequency with which each countermeasure was activated or accessed, and classifies drivers' responses and subsequent performance outcomes. The top row delineates each of the countermeasures, indicating the percentage of drivers who received or accessed the feature (note that these categories are not mutually exclusive since drivers may have received multiple countermeasures).

A wide range of behaviors were observed as this conflict scenario unfolded as drivers backed with the incurring surrogate pedestrian located 15 ft behind the vehicle. Approximately 38% of drivers were judged to have spotted the pedestrian object while backing, yet only one-third of these drivers managed to avoid striking the object. Although half of the drivers received Park Aid alerts, only one responded by braking; this driver ultimately struck the pedestrian when they continued backing. The vast majority of drivers who received Park Aid (75% or 3 out of 4) did not respond, appearing to ignore the audible cues, or did not have sufficient time to respond. Automatic Braking was activated in 38% of the cases, with another 50% of potential cases where it could have been beneficial but did not activate.

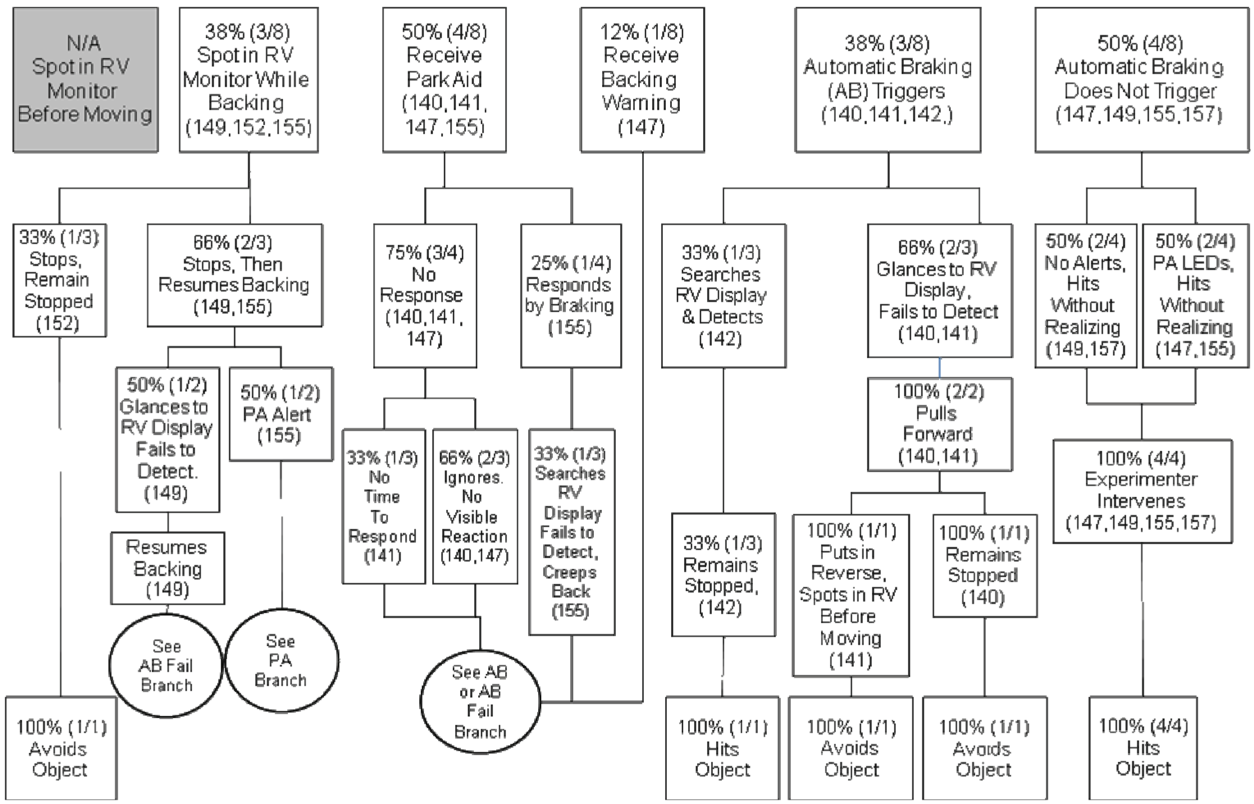


Figure 98. Driver Interactions and Responses to the Backing Countermeasures, Pedestrian Scenario 4, Intermediate Incurring Pedestrian

As illustrated in the above figure, several aspects related to driver interactions under this particular scenario are noteworthy:

- Most drivers (62%, or 5 out of 8) did not access the information available to them in the Rear Vision system before activation of Automatic Braking or collision with the test object. Even if the display is accessed, there is some likelihood that under this scenario, drivers will fail to detect or respond to the hazard; only 33% of drivers who glanced to the Rear Vision display actually stopped and remained stopped.
    - Only one driver managed to avoid the obstacle without intervention by the automatic braking feature. This driver spotted the child object in the Rear Vision system while backing.
- Few drivers were observed to respond to the audible and visual Park Aid alerts under this scenario; of those who received alerts, only 25% (one driver) responded by braking to a stop and this driver ultimately resumed backing.

  - A full 75% of the drivers (3 out of 4) who received Park Aid alerts did not exhibit any discernable behavioral response, or did not have sufficient time to respond to these alerts.
- The activation rate for Automatic Braking under this particular scenario was lower than expected due to instances where it did not trigger – there were four cases where drivers struck the mannequin without any prior automatic braking. In situations where the automatic braking feature did trigger, two-thirds resulted in avoidance.
- None of the drivers were observed to override the Automatic Braking system and resume backing directly without first pulling forward.

Detection Failures: "Looked But Did Not See"

This scenario had a relatively high incidence of "looked but did not see" cases with an incidence rate of approximately 50% - meaning half of the drivers were observed to make one or more glances to the display, yet did not have any discernable detection response. The location of the pedestrian target may have contributed to this relatively high rate; the obstacle was not necessarily centered in the frame and sometimes only part of the child was visible. The area behind the car also had other obstacles present to include a trash can and debris - this may have created a visually noisy background.

6.7.4 Test 14: Near Static Vehicle (Scenario 7)

This Driver-in-the-Loop test simulated a backing crash scenario wherein a driver backs the vehicle in the presence of an unexpected vehicle which is stationary directly 1.5 meters (5 ft) behind the vehicle (Vehicle Scenario 7). Testing was performed with a group of 35 drivers (ages 26 to 68 years) recruited from the general driving public; each owned a large SUV, comparable in size to the test vehicle (a 2003 Cadillac Escalade), and had no previous experience with Park Aid or Rear Vision features. Data for this particular test were collected from a previous effort, and therefore follow a somewhat different pattern than the other Driver-in-the-Loop tests in this report, including the use of a larger sample. Like the other tests, drivers were provided opportunities to experience the Park Aid and Rear Vision system features during a series of backing and parking practice trials, but they were also informed of the existence of the Backing Warning and Automatic Braking features of the vehicle. This section summarizes the scenario-specific protocols used to stage and execute this conflict situation and the test results, highlighting key performance measures of relevance to the SIM. The prescriptive, standardized objective test protocols for this scenario are presented in Appendix A.

6.7.4.1 Scenario Site Characteristics

Test conditions were mapped to the vehicle conflict situation (Scenario 7) in which a test object (a standard 3-foot tall orange traffic cone) was placed approximately 5 ft behind the vehicle in a driveway-like environment, requiring drivers to back down a designated path. As shown in Figure 99, the actual staged environment was comparable to the target conflict scenario. Use of a cone was substituted for a vehicle in order to simulate a lapse in driver attention (situation where the driver fails to detect the vehicle and assumes the path is clear); the cone simulated this since it was not visible through either direct or mirror glances. The cone also reliably triggered the Automatic Braking feature.

Figure 99. Vehicle Scenario 7: Near, Static Vehicle, as Conceptualized (Left) and Realized (Right)

6.7.4.2 <u>Scenario Staging and Driver Instructions</u>

As specified in the test protocols, all testing was conducted on a straight, level, dry surface under daytime conditions. Test conditions were designed to capture and elicit representative driver behaviors without necessarily focusing on the vehicle's backing countermeasures. Participants in this effort had experienced the full range of vehicle backing countermeasures prior to this conflict scenario, and were led to believe that the study was over while being debriefed (through use of a post-drive questionnaire) while seated in the vehicle. This debriefing process was interrupted, and drivers were asked to back the vehicle to an open parking spot - the conflict occurred during this maneuver. Driver interactions with the backing countermeasures were video recorded as they backed the vehicle under this staged conflict scenario. Once the conflict scenario was completed, drivers were immediately de-briefed following the procedures and question paths detailed in Appendix C in order to gauge their understanding of the event and reliance on the backing countermeasures.

6.7.4.3 <u>Participants</u>

This Driver-in-the-Loop test recruited 35 drivers ranging from 26 to 68 years of age. All were licensed drivers who owned and routinely drove a large SUV comparable in size to the test vehicle; drivers also had no previous exposure to Park Aid or Rear Vision systems. Sample characteristics are detailed in Table 50.

Table 50. Driver Age and Gender Characteristics for Pedestrian Scenario 3

Driver Gender	N	Mean Age	Min Age	Max Age
Males	17	47	26	68
Females	18	44	26	61
Total	**35**	**45**	**26**	**68**

6.7.4.4 Results

Overall Avoidance & Detection

Results of the Vehicle 1 conflict scenario found that the majority of drivers (69%, or 24 out of 35) were able to successfully avoid the in-path obstacle; as described in subsequent sections, data suggest that this result is due to the availability of backing countermeasure features, including Automatic Braking (refer to Figure 100). Detection rates also suggest that the vast majority of drivers (86%, or 30 out of 35) were able to spot the in-path hazard in the Rear Vision system, likely due to the high rate of observed glances to the display. The remaining 14% of participants (5 out of 35) who did not detect the hazard either overrode the Automatic Braking without searching the Rear Vision display or the Automatic Braking feature did not trigger.

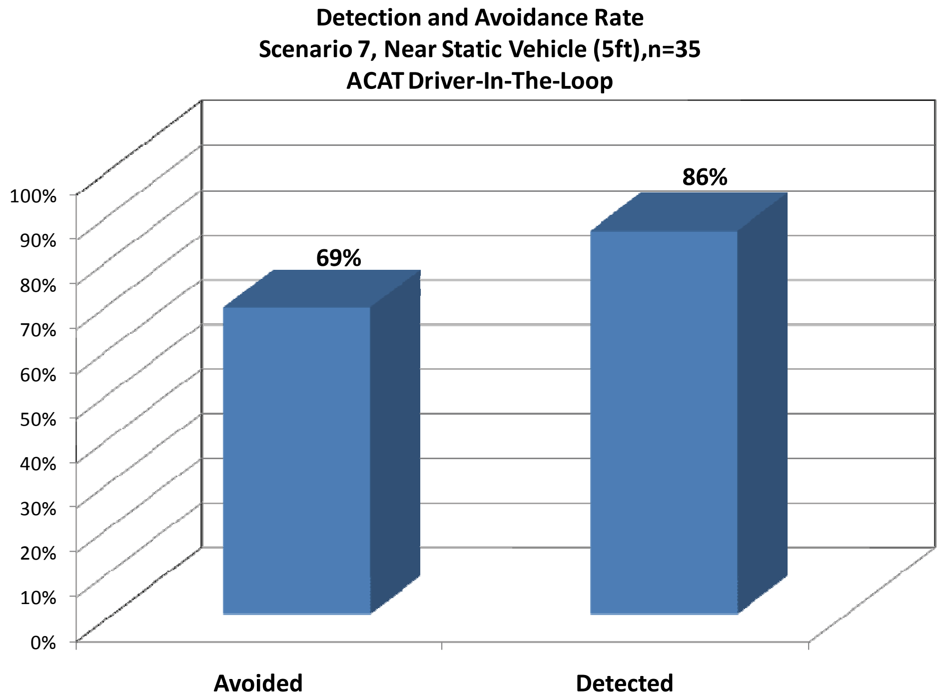


Figure 100. Avoidance and Detection Rates for Vehicle Scenario 7

As presented above, nearly 86% of drivers (30 out of 35) in this scenario detected the rear obstacle at some point during the conflict. The time-course of detection is illustrated in Figure 101, and indicates that approximately 31% of drivers spotted the hazard before backing (via the Rear Vision system), with an additional 20% detected the pedestrian in the Rear Vision display while backing. Approximately 34% of drivers (12 out of 35) detected the hazard following Automatic Braking, which generally cued drivers to search the Rear Vision display.

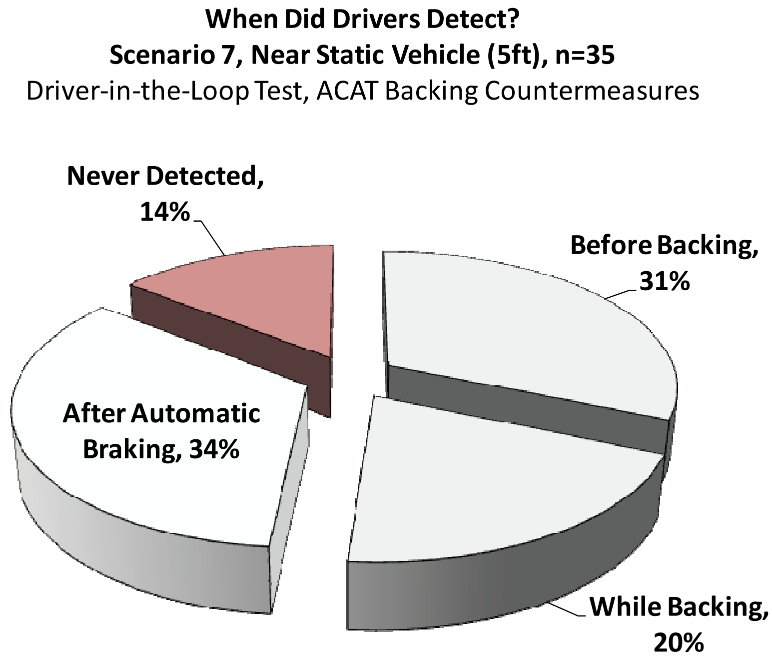


Figure 101. Detection Rates as a Function of Backing Phase

Countermeasure Activations

As a group, drivers were observed to exercise nearly all of these features under this backing scenario with the exception of Backing Warning which was never triggered (the backing warning feature is only active at backing speeds above 4 mph). Data are presented here which show the extent to which features were exercised by plotting the “highest” countermeasure received by drivers as a group. As described in Appendix B (Variable Coding Data Dictionary) the “highest” countermeasure represents the most intrusive or urgent level of intervention received by drivers (information, alert, warning, or active control assist); the approach views the available countermeasures along a continuum, with Rear Vision representing the lowest form of intervention and Automatic Braking offering the highest level of intervention. This chart shows the progression through the backing countermeasures hierarchy (but does not necessarily assume drivers received each feature). As depicted in Figure 102, one driver (3% or 1 out of 35) never triggered any countermeasures beyond accessing the Rear Vision display. Nearly half of the participants (49%, or 17 out of 35) never activated warnings beyond Park Aid alerts; note that given the close proximity to the rear obstacle, Park Aid alerts were triggered nearly simultaneously with shifting into reverse gear. The remaining participants (49%, or 17 out of 35) backed until Automatic Braking engaged. Activation of Automatic Braking also suggests that drivers largely did not access or act on information provided by the Rear Vision and/or Park Aid systems.

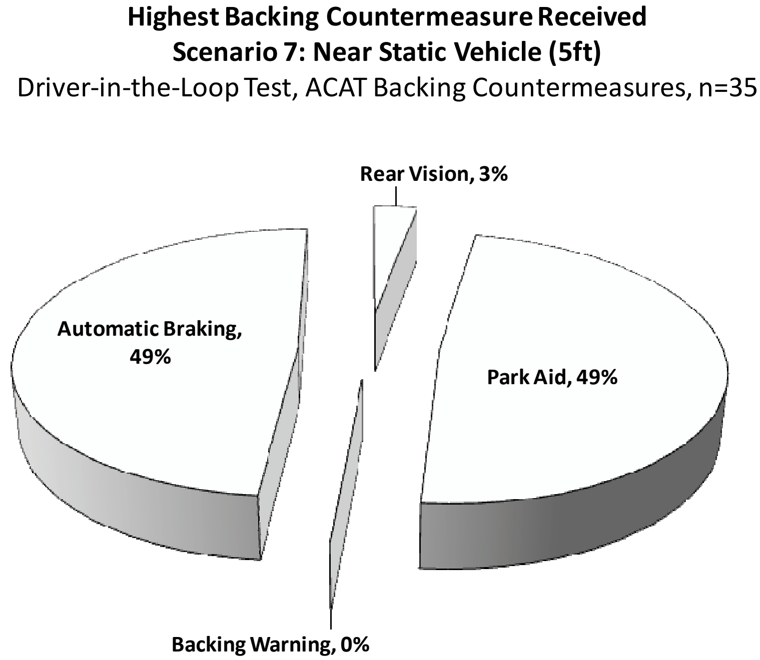


Figure 102. Highest Backing Countermeasure Received, Vehicle Scenario 7

Search Behavior & Glances to Rear Vision System

Analysts reviewed and scored the video to determine driver glance patterns during this conflict scenario, including the incidence of glances to the Rear Vision system display located on the dash above the center console area. In all, over the course of the backing event, 86% of drivers (30 out of 35) were observed to make at least one glance to the Rear Vision system; 5 drivers (14%, or 5 out of 35) did not glance to the Rear Vision system during the event (all of whom did not detect the obstacle). Figure 103 breaks down the incidence of glances to the Rear Vision display as a function of maneuver phase – before backing, during backing, or following Automatic Braking. Approximately half (51%, or 18 out of 35) scanned the Rear Vision display before the onset of the Automatic Braking: 31% of drivers scanned the Rear Vision Display before backing (11 out of 35), and 20% (7 out of 35) while backing. The remaining drivers (34%, or 12 out of 35) glanced to the Rear Vision system following activation of the Automatic Braking feature, enabling the cause of the braking to be identified and/or confirmed.

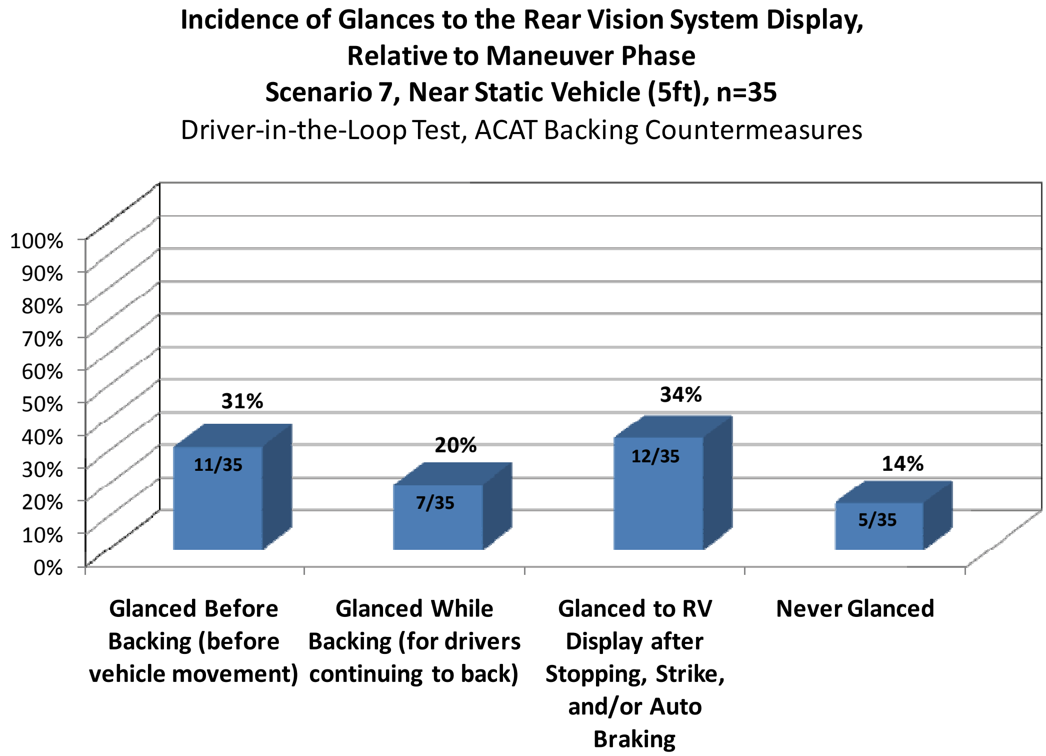


Figure 103. Incidence of Glances to the Rear Vision System Display as a Function of Backing Phase, Vehicle Scenario 7

Reliance on the Rear Vision system was found to moderate performance as measured by the incidence of automatic braking events (in this scenario, a surrogate for vehicle strikes). Drivers who did not search the Rear Vision display at least once before and/or while backing tended to trigger the Automatic Braking feature – indicative of a failure to detect and respond to the hazard. As shown in Figure 104, 88% (or 15 out of 17) of the drivers who did not search the Rear Vision system display activated the emergency braking feature and would have likely struck the rear object. Automatic Braking did not activate for the remaining 12% of those who did not look, thereby resulting in a collision with the obstacle. In contrast, only 11% of drivers who were observed to search the Rear Vision display at least once (either before or while backing) activated the Automatic Braking system during this scenario.

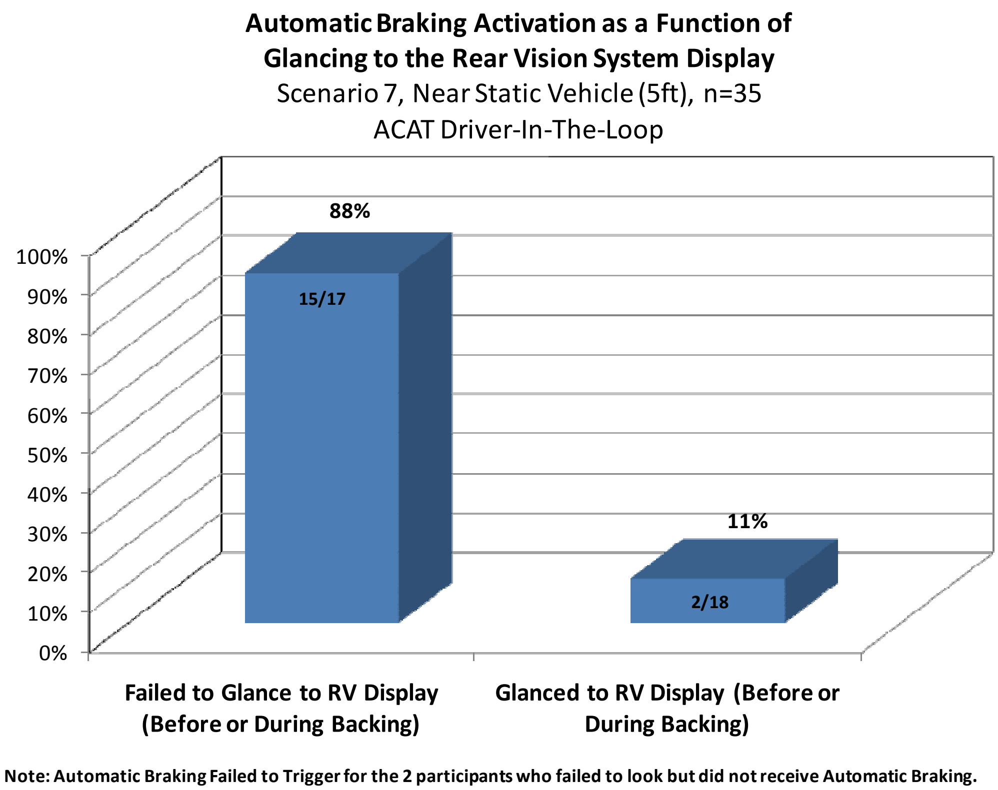


Figure 104. Automatic Braking System Activation Rates as a Function of Glancing to the Rear Vision Display

Table 51 presents the glance frequencies and mean single glance durations to the Rear Vision system display during the surprise event trial. Note that eye glance analysis was performed on a sample of 8 drivers (out of the original sample of 35).

Table 51. Frequency and Duration of Glances to the Rear Vision System Display Over the Course of the Vehicle Scenario 7 Conflict Event (Note: Only 8 Participant Events were reviewed for Eye Glance Analysis)

Reliance on RV System Display	Mean	Min	Max
Frequency of Glances to Display (number)	1.0	0	2
Duration of Single Glance to Display (seconds)	0.7	0.3	0.9

Summary of Driver Interactions with Countermeasures

This section summarizes driver interactions with the integrated backing countermeasure suite. It is important to recognize that the test-bed vehicle was equipped with a collection of inter-related backing countermeasures (Rear Vision, Park Aid, Backing Warning, and Automatic Braking) and drivers generally experienced several during the course of the conflict scenario (e.g., Park Aid alert and Automatic Braking). As a result, assessments of direct cause-and-effect relationships between individual feature outputs and driver responses are extremely difficult to determine. Nevertheless, this section makes an attempt to lay out driver responses to features, or more appropriately, feature combinations, by delineating the time-course of events identifying which countermeasure features were activated at the onset of the behavior.

A wide range of behaviors were observed as this conflict scenario unfolded and drivers backed toward the traffic cone located approximately 5 ft behind the vehicle. Some were judged to ignore system alerts and continued to back, while others responded to system outputs by searching and/or braking to a stop then attempting to verify or confirm the presence of an obstacle. Drivers were even observed to pull forward in response to the Automatic Braking and attempt backing a second time. The availability of the Rear Vision system led some to detect the hazard before backing and before receiving any assistance from other countermeasure features.

Figure 105 maps out the interactions between each driver and the backing countermeasure suite during the vehicle conflict scenario. The chart details the frequency with which each countermeasure was activated or accessed, and classifies drivers' responses and subsequent performance outcomes. The top row delineates each of the countermeasures, indicating the percentage of drivers who received or accessed the feature (note that these categories are not mutually exclusive since drivers may have received multiple countermeasures). For example, results show that 31% of the drivers accessed the Rear Vision display and detected the hazard before backing, while 97% of the sample received Park Aid alerts, and 49% of drivers triggered the Automatic Braking feature. Driver responses to these countermeasures are specified in the body of the chart, with the bottom-most row showing the overall outcome indicating whether the pedestrian was struck or avoided. The chart traces the interactions for a given driver (subject identification numbers are annotated within each major cell), showing which countermeasures were accessed and the behavioral responses and outcomes tied to the highest countermeasure received. Organizing the data in this form helps identify behavioral patterns and characteristics associated with countermeasure systems.

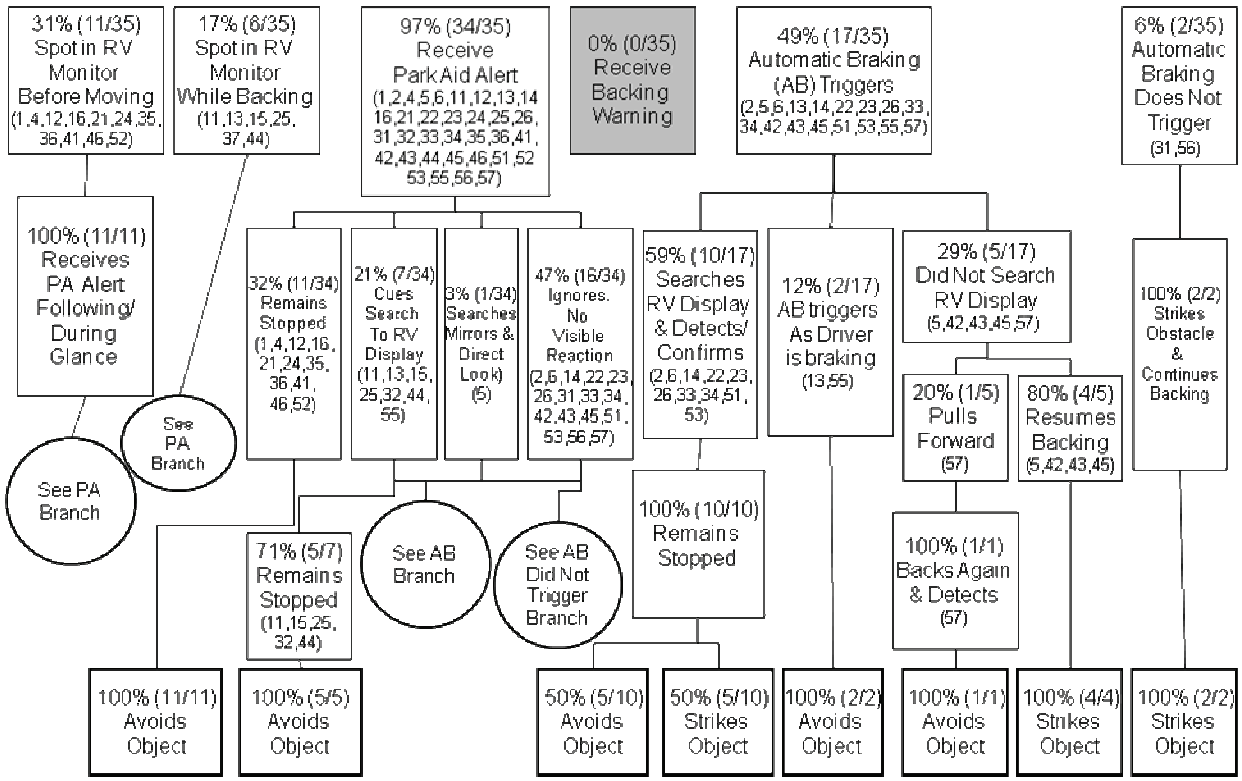


Figure 105. Driver Interactions and Responses to the Backing Countermeasures, Vehicle Scenario 7, Near Static Vehicle

As illustrated in Figure 105, several aspects related to driver interactions under this particular scenario are noteworthy:

- Approximately 31% (11 out of 35) of drivers did not appear to require the use of a countermeasure beyond the Rear Vision and Park Aid (given the close proximity to the obstacle, Park Aid alerts were issued nearly simultaneously with shifting into reverse). These participants were observed to glance to the Rear Vision display shortly after shifting into Reverse.
- All but one participant received Park Aid alerts (97%, or 34 out of 35), although many had already detected the obstacle prior to issuance of the first alert. Of the remaining drivers, 21% (or 7 out of 34) appeared to react to the Park Aid alert by searching the RV display, but 45% (or 16 out of 34) were judged to have no observable response to the Park Aid alerts.
- Automatic Braking under this particular scenario contributed to the 69% avoidance rate; in 23% (8 out of 35) of the total cases, Automatic Braking led to an avoidance behavior.
- Drivers who searched the Rear Vision system following an Automatic Braking event tended to remain stopped. Fifty-nine percent of drivers (or 10 out of 17) were observed to search the Rear Vision display following Automatic Braking and all who searched remained stopped.
- Drivers who did not search the Rear Vision system display following an Automatic Braking event (equivalent to 29%, or 5 out of 17 drivers) either pulled forward or resumed control and continued backing; data show that some drivers will attempt to back after having pulled forward.
- Four of the drivers were observed to override the Automatic Braking system and resume backing directly without first pulling forward.

- This study did not address the potential for increased effectiveness due to driver training or driver educations.

Detection Failures: "Looked But Did Not See"

Glances to the Rear Vision system display (as with glances to vehicle mirrors) may not always be accompanied by a detection; drivers may sometimes glance to the display with the hazard present, yet fail to detect and/or recognize the obstacle. Drivers in this scenario did not appear to experience any "looked but did not see" events; all of the 30 drivers who glanced to the rear vision display detected the hazard.

6.7.5 Test 15: Intermediate Static Pole (Scenario 10)

This Driver-in-the-Loop test simulated a backing crash scenario wherein the driver strikes a pole, mailbox, or other fixed object in the path of the vehicle when backing out of a driveway or garage; the pole is located 4.5 meters (or 15 ft) from the vehicle (Scenario 10). Testing was performed with a group of nine drivers (ages 34 to 61 years) recruited from the general driving public; each owned a large SUV, comparable in size to the test vehicle (a 2008 Chevrolet Tahoe), and had no previous experience with Park Aid or Rear Vision features. Drivers were provided opportunities to experience the Park Aid and Rear Vision system features during a series of 12 backing and parking practice trials performed as part of a vehicle familiarization phase preceding the surprise conflict scenario. Drivers were not informed of the existence of the Backing Warning or Automatic Braking features of the vehicle, nor did they experience these features during practice. This section summarizes the scenario-specific protocols used to stage and execute this conflict situation and the test results, highlighting key performance measures of relevance to the SIM. The prescriptive, standardized objective test protocols for this scenario are presented in Appendix A.

6.7.5.1 Scenario Site Characteristics

Test conditions were mapped to the Scenario 10 conflict situation in which a test object (a low contrast 36" tall metal pole) was placed 15 ft behind the vehicle in a driveway-like environment requiring drivers to back down a designated path and carefully maneuver the vehicle to exit the space (this required turning the vehicle into the path of the pole in order to pull forward and exit the driveway). As shown in Figure 106, the actual staged environment was designed to mimic a situation where the driver would fail to detect the fixed pole, due to either a momentary distraction or a lapse in attention. In order to simulate this "lapse in attention", measures were taken to decrease the conspicuity of the pole; this included partially obstructing the view of the pole by locating it behind a vehicle, and reducing its contrast and height.

Figure 106. Vehicle Scenario 10: Intermediate Static Pole, as Conceptualized (Left) and Realized (Right)

During the preceding parking trials leading up to this surprise scenario, participants had been asked to perform this same task twice with no in-path obstacle present. This helped to reinforce expectancy and attempted to lull participants into a more natural state of reversing in a familiar environment. It should also be noted that the setting where this task took place was visually noisy, meaning that there were a number of other obstacles present, including pylons and a vehicle, that the participant had to be aware of when backing.

6.7.5.2 Scenario Staging and Driver Instructions

As specified in the test protocols, all testing was conducted on a straight, level, dry surface under daytime conditions. Test conditions were designed to capture and elicit representative driver behaviors without necessarily focusing on the vehicle's backing countermeasures. Participants were instructed that the purpose of the study was to solicit impressions and comments regarding a variety of vehicle features, convenience devices, and aids. Although Park Aid and Rear Vision were among these aids, drivers were initially made aware of a variety of devices including advanced radio features, OnStar, and ACC, among others. Drivers were first provided opportunities to experience and comment on the parking features (Park Aid and Rear Vision) during 12 practice trials, with the expectation that they would undergo similar opportunities to experience and evaluate the other previously described devices and aids. Pilot testing found that some limited exposure to Park Aid and Rear Vision features is important in order to eliminate and/or reduce potential novelty effects which may otherwise lead drivers to artificially focus or overly rely on these new features.

These parking trials concluded with the third repetition of the 'backing out of a garage' task, although this time with the pole positioned as described earlier. Driver interactions with the backing countermeasures were video recorded as they backed the vehicle under this staged conflict scenario. Once the conflict scenario was completed, drivers were immediately de-briefed following the procedures and question paths detailed in Appendix C in order to gauge their understanding of the event and reliance on the backing countermeasures.

6.7.5.3 Participants

This Driver-in-the-Loop test recruited nine drivers ranging from 34 to 61 years of age. All were licensed drivers who owned and routinely drove a large SUV comparable in size to the test vehicle; drivers also had no previous exposure to Park Aid or Rear Vision systems. Sample characteristics are detailed in Table 52.

Table 52. Driver Age and Gender Characteristics for Pedestrian Scenario 3

Driver Gender	N	Mean Age	Min Age	Max Age
Males	5	49	34	61
Females	4	49	36	61
Total	**9**	**49**	**34**	**61**

6.7.5.4 Results

Overall Avoidance & Detection

Results of the Vehicle 10 conflict scenario found that just over half of the drivers (56%, or 5 out of 9) were able to successfully avoid the in-path obstacle; as described in subsequent sections, data suggest this result is due to the availability of backing countermeasure features, including Automatic Braking. Nevertheless, the automatic braking did not always prevent drivers from striking the pole. As illustrated in Figure 107, only 44% of drivers (5 out of 9) managed to detect the obstacle during the course of the scenario. The detection rates are also much lower when compared to the other scenarios. Some drivers completed the maneuver without detecting the obstacle, and assumed alerts were in reference to other known objects that were positioned around the immediate area behind the car. In a number of cases, pole strikes resulted because drivers falsely assumed the Park Aid alerts were in reference to a known obstacle and continued to back, striking the pole. Two participants, following automatic braking, pulled forward and exited the vehicle (not counted as detection).

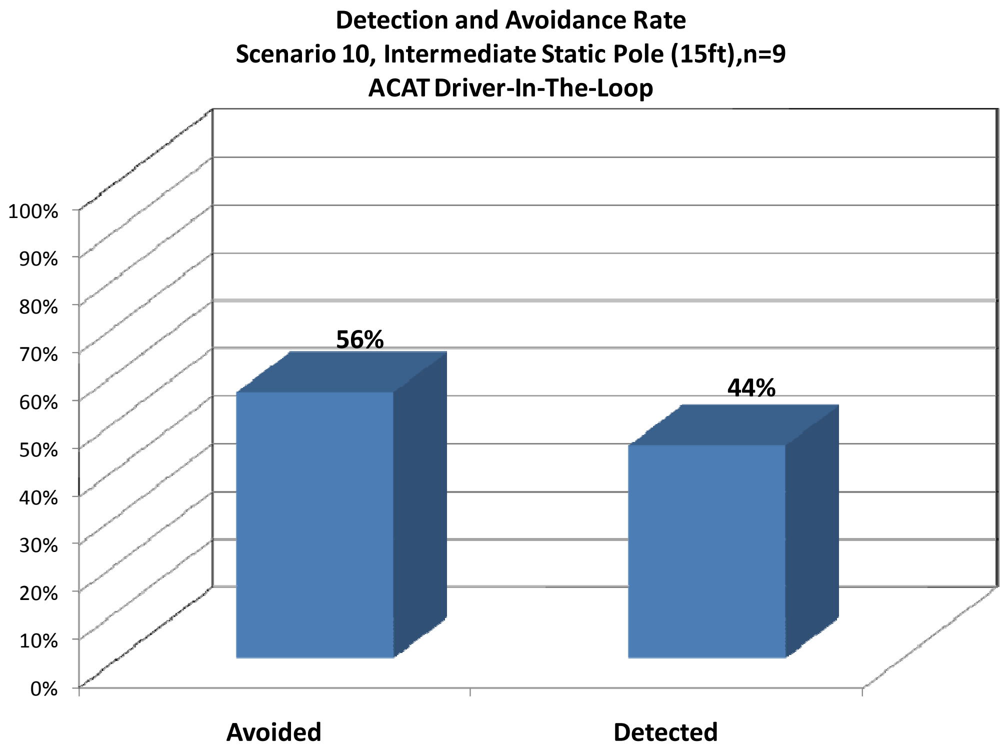


Figure 107. Avoidance and Detection Rates Vehicle Scenario 10

As presented earlier, nearly 56% of drivers (5 out of 9) in this scenario were unable to detect the rear obstacle during the conflict scenario. The time-course of detection is illustrated in Figure 108, and indicates that approximately 22% of drivers spotted the hazard while backing (via the Rear Vision system), with an additional 22% detecting the obstacle following automatic braking.

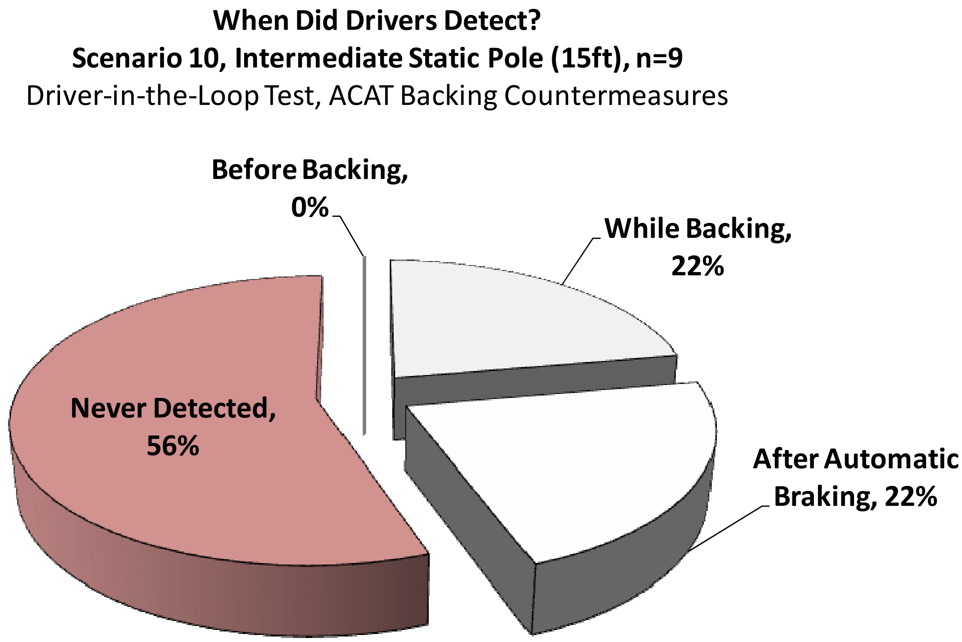


Figure 108. Detection Rates as a Function of Backing Phase

Countermeasure Activations

The test-bed vehicle afforded drivers an integrated suite of backing countermeasures comprised of Rear Vision, Park Assist, Backing Warning, and Automatic Braking. As a group, drivers were observed to exercise nearly all of these features under this backing scenario, with the exception of Backing Warning which was never activated (the backing warning feature is only active at backing speeds above 4 mph). Data are presented here which show the extent to which features were exercised by plotting the “highest” countermeasure received by drivers as a group. As described in Appendix B (Variable Coding Data Dictionary) the “highest” countermeasure represents the most intrusive or urgent level of intervention received by drivers (information, alert, warning, or active control assist); the approach views the available countermeasures along a continuum with Rear Vision representing the lowest form of intervention and Automatic Braking offering the highest level of intervention. Data are intended to show the progression through the backing countermeasures hierarchy (but do not necessarily assume drivers received each feature).

As depicted in Figure 109, none of the drivers stopped in response to information gathered from the Rear Vision system alone, likely due to the fact that the pole was not visible in the Rear Vision system during most of the scenario, and even when it was visible, it was very hard to detect. The number of drivers receiving only Park Aid and those experiencing Automatic Braking are almost evenly split, at 44% (4 out of 9) and 56% (5 out of 9), respectively. Activation of Automatic Braking also suggests that, in many cases, drivers largely failed to access or act on information provided by the Rear Vision and/or Park Aid systems. In the end, all participants received some form of alert, likely due to the noisy environment and length of the maneuver.

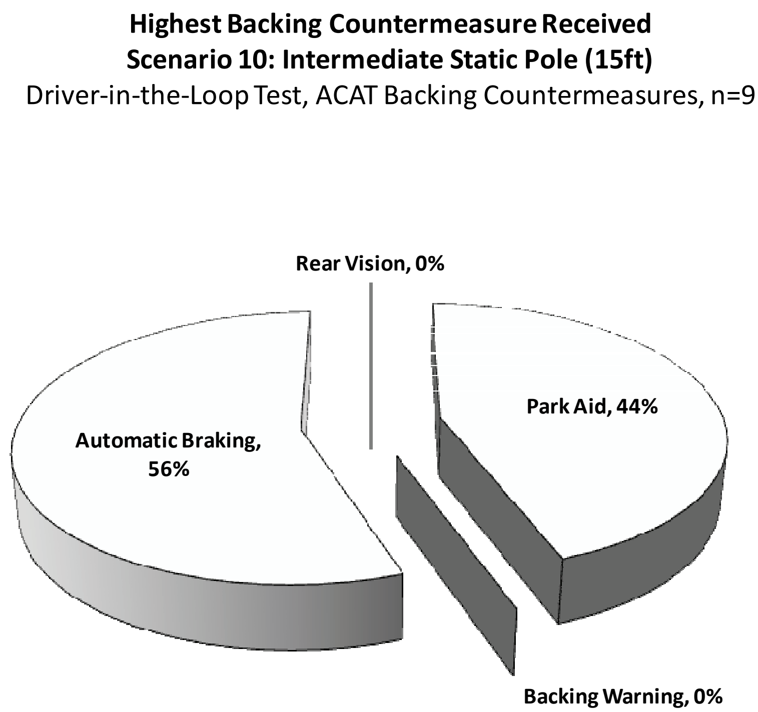


Figure 109. Highest Backing Countermeasure Received, Vehicle Scenario 10

Search Behavior & Glances to Rear Vision System

Analysts reviewed and scored the video to determine driver glance patterns during this conflict scenario, including the incidence of glances to the Rear Vision system display located on the dash above the center console area. Due to the length of this scenario, drivers were observed to make more frequent glances to the Rear Vision display, and therefore the categories in Figure 110 are not mutually exclusive. In all, over the course of the backing event, 89% of drivers (8 out of 9) were observed to make at least one glance to the Rear Vision system; only one driver (11%, or 1 out of 9) did not glance to the Rear Vision system during the event (and subsequently did not detect). Figure 110 breaks down the incidence of glances to the Rear Vision display as a function of maneuver phase – before backing, during backing, or following Automatic Braking. The vast majority of drivers (89%, or 8 out of 9) scanned the Rear Vision display before the onset of the Automatic Braking, but due to the scenario design the pole may not have been visible during many of these glances. Only one participant was observed to scan the Rear Vision display following Automatic Braking.

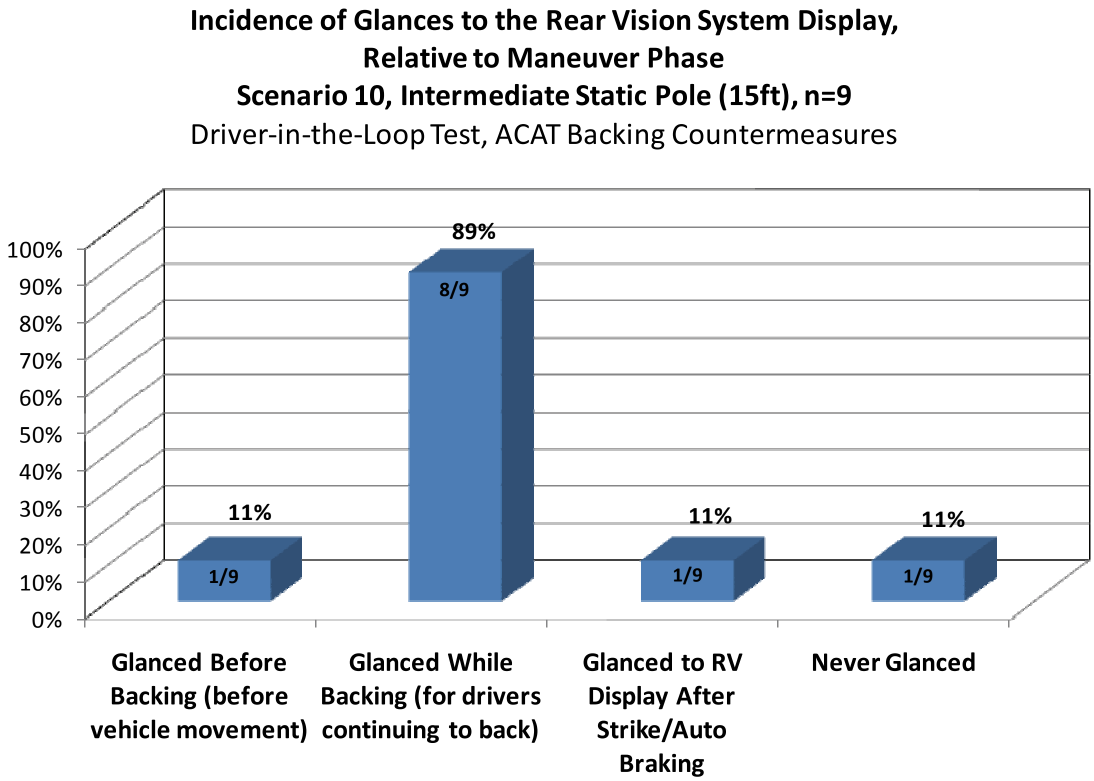


Figure 110. Incidence of Glances to the Rear Vision System Display as a Function of Backing Phase, Vehicle Scenario 10

Table 53 presents the glance frequencies and mean single glance durations to the Rear Vision system display during the surprise event trial.

Table 53. Frequency and Duration of Glances to the Rear Vision System Display Over the Course of the Pedestrian 3 Scenario Conflict Event

Reliance on RV System Display	Mean	Min	Max
Frequency of Glances to Display (number)	4.3	1	13
Duration of Single Glance to Display (seconds)	2.17	0.3	6

Summary of Driver Interactions with Countermeasures

This section summarizes driver interactions with the integrated backing countermeasure suite. It is important to recognize that the test-bed vehicle was equipped with a collection of inter-related backing countermeasures (Rear Vision, Park Aid, Backing Warning, and Automatic Braking) and drivers generally experienced several during the course of the conflict scenario (e.g., Park Aid alert and Automatic Braking). As a result, assessments of direct cause-and-effect relationships between individual feature outputs and driver responses are extremely difficult to determine. Nevertheless, this section makes an attempt to lay out driver responses to features, or more appropriately, feature combinations, by delineating the time-course of events identifying which countermeasure features were activated at the onset of the behavior.

A wide range of behaviors were observed as this conflict scenario unfolded and drivers backed toward the pole located 15 ft behind the vehicle. The backing event averaged 46 seconds in duration, ranging from 30 to 72 seconds. Some ignored system alerts and continued to back, while others responded to system outputs by searching and/or braking to a stop then attempted to verify or confirm the presence of an obstacle. Drivers were even observed to pull forward in response to the Automatic Braking before exiting the vehicle. Figure 111 maps out the interactions between each driver and the backing countermeasure suite during the pedestrian conflict scenario. The chart details the frequency with which each countermeasure was activated or accessed, and classifies drivers' responses and subsequent performance outcomes. The top row delineates each of the countermeasures, indicating the percentage of drivers who received or accessed the feature (note that these categories are not mutually exclusive since drivers may have received multiple countermeasures). For example, results show that none of the drivers detected the hazard while backing, while 100% of the sample received Park Aid alerts and 56% of drivers triggered the Automatic Braking feature. Driver responses to these countermeasures are specified in the body of the chart, with the bottom-most row showing the overall outcome indicating whether the obstacle was struck or avoided. The chart traces the interactions for a given driver (subject identification numbers are annotated within each major cell), showing which countermeasures were accessed and the behavioral responses and outcomes tied to the highest countermeasure received. Organizing the data in this form helps identify behavioral patterns and characteristics associated with countermeasure systems.

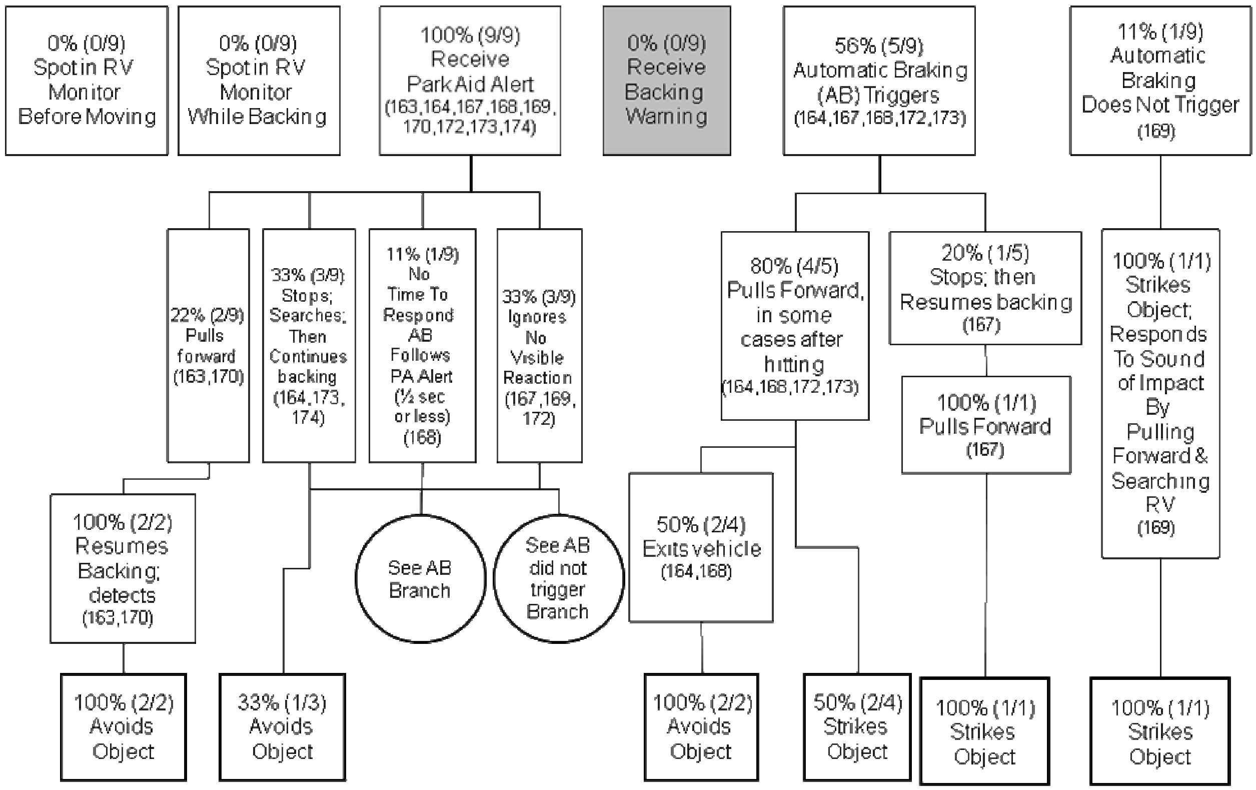


Figure 111. Driver Interactions and Responses to the Backing Countermeasures, Vehicle Scenario 10, Intermediate Static Pole

As illustrated in Figure 111, several aspects related to driver interactions under this particular scenario are noteworthy:

- 100% of drivers received Park Aid alerts under this scenario. Five of the nine participants stopped to either search the rear display or pull forward following first issuance of the alerts. Only the two that pulled forward actually detected the object. Four out of the nine drivers either ignored the Park Assist alerts or had insufficient time to respond.
- Automatic Braking under this particular scenario contributed to the 56% avoidance rate.
- All five drivers who received Automatic Braking did not search the display following activation. Four of these drivers pulled forward, two of whom exited the vehicle. One driver was observed to resume backing.

<u>Detection Failures: “Looked But Did Not See”</u>

Glances to the Rear Vision system display (as with glances to vehicle mirrors) may not always be accompanied by a detection response; it is possible for drivers to scan the display with the hazard present, yet fail to detect and/or recognize the obstacle. Due to the nature of this scenario, the obstacle was hidden and camouflaged in order to reduce its detectability. Therefore, “looked but did not see” glances should not be considered for this scenario.

6.8 Summary of Objective Tests and Results

A prototype suite of integrated backing crash countermeasures was evaluated and performance characterized using a set of objective test protocols which involved the application of 15 unique tests. These tests were designed to assess system parameters relating to response sensitivity to stationary and moving obstacles (of varying types and sizes) under a range of backing conditions, false alarm rates, and driver interactions and responsiveness to system information, warnings and interventions. Together, these test results provide data for use in a computer-based SIM model which is used to estimate the effectiveness and potential safety benefits of the backing crash countermeasure system evaluated.

Grid tests of system response performance measured the countermeasure system response to various obstacles. Data were used to define areas behind the vehicle where an object is likely to trigger a system response (i.e., response zones), response latencies, and lateral and longitudinal distances at first response as a function of object type, vehicle backing speeds, and object movement speeds.

Data from the False Alarm Performance tests aid in estimating the degree to which backing countermeasures may falsely activate under typical operating environments. Assessments required backing to over 40 unique test objects and features as part of a “test course.” Preliminary data were collected to derive false alarm rate estimates for a given countermeasure feature across each of the four operating environments tested (i.e., residential driveway, residential garage, commercial parking lot, and public city street) by supplying incident data for each of the individual test objects assessed. This does not, however, estimate false alarm rates across any given environment or countermeasure feature. While efforts were made to draw from a plausible range of environmental characteristics and elements commonly found in these environments, these are by no means exhaustive. The full range of potential situations and objects, as well as the base rate occurrences for these types of scenarios (i.e., the number of times any particular driver may experience these same conditions under normal usage), is unknown. Additional data are needed to understand and map the exposure rates for these specific situations. Regional variation in the driving environment and individual driving style are also likely to play a significant role in determining the incidence of false system activations.

Driver-in-the-Loop Performance tests characterized performance of the driver interacting with the system across a variety of conflict situations. Unlike the Grid tests, Driver-in-the-Loop tests are not meant to assess the system’s response performance. Rather, these tests yield measures of driver responsiveness to the information, warnings, and control assistance provided by the backing countermeasures. Tests were administered in five different scenarios encompassing pedestrian, vehicle, and fixed-object crash scenarios. Driver-in-the-Loop tests provide data necessary to model driver behavior in response to the integrated backing countermeasures. Some limitations in these tests are described below:

- Since drivers generally experienced several backing crash countermeasures during the course of a conflict scenario, assessments of direct cause-and-effect relationships between individual feature outputs and driver responses are extremely difficult to determine. The data collected more accurately describe driver response to feature combinations provided by the integrated system over the time-course of events.

- Data are based on a limited sample of drivers. Larger samples may produce more robust results. Pooling across the available Driver-in-the-Loop scenarios provides a means for increasing the available data set, but assumes that the data generalize across situations.

- Drivers were novice users, provided with only a basic level of understanding regarding the Park Aid and Rear Vision features. Limited training was necessary to mitigate novelty effects observed in other studies. No mention of the Backing Warning or Automatic Braking countermeasures was provided to drivers.

- Driver reliance and trust of system outputs can be an important moderating factor influencing behavior. Both are expected to be influenced by a number of parameters, including prior experience with and exposure to the backing countermeasure technologies, as well as the rate of false system activations (false alarm rate). Real-world exposure and experience with these countermeasures may influence drivers' reliance and trust.

- All testing was conducted with an experimenter in the vehicle.

While data from the three basic test types are summarized here, it is important to remember that these objective tests are designed to provide inputs to the SIM and not to provide direct assessment of system effectiveness. Results of different test types are presented in a manner to aid in understanding of how tests were measured, scored, and characterized in the SIM, however the results of any given test type, or subset of tests, should not be used in isolation, since the SIM model is required to integrate the performance results as a whole.

7 FINAL MODEL DESCRIPTION AND USE

7.1 Overview

The sections within this chapter are ordered based on the flow that a single execution of the SIM model would follow. Each section describes the function of each of the high-level structures within the SIM model (including inputs and outputs, when applicable), the key parameters and variables, summarizes how those parameters were derived (where applicable, references other sections of the document that contain more information about that derivation) and their default values, and explains the logic to transform inputs into outputs.

The process flow of the SIM model is depicted in Figure 112. This figure re-interprets the “Data Generation”, “Countermeasure Performance Analysis”, and “Safety Benefits” aspects of Figure 22 in the context of the GM/VTTI backing SIM. There are also some “Model Creation” aspects included in Figure 112, especially within the definition of variant and non-variant parameters, which are described in this chapter. This chapter includes a description of the model’s structure and content, which should facilitate the understanding of the “Validation/Calibration of model” process (contained in box #15 of Figure 22). This process, however, is discussed in more detail in the next chapter (Chapter 8). Specifically, the description in this chapter is designed to facilitate the understanding of each calibration and validation activity undertaken and discussed in chapter 8.

As shown in Figure 112, the initial modules of the SIM model define parameters that will remain fixed throughout the simulation (Non-Variant Parameters). Subsequent modules define parameters that change as the simulation progresses (Variant Parameters), which are defined inside the Simulation Control loops. For example, these may be parameters that are dependent on the scenario, or parameters that are dependent on whether a countermeasure component exists in the simulation trial being executed. Once all the parameters are defined, the SIM starts the Monte Carlo Simulation Model, which represents the core of the SIM. As that simulation process is completed, Simulation Output is obtained and aggregated. Once all simulation control loops are completed, Estimation of Safety Benefits is performed and the SIM produces those safety benefits as output. Note that the numbers in the figure refer to the respective section numbers in this chapter.

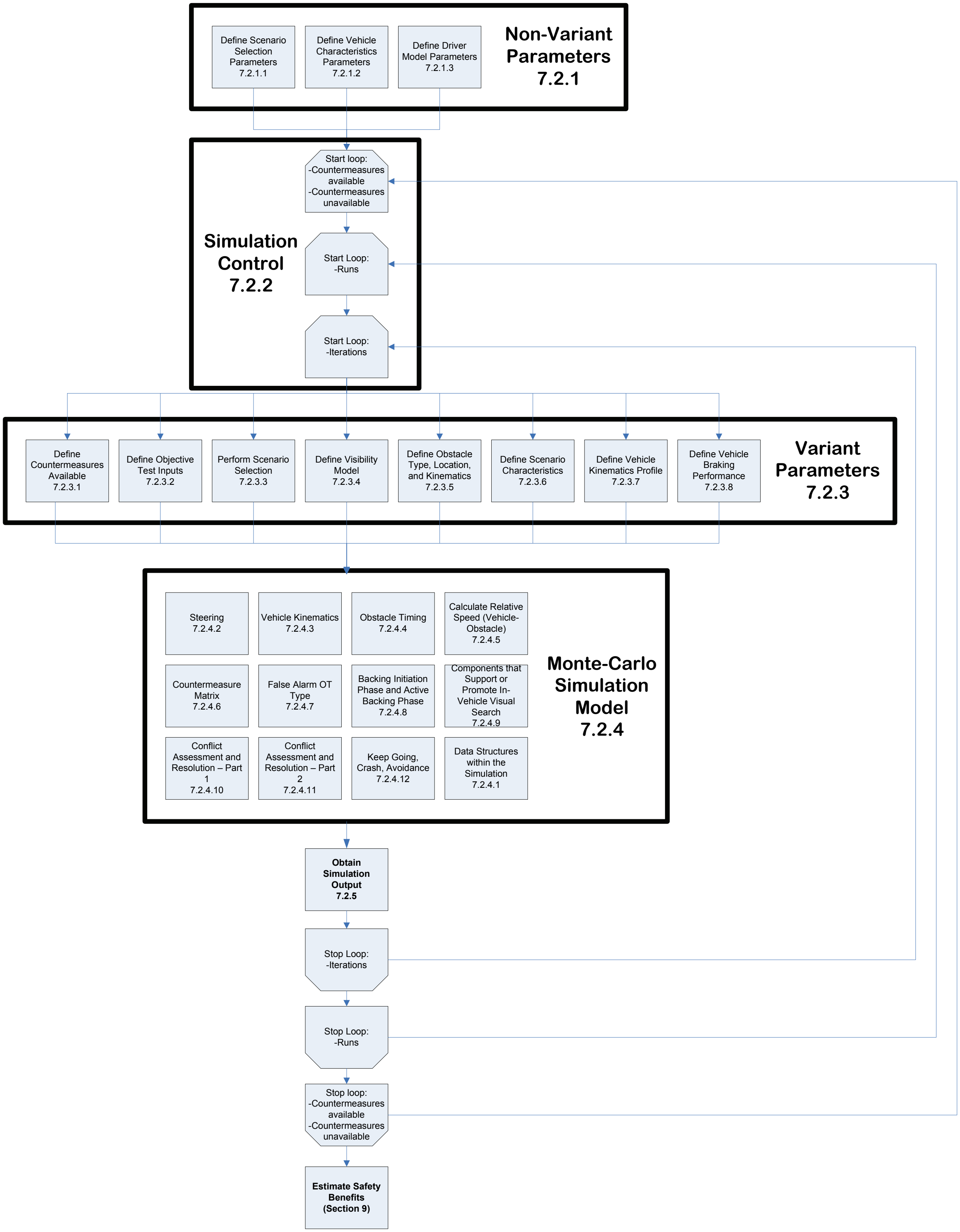


Figure 112. SIM Model Flowchart.

As depicted in the flowchart, the typical simulation flow follows a number of sequential steps. The high-level steps are implicit in the structure of the flowchart, and their discussion in this chapter follows the same order. Further discussion of these steps will be provided as the SIM model is discussed in more detail in subsequent sections.

An important component embedded throughout different parts of the simulation model is the use of generated random numbers to select values from different parameter distributions. The generator for these random numbers is periodically initialized within the simulation (see section 7.2.2) as the model flow progresses. The random numbers themselves are taken sequentially from the random number generator as required by the simulation flow. There are two different types of random number use approaches in the simulation. The first type refers to random numbers selected at the beginning of each iteration that remain fixed for its duration. For example, random numbers used to select the maximum speed for an iteration, the time duration for the backing maneuver, or comparison probabilities to the different look-up tables all conform to this fixed-value use-approach. The second type refers to random numbers that are used to select time-varying aspects of the simulation. These random numbers are periodically selected throughout each iteration until they are no longer needed. The main example of this use approach is the numbers used to generate the eyeglance locations, which are required periodically through the simulation. The presence of random numbers is ubiquitous in the Monte Carlo simulation model and its control code. Essentially, every time a parameter is represented as a statistical distribution, one or more random numbers will be required throughout an iteration.

7.2 Description of high-level simulation model structures

7.2.1 Non-variant Parameters

This section describes the various parameters that do not change through a single execution of the SIM. These parameters, while adjustable between SIM executions, set up the environmental, vehicle, and driver model conditions that are either independent of the scenario being executed or are stored in data structures that consider the scenario as one of their dimensions (which are later in the process used to select scenario-specific values).

Before undertaking this discussion, however, it is important to define the simulation flow. There are two terms that are important in this discussion as used with respect to the Monte Carlo simulation (but relevant also for this discussion): run and iteration. The Monte Carlo simulation portion of the SIM operates under two main loops. The first loop runs equivalent sets of simulations with the countermeasure(s) active and inactive. This allows for the estimation of the safety benefits by providing for a direct comparison between estimated crashes and estimated fatalities occurring with and without the countermeasure. Note that these equivalent sets of simulations do not include identical scenarios. Instead, different random selection processes are used to construct different scenario sets with countermeasures active and inactive. The random processes, combined with the large number of iterations executed for each run, combine to make the different sets of scenarios comparable from an analysis standpoint without being identical. The second loop runs independent sets of simulations.

Each of these independent sets of simulations is referred to as a "run." Each individual simulation within each "run" is referred to as an "iteration."

7.2.1.1 Scenario Selection

This initial stage of the SIM defines the list of one or more scenarios from which the different simulation iterations will be selected. The SIM provides the user with the capability to customize the list of scenarios that are used (from a minimum of 1 to a maximum of all 10). If more than one scenario is on the list, then the number of iterations is distributed equally (with round-off constraints) across the different scenarios. Note that this section of the SIM only allows the user to select the scenarios that are simulated; the relative weightings of those scenarios in calculating overall safety benefits is established in a different portion of the SIM (see Chapter 9 for more details on that process). Descriptions and depictions of the 10 scenarios are available in Section 5.2.8. Note that the scenarios were referred to interchangeably based on their description (e.g., Pedestrian Scenario 1) or their number (e.g., Scenario #1). Both are provided within the scenario descriptions.

The table below describes the variables and logic used in the scenario selection process. The Location of use within Monte Carlo model (LUMCM) descriptor indicates the simulation module within the Simulink environment where each variable is used. A LUMCM of N/A indicates variables that are not used in the simulation but are used within the control code that executes the simulation.

Relevant SIM Variables	
Variable	*Description/Possible Values*
ScenarioGen	▪ 1 for equal distribution of iterations amongst possible scenarios, 0 when only 1 scenario is being simulated ▪ ScenarioGen=1 (default) ▪ LUMCM: N/A
PossibleScenarios	▪ Matrix of possible scenarios, each column represents one scenario, from 1 through 10; a value of 0 indicates the scenario is not being simulated, 1 indicates the opposite ▪ PossibleScenarios= [1,1,1,1,1,1,1,1,1,1] (default) ▪ LUMCM: N/A
Logic:	
These two variables are used later to determine the particular scenario being used in a simulation iteration (i.e., single independent backing maneuver). That scenario is selected from all non-zero values of PossibleScenarios (if ScenarioGen is 1) or the first non-zero value from PossibleScenarios (if ScenarioGen is 0).	

7.2.1.2 Vehicle Characteristics

These parameters define the vehicle characteristics that are relevant for the simulation and are not affected by the simulated scenario. In the SIM, only vehicle width is defined as a non-variant vehicle characteristic.

Relevant SIM Variables	
Variable	*Description/Possible Values*
VehicleWidth	▪ Vehicle half-width (in meters). Defined as 1.01 m for the vehicle used in the testing (Chevrolet Tahoe), based on a specified width of 2.01 m. ▪ VehicleWidth=1.01 (default) ▪ LUMCM: ▪ BackingSIM/Conflict Assessment and Resolution – Part 2/Crash Checker
Logic:	
VehicleWidth is later used in the Monte Carlo simulation model to aid in determining whether a crash has occurred. If an obstacle is outside the track defined by the vehicle's width, then it cannot be hit by the vehicle. This parameter is especially applicable for scenarios with incurring obstacles.	

7.2.1.3 Driver Model Parameters

This portion of the SIM model defines the parameters and distributions that are used to infer driver behaviors during backing maneuvers. There are three main components: Brake Reaction Time, Braking Performance, and Glances. Behaviors related to controlling the speed and direction of the vehicle are described separately since they vary based on the type of maneuver being performed, which is in turn a direct function of the scenario(s) being simulated.

Note that these sections are limited to discussion of the parameters that are used in the SIM model and how they were implemented in the SIM model. Substantial effort was also directed to surveying the literature and previously proprietary work for applicable values of all of these parameters. That work is summarized within Chapter 4.

Brake Reaction Time Distribution

Parameters for a Weibull distribution fit were obtained for alerted and non-alerted reaction times, and implemented into the SIM as described in the table below (Description/Possible Values column).

Relevant SIM Variables	
Variable	*Description/Possible Values*
RTAlertedScale RTAlertedShape	Reaction time distribution parameters (in sec). LUMCM:

RTNonAlertedScale RTNonAlertedShape	▪ BackingSIM/Conflict Assessment and Resolution – Part 2/Driver Response to Detection ▪ Weibull distribution with mean of 0.82 sec and standard deviation of 0.34 sec translates into the following Scale and Shape parameters for use in the model: ▪ RTAlertedScale=0.9279 ▪ RTAlertedShape=2.5733 ▪ Parameters were obtained by shifting the Paine & Henderson (2001) empirical distribution to match the central tendency observed by Llaneras, McLaughlin, et al. (proprietary) ▪ Weibull distribution with mean of 1.11 sec and standard deviation of 0.36 sec translates into the following Scale and Shape parameters for use in the model: ▪ RTNonAlertedScale=1.2360 ▪ RTNonAlertedShape=3.3846 ▪ Parameters were obtained by shifting the Paine & Henderson (2001) empirical distribution to match the central tendency observed by Mazzae & Garrott (2006).
Logic:	
These values are used in determining a driver brake reaction time when the Monte Carlo simulation model determines that such a reaction is occurring. If the driver's response is triggered by an alert, then the RTAlerted parameters are used in finding a brake reaction time for the simulation iteration. Otherwise, the RTNonAlerted parameters are used.	

Braking Performance Distribution

The variables related to determining these values are shown in the following table.

Relevant SIM Variables	
Variable	*Description/Possible Values*
BrakeDataPeak BrakeDataAverage	Matrices containing the different data describing the distributions used to infer the parameters that are employed in the derivation of BrakePeakDecelerationXX and BrakeAverageDecelerationXX, respectively, which are used to represent braking parameters in the Monte Carlo simulation model. The matrices have three dimensions (10X2X2):

	scenario (10 different scenarios), whether an alert is being received (Alert or No Alert), and the parameter (Scale or Shape). All parameter values assume a Weibull distribution. Non-alerted Scenarios 1, 5, and 9: - Peak: Mean=0.10 *g*, Standard Deviation=0.02 *g* (translates to Weibull distribution parameters of scale=0.1125, shape=5.6094 in the model) - Average: Mean=0.31 *g*, Standard Deviation=0.07 *g* (translates to Weibull distribution parameters of scale=0.3404, shape=5.2445 in the model) Non-alerted Scenario 2: - Peak: Mean=0.09 *g*, Standard Deviation=0.01 *g* (translates to Weibull distribution parameters of scale=0.0932, shape=8.839 in the model) - Average: Mean=0.31 *g*, Standard Deviation=0.07 *g* (translates to Weibull distribution parameters of scale=0.3404, shape=5.2445 in the model) Non-alerted Scenarios 3, 4, 6, 7, 8 and 10: - Peak: Mean=0.11 *g*, Standard Deviation=0.03 *g* (translates to Weibull distribution parameters of scale=0.1263, shape=4.2134 in the model) - Average: Mean=0.31 *g*, Standard Deviation=0.07 *g* (translates to Weibull distribution parameters of scale=0.3404, shape=5.2445 in the model) Alerted All Scenarios: - Peak: Mean=0.33 *g*, Standard Deviation=0.07 *g* (translates to Weibull distribution parameters of scale=0.3572, shape=5.7115 in the model) - Average: Mean=0.22 *g*, Standard Deviation=0.03 *g* (translates to Weibull distribution parameters of scale=0.2336, shape=7.704 in the model) LUMCM: N/A
AutoBrakeMaximum AutoBrakeSlope	Matrices containing the different data describing the automatic braking system performance based on maximum acceleration achieved and the rate at which that acceleration is attained.

	AutoBrakeMaximum=0.95 (*g*) AutoBrakeSlope=2 (*g*/sec) LUMCM: BackingSIM/Conflict Assessment and Resolution – Part 2/REB Response to Detection

Logic:
The BrakeDataXXX variables are repositories of the data described in this section. They are used to update BrakePeakDecelerationXXX and BrakeAverageDecelerationXXX, which are described later, and are directly used in the Monte Carlo simulation. Updates to these variables occur based on the scenario being simulated on an iteration. The AutoBrakeXXX variables are used directly in the Monte Carlo simulation model to define the deceleration profile generated by the automatic braking countermeasure if it is activated in a specific simulation trial.

Glances Distributions

The following table summarizes the variables defined in this section of the control code.

Relevant SIM Variables	
Variable	*Description/Possible Values*
OverLeftShoulderXXXX ForwardXXXX InstrumentPanelXXXX LeftMirrorXXXX CenterMirrorXXXX OtherXXXX OverRightShoulderXXXX ProxDisplayXXXX RightMirrorXXXX EnhancedVisionXXXX	These variables each represent three different parameters that describe Weibull distributions for glance durations to different locations that are visually accessed during backing maneuvers. There are three variables per location, with XXXX being replaced by either: - Location: Weibull distribution location parameter - Scale: Weibull distribution scale parameter - Shape: Weibull distribution shape parameter The values were derived by Garrott (S. Wilson, personal communication, February 9, 2009) based on data collected for the ORSDURVS study (Mazzae et al., 2008). Values are as follows: Values for glances over the left shoulder: Mean=4.59 sec, Standard Deviation=4.97 sec, translating to the following values in the model: - OverLeftShoulderLocation=0.07 - OverLeftShoulderScale=4.325 - OverLeftShoulderShape=0.911 Values for glances forward: Mean=1.83 sec, Standard Deviation=3.21 sec, translating to the following values in the model: - ForwardLocation=0.07 - ForwardScale=1.12 - ForwardShape=0.58208

	Values for glances to the instrument panel: Mean=2.24 sec, Standard Deviation=3.62 sec, translating to the following values in the model: - InstrumentPanelLocation=0.07 - InstrumentPanelScale=1.519 - InstrumentPanelShape=0.62594 Values for glances to the left mirror: Mean=2.02 sec, Standard Deviation=3.32 sec, translating to the following values in the model: - LeftMirrorLocation=0.07 - LeftMirrorScale=1.339 - LeftMirrorShape=0.61548 Values for glances to the center mirror: Mean=1.54 sec, Standard Deviation=2.58 sec, translating to the following values in the model: - CenterMirrorLocation=0.07 - CenterMirrorScale=0.98 - CenterMirrorShape=0.60099 Values for glances to other locations: Mean=2.12 sec, Standard Deviation=3.60 sec, translating to the following values in the model: - OtherLocation=0.05 - OtherScale=1.39 - OtherShape=0.6048 Values for glances over the right shoulder: Mean=3.29 sec, Standard Deviation=4.80 sec, translating to the following values in the model: - OverRightShoulderLocation=0.08 - OverRightShoulderScale=2.487 - OverRightShoulderShape=0.68652 Values for glances to the proximity display: Mean=2.05 sec, Standard Deviation=1.59 sec, translating to the following values in the model: - ProxDisplayLocation=0 - ProxDisplayScale=2.28886 - ProxDisplayShape=1.66394 Values for glances to the right mirror: Mean=1.88 sec, Standard Deviation=3.45 sec, translating to the following values in the model: - RightMirrorLocation=0.05 - RightMirrorScale=1.13 - RightMirrorShape=0.56802 Values for glances to the enhanced vision display: Mean=2.40 sec, Standard Deviation=3.97 sec, translating to the following values in the model: - EnhancedVideoLocation=0.08 - EnhancedVideoScale=1.58 - EnhancedVideoShape=0.61213

	LUMCM: BackingSIM/Conflict Assessment and Resolution – Part 1/Glance Behavior/Glance/Glance Time Generator
EyeglanceSequence	Matrix with five dimensions, initialized to zeros. Defines the next glance location based on five input parameters: - Whether Enhanced Vision is available as a countermeasure (Yes/No) - Which Driver-Vehicle-Interface (DVI) is active (0 through 4, representing None, Proximity Information, Cautionary Warning, Imminent Warning, and Automatic Braking) - A randomly selected probability, ranging from 0.025 to 1 in increments of 0.025. The probability value is used to select the closest value from the matrix (e.g. if the input probability is 0.070, then the value corresponding to 0.075, which is closer than the value corresponding to 0.050, would be selected). - Duration of current glance (<1.75 sec, >=1.75 sec, <3 sec, >= 3 sec) - Location of the current glance (glance location codes below) Numbers in the matrix represent glance locations, as follows: 1- Forward 2- Left Mirror 3- Right Mirror 4- Center Rearview Mirror 5- Over the Right Shoulder Glance 6- Center Stack/Enhanced Vision Display 7- Proximity Information Display 8- Over the Left Shoulder Glance 9- Other 10- Instrument Panel Each glance location is represented proportionally to the probability that it will follow the current glance. For example, if the current glance (given its location and characteristics) is followed by a forward glance 20% of the time, then 20% of the values in the matrix corresponding to the current conditions will be “1”. It is relevant to note that eyeglance sequence data

	on DVIs that were present in the absence of enhanced video were not available. Therefore, these conditions are not considered in the SIM model. However, driver-in-the-loop objective tests for such a system would provide the necessary information. Given the size of the table, the numbers used in the simulation are not included in this document, but can be observed in the source code for the SIM. LUMCM: BackingSIM/Conflict Assessment and Resolution – Part 1/Glance Behavior/Glance/EyeglanceSequence
Logic:	
The Location, Scale, and Shape parameters are passed to the Monte Carlo simulation model to be used to generate glance durations as new glances are needed during a single independent iteration. The EyeglanceSequence variable is also passed directly to the Monte Carlo simulation model, and used in a look-up table that selects the next glance based on the current values for the parameters that are included in the matrix. A look-up table is a data structure within the simulation that produces as an output the content of the cell that represents the intersection of all its input values. Interpolation or extrapolation within the table may be used as necessary.	

7.2.2 Simulation Control

With the non-variant parameters established, the next section of the simulation defines how the Monte Carlo simulation will be executed, which depends on the concepts of "run" and "iteration" that were previously discussed in section 7.2.1. When each simulation iteration is completed, there is either an avoidance or crash outcome. These outcomes are aggregated for all iterations within a run, allowing for the averaging of estimates and subsequent calculation of statistical confidence intervals for the estimates that are obtained. For example, a simulation with 5 runs and 50 iterations per run will be run 500 times (5 runs X 50 iterations per run with countermeasures on and 5 runs X 50 iterations per run with countermeasures off). For each countermeasure state, there would be 50 values aggregated to determine the output. A potential question is: why are both runs and iterations necessary? Following the example, why is running 1 run with 250 iterations for the countermeasure on and then 1 run with 250 iterations for the countermeasure off different from running 5 runs of 50 iterations each? The combination of both iterations and runs allows for the estimation of statistical bounds for the average effectiveness and benefits obtained as an output of the SIM. Note that these measures are calculated independently for each run. Since the equations used to calculate these measures become unstable with low numbers of iterations per run (e.g., the denominator may be close to zero, or zero) the estimates cannot be calculated for a single iteration or for a run consisting of a single iteration. The alternative is to group iterations, calculate an effectiveness for that group (which becomes a "run"), and then average results across runs, which is the approach employed in the SIM. The following table describes the parameters that are used in the control code to establish the two Monte Carlo simulation control loops and some other constraints on the Monte Carlo simulation.

Relevant SIM Variables	
Variable	*Description/Possible Values*
wholeindex	Controls the simulation flow by determining whether countermeasures are active (1) or inactive (2) in the current loop. Each of these loops has the same number of runs associated with it. LUMCM: N/A
NumberofRuns	The number of runs that will be completed for the simulation for conditions where the countermeasure is available and/or active and for conditions where the countermeasure is unavailable and/or inactive. Runs are composed of iterations. NumberofRuns=5 (default) LUMCM: N/A
NumberofIterations	The number of independent simulations that will be completed for each run. NumberofIterations=1000 (default) LUMCM: N/A
MaxTime	Maximum time (in sec) that the simulation will be allowed to run. The value is set to be high enough to not interfere with a run unless there is an error that causes the simulation not to converge to an outcome. MaxTime=90 (default) LUMCM: BackingSIM/Conflict Assessment and Resolution – Part 2
Logic:	
These variables are used within the simulation control program to determine the number of times the Monte Carlo simulation model is executed, whether the countermeasures are available in a particular simulation iteration, and the maximum time (i.e., simulation time) that the simulation is allowed to run.	

In order to ensure that the simulations within each run are independent, the random number seed is re-initialized for each run, as described in the table below.

Relevant SIM Variables	
Variable	*Description/Possible Values*
RandomSeed	Establishes a random number seed to initialize the random number generator. LUMCM: N/A
Logic:	
The random number seed is re-initialized for every run so that results from different runs are independent. Different seed values are ensured by initializing the seed based on the value for the current time, which is a non-repeating vector.	

7.2.3 Variant Parameters

At this point in the SIM, those parameters that are not affected by the scenario being modeled or the countermeasures that are available have been defined. The next step in the control code prior to calling the Monte Carlo simulation model is to define those parameters that will be used in the simulation model and are dependent on scenario and/or countermeasure availability. Those definitions are described in this section.

7.2.3.1 Countermeasures

This section of the SIM identifies the components of the countermeasure suite, any interactions between the different components, and whether they are available to the driver for a particular scenario. The user of the SIM controls this availability. Unless otherwise specified in this section of the SIM, countermeasure components are assumed to be independent in their operation. Therefore, any combination of available countermeasure components is possible. It is up to the user to ensure that the suite of countermeasures available in the SIM is an accurate reflection of the suite available in the real world.

Relevant SIM Variables	
Variable	*Description/Possible Values*
VehicleApproach	Whether this countermeasure is available and/or active (0 represents inactive, 1 represents active) VehicleApproach=0 (default, regardless of countermeasure availability, since countermeasures active during the Vehicle Approach phase were outside of the scope of the project) LUMCM: BackingSIM/Countermeasure Matrix
EnhancedVisibility	Whether this countermeasure is available and/or active (0 represents inactive, 1 represents active) LUMCM: BackingSIM/Countermeasure Matrix
ProximityInformation	Whether this countermeasure is available and/or active (0 represents inactive, 1 represents active) LUMCM: BackingSIM/Countermeasure Matrix
Warning Stage1	Whether this countermeasure is available and/or active (0 represents inactive, 1 represents active) LUMCM: BackingSIM/Countermeasure Matrix
WarningStage2	Whether this countermeasure is available and/or active (0 represents inactive, 1 represents active) LUMCM: BackingSIM/Countermeasure Matrix
AutomaticBraking	Whether this countermeasure is available and/or active (0 represents inactive, 1 represents active) LUMCM: BackingSIM/Countermeasure Matrix
BackInitSpeedThreshold	This variable illustrates an example of non-independence between countermeasure systems. For the countermeasure suite of interest, there are changes in the availability of Proximity Information and the Backing Warning (both Cautionary and Imminent) based on the vehicle speed. This variable contains the value for the speed threshold at which these changes occur. LUMCM: ▪ BackingSIM/Active Backing Phase ▪ BackingSIM/Backing Initiation Phase

Logic:
Other than VehicleApproach, all of the variables denoting countermeasure availability are set to 1 when wholeindex (see previous section) is 1, and 0 otherwise. VehicleApproach is always zero. Each of these variables is used directly in the Monte Carlo simulation model to define the availability of the countermeasures to the driver in any particular iteration. BackInitSpeedThreshold is also used directly in the Monte Carlo simulation model to appropriately switch over the countermeasure availability as the speed of the vehicle in an iteration changes. Additional countermeasures (or relationships between countermeasures) could be added by incorporating new variables in this section and updating the simulation diagram accordingly.

7.2.3.2 Objective Test Inputs

Although objective test inputs are not variant within iterations, the portion of the inputs that is used in the Monte Carlo simulation model changes based on the characteristics of the scenario and the availability of various countermeasures. The objective test inputs are discussed in detail as part of Chapter 8. The reader is referred to that chapter for details concerning the implementation of these test results into the SIM.

7.2.3.3 Scenario Selection

With the definition of parameters that come from the objective test results, the control code then proceeds to select the scenario that will be modeled for the iteration. Note that from this point on in the discussion, these steps are repeated as many times as there are iterations required. Once each Monte Carlo simulation iteration is completed and its results stored, this set of variables is reinitialized for a new iteration. For each iteration, a scenario must be selected, and that is achieved through the variable shown in the next table.

Relevant SIM Variables	
Variable	*Description/Possible Values*
SelectedScenarios	Identifies the scenario being simulated on a particular simulation iteration by number, from 1 through 10 LUMCM: ▪ BackingSIM/Backing Initiation Phase/Proximity Information ▪ BackingSIM/Backing Initiation Phase/Automatic Braking ▪ BackingSIM/Active Backing Phase/Cautionary Backing Warning ▪ BackingSIM/Active Backing Phase/Imminent Backing Warning ▪ BackingSIM/Active Backing Phase/Automatic Braking

	▪ BackingSIM/Conflict Assessment and Resolution – Part 2/Crash Checker ▪ BackingSIM/False Alarm OT Type ▪ BackingSIM/Steering ▪ BackingSIM/Vehicle Kinematics
Logic:	
For every iteration within every run, SelectedScenarios is updated to reflect the scenario to be simulated, either selected from available scenarios within PossibleScenarios (if ScenarioGen is 1) or the first non-zero value from PossibleScenarios (if ScenarioGen is 0). The SelectedScenarios variable is submitted to the Monte Carlo simulation to restrict the simulation to the scenario of interest for the iteration.	

7.2.3.4 Visibility Model

These parameters define the outside visibility through mirrors and the vehicle backlite, as shown on the next table. These parameters are scenario-specific because in certain scenarios where visual occlusion of the obstacle is present, portions of the visibility matrices (representing visibility probabilities) are zeroed out. This occurs as follows:

- Scenarios 1, 5, and 9: lateral obstacle visibility beyond the width of the vehicle is not possible (there are vehicles parked on both sides of the subject vehicle)
- Scenario 2: lateral visibility of the obstacle beyond the right side of the subject vehicle is not possible (subject vehicle is initially parked alongside a vehicle on the right)
- Scenario 6: lateral visibility of the obstacle beyond the left side of the subject vehicle is not possible (there is visual clutter on the left side of the driveway)

Relevant SIM Variables	
Variable	*Description/Possible Values*
LeftMirrorOTProxGrid	Defines the visibility of obstacles within the left mirror. Matrix with three indices: - Obstacle Type - Longitudinal obstacle distance from rear bumper - Lateral obstacle distance from rear bumper Each matrix cell contains the probability (0…1) that an obstacle will be visible in the left mirror if it is located a certain longitudinal and lateral distance from the rear bumper. Obstacles are assumed to not be visible when placed outside the grid's boundaries. Longitudinal boundaries range from 19.5 m in front of the rear bumper (to allow for a complete representation of mirror visibility, but these forward locations are not used in any of the scenarios for this project) to 89.5 m behind the

	rear bumper. Lateral visibility is assessed from 34.5 m driver's left to 34.5 m driver's right (79 m wide). Visibility in the left mirror is assumed to be equivalent across obstacles and independent of any Driver-Vehicle Interface that is active. The data were obtained from Mazzae and Garrott (Mazzae & Garrott, 2008). Data from their two different driver anthropometries were combined by calculating joint detection probabilities. LUMCM: BackingSIM/Components that Support or Promote In-Vehicle Visual Search/Left Side Mirror
RightMirrorOTProxGrid	See description for LeftMirrorOTProxGrid. LUMCM: BackingSIM/Components that Support or Promote In-Vehicle Visual Search/Right Side Mirror
RearViewMirrorOTProxGrid	See description for LeftMirrorOTProxGrid. Not directly available from Mazzae and Garrott (2008), but derived from their direct glances visibility data by using only data indicating visibility within the vehicle's C pillars. LUMCM: BackingSIM/Components that Support or Promote In-Vehicle Visual Search/Rear View Mirror
OvertheShoulderOTProxGrid	See description for LeftMirrorOTProxGrid. Derived from Mazzae and Garrott (2008) direct glances visibility data. LUMCM: BackingSIM/Components that Support or Promote In-Vehicle Visual Search/Over-the-Shoulder Glance

Logic:

All of these variables are read directly into the Monte Carlo simulation model and used to determine whether an obstacle is visible in any of the vehicle's mirrors.

7.2.3.5 Obstacle Type, Location, and Kinematics

The parameters in this section fully determine the characteristics of the obstacle within each Monte Carlo simulation iteration. Important parameters include the type of obstacle, the initial location, whether the obstacle is static or dynamic, and the characteristics of the obstacle's motion that will allow for a crash to occur if no driver or automatic intervention occurs.

Relevant SIM Variables	
Variable	*Description/Possible Values*
NoObstacle	Whether an obstacle will always be present for all iterations (0), or if no obstacle will be present (1) for a subset of the iterations. Default value is zero. LUMCM: N/A
NoObstacleProbability	If NoObstacle=1 then this variable is used to define the probability (0…1) that an obstacle will not be present. Default value is one (i.e., if it is possible than an obstacle may not be present, it will never be present). LUMCM: N/A
ObstacleAbsence	Determined randomly based on the value of NoObstacleProbability. If the variable is 1, no obstacle will be present for the current iteration; if it is 0, then there will be an obstacle present. LUMCM: N/A
ObstacleType	Define what the obstacle type present in the scenario is. Possible values are: - 0 – No obstacle - 1 – Two-year old pedestrian standing - 2 – Two-year old pedestrian sitting - 3 – Two-year old pedestrian lying prone - 4 – Five-year old standing pedestrian - 5 – Vehicle - 6 – Fixed pole LUMCM: BackingSIM/Obstacle Timing
ObstacleStatic	Whether the obstacle is static or not (0 represents static, 1 represents moving) LUMCM: BackingSIM/Obstacle Timing
ObstacleStrikingPoint	Only applicable to moving pedestrian obstacles. Location on the rear bumper where a moving

	obstacle is expected to be struck. Expressed as a proportion of vehicle width; limited to 90% of each half-width (-0.9 … 0.9). Negative values imply impact on the driver's left side, positive values imply the right side. The obstacle's kinematics and initial location are adjusted so that, after considering the likely vehicle kinematics, the obstacle will be struck by the area in the rear bumper defined by this variable. LUMCM: N/A
ObstaclePositionLimits	Only applicable to static obstacles (in meters). The area behind the vehicle in which an obstacle may be initially located. Composed of four distances from the rear bumper to the obstacle: - Minimum longitudinal distance - Maximum longitudinal distance - Minimum lateral distance - Maximum lateral distance Note that this variable does not imply the obstacle is mobile, it simply allows for some randomness in the initial obstacle location across simulation iterations; however, the obstacle can be defined to remain in the same initial location across iterations by specifying equal minimum and maximum longitudinal and lateral distances. Default values for each obstacle are based on the scenario definitions: - Pedestrian Scenario 1: [1.524,1.524,0,0] (5 feet) - Pedestrian Scenario 2: [7.62,7.62,2.5*VehicleWidth,2.5*VehicleWidth] (25 feet for longitudinal distance, 2.5 times the vehicle width for lateral distance) - Pedestrian Scenario 3: [4.572,4.572,-0.6096,-0.6096] (15 feet,-2 feet) - Pedestrian Scenario 4: N/A - Pedestrian Scenario 5: N/A - Pedestrian Scenario 6: N/A - Vehicle-Vehicle Scenario 1: [1.524,1.524,0,0] (5 feet) - Vehicle-Vehicle Scenario2: N/A - Vehicle-Vehicle Scenario 3: [7.62,7.62,0,0]; (25 feet) - Vehicle-Fixed Object Scenario 1: [4.572,4.572,0,0] (15 feet) Minimum and maximum values are set equally so

	that static obstacles are always at the same location relative to the vehicle's rear bumper. LUMCM: N/A
ObstaclePositionLong	Distance in meters. Longitudinal distance between the obstacle and the vehicle at the start of the simulation. Calculated based on the values for ObstaclePositionLimits. Only positive values are valid. LUMCM: BackingSIM/Obstacle Timing/Dynamic Obstacle BackingSIM/ObstacleTiming/Static Obstacle
ObstaclePositionLat	Distance in meters. Lateral distance between the obstacle and the vehicle at the start of the simulation. For static obstacles, it is calculated based on the values for ObstaclePositionLimits. For dynamic obstacles, it is calculated based on the obstacle speed and striking point (if defined). Negative values imply a location on the driver's left hand side, positive values the right hand side. LUMCM: BackingSIM/Obstacle Timing/Dynamic Obstacle BackingSIM/ObstacleTiming/Static Obstacle
ProbabilityofPreviewData	Defines, on a scenario by scenario basis, the probability (0…1) that there are obstacles around the vehicle (e.g., other vehicles) that obstruct the driver's view of dynamic obstacles approaching from the sides. Given that scenarios are precisely defined, default values are either one (no sight-impairing obstacles are present) or zero (there are sight-impairing obstacles on both sides of the subject vehicle). LUMCM: N/A
ProbabilityofPreview	Holds the value for the probability (0…1) selected from ProbabilityofPreviewData for the current scenario. This value is used to decide whether the obstructed or unobstructed line-of-sight objective test results are applicable to (and should be used for) the current scenario. LUMCM: N/A
ObstacleSpeedLong	Obstacle speed in the longitudinal direction in m/s. Since none of the scenarios have obstacles moving in the longitudinal direction, this variable is always

	zeroed. LUMCM: BackingSIM/Obstacle Timing/Dynamic Obstacle
ObstacleSpeedLat	Obstacle speed in the lateral direction (m/s). For pedestrians, determined assuming a uniform distribution of walking speeds based on Cavagna, Franzetti, & Fuchimoto (1983). These authors limit locomotion speed between 0.78 and 1.39 m/s for children from 2 to 12 (and subsequently into adulthood). For vehicle-to-vehicle crash scenarios, a 25 mph limit is assumed for a residential area, resulting in an assumption of uniformly distributed vehicle speeds between 10 mph and 20 mph (4.47 m/s and 8.94 m/s). LUMCM: BackingSIM/Obstacle Timing/Dynamic Obstacle
Logic:	
These variables are updated once for every iteration of the simulation and provide the basis for the different vehicle and obstacle (as applicable) positions and kinematics observed for every iteration. Unless otherwise specified, each of these variables is read directly into the Monte Carlo simulation model.	

In addition to these variables, a separate data collection effort was undertaken to characterize the dimensions (i.e., effective height and width) of the different obstacles used in the objective tests and integrate them into the SIM. This integration was accomplished via a look-up table. The following table describes the location of this particular look-up table, its input dimensions, and resultant values.

SIM Module Location (Look-up table):	BackingSIM/Obstacle Timing/Obstacle Height and Width Cross-Sectional, in meters
Data	
Obstacle Type – Description – Dimensions 1 – Two-year old pedestrian standing – (H X W, meters) 0.83 X 0.25 2 – Two-year old pedestrian sitting - (H X W, meters) 0.56 X 0.25 3 – Two-year old pedestrian lying prone - (H X W, meters) 0.13 X 0.84 4 – Five-year old pedestrian standing sideways to vehicle - (H X W, meters) 1.12 X 0.15 5 – Vehicle (represented by ISO pole) - (H X W, meters) 1.02 X 0.08 6 – Pole - (H X W, meters) 1.20 X 0.30	

7.2.3.6 Scenario Characteristics

While the definition of the obstacle type, location, and kinematics (discussed in the previous section) and the vehicle kinematics (discussed in the next section) specifies most of the scenario that is simulated on each iteration, it is also necessary to specify some additional characteristics of the scenarios. The variables on the following table are used to complete that specification.

Relevant SIM Variables	
Variable	*Description/Possible Values*
LowerBackingDistanceX LowerBackingDistanceY	Minimum distance that the vehicle's driver intends to travel to accomplish their desired maneuver. Defined based on the description of each scenario to ensure that 1) there is the opportunity for a crash if there is no countermeasure intervention and the driver fails to detect the obstacle prior to impact, and 2) that if there was no opportunity for an impact (e.g., there is no obstacle presence), the next step the driver would have to perform would be to move the gear selector to start moving forward. X refers to longitudinal distance traveled, whereas Y refers to lateral distance traveled. Used to calculate PlannedBackingDistance, as discussed in the Vehicle Kinematics Profile section. LUMCM: N/A
UpperBackingDistanceX UpperBackingDistanceY	Maximum distance that the vehicle's driver intends to travel to accomplish their desired maneuver. As for the LowerBackingDistance variables, these are defined based on the description of each scenario to ensure that 1) there is the opportunity for a crash if there is no countermeasure intervention and the driver fails to detect the obstacle prior to impact, and 2) that if there was no opportunity for an impact (e.g., there is no obstacle presence), the next step the driver would have to perform would be to move the gear selector to start moving forward. X refers to longitudinal distance traveled, whereas Y refers to lateral distance traveled. Used to calculate PlannedBackingDistance, as discussed in the Vehicle Kinematics Profile section. LUMCM: N/A
TargetPosition	Distances in meters. Only applicable to scenarios where the driver is backing to a known object

	("target" – for example, the rearward vehicle in a parking space, a wall, a parking barrier, or the street). The area behind the vehicle in which a target may be initially located. Composed of four distances from the rear bumper to the target: - Minimum longitudinal distance - Maximum longitudinal distance - Minimum lateral distance - Maximum lateral distance Note that this variable does not imply the target is mobile, it simply allows for some randomness in the initial target location across simulation iterations; however, the target can be defined to remain in the same initial location across iterations by specifying equal minimum and maximum longitudinal and lateral distances. Default values for each target are based on the scenario definitions. Minimum and maximum values are set equally so that targets are always at the same location relative to the vehicle's rear bumper. LUMCM: N/A
TargetPositionLong	Distance in meters. Longitudinal distance between the target and the vehicle at the start of the simulation. Calculated based on the values for TargetPosition. Only positive values are valid. LUMCM: BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2/Distance to Target BackingSIM/Vehicle Kinematics/Used for Vehicle Scenario 3/Distance to Target
TargetPositionLat	Distance in meters. Lateral distance between the target and the vehicle at the start of the simulation. Calculated based on the values for TargetPosition. Negative values imply a location on the driver's left hand side, positive values the right hand side. LUMCM: BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2/Distance to Target BackingSIM/Vehicle Kinematics/Used for Vehicle Scenario 3/Distance to Target

Logic:
These variables are updated once for every iteration of the simulation and provide the basis for the vehicle's planned backing distance (further discussed in the next section) and the target position (as applicable) observed for every iteration. The variables are read directly into the Monte Carlo simulation model.

7.2.3.7 Vehicle Kinematics Profile

The table below describes the different variables that provide all the kinematics information to the simulation model.

Relevant SIM Variables	
Variable	*Description/Possible Values*
HurriedBacking	Probability (0…1) that the backing maneuver is performed under time constraints. Assumed arbitrarily, since exposure data indicating the frequency of this backing condition are not available. Default value is 0.10 (~10% of simulation iterations). LUMCM: N/A
MeanMaxSpeed SDMaxSpeed	Mean and standard deviation (in m/s) of the maximum speed that will be reached for a backing maneuver. These are treated as μ and σ parameters of a normal distribution for finding the particular maximum speed applicable to each simulation iteration. LUMCM: N/A
MeanMinimumDistance SDMinimumDistance	Mean and standard deviation (in meters) of the minimum distance that a driver will allow between their vehicle and a target object they are backing to. These are treated as μ and σ parameters of a normal distribution in finding the particular minimum distance applicable to each simulation iteration. LUMCM: N/A
PlannedBackingDistanceX PlannedBackingDistanceY PlannedBackingDistance	How much distance (in meters) the planned backing behavior would cover if it wasn't interrupted by a collision with an obstacle in the 'X' (longitudinal) and 'Y' (lateral) directions as well as an overall distance based on the expected vehicle's travel path. Depending on the scenario, the expected travel

	path may be straight or curved. PlannedBackingDistance for straight paths is calculated as a straight-line distance. For curved paths, it is calculated assuming that paths follow a parabolic shape during their curved sections. LUMCM: *PlannedBackingDistanceX and Y* BackingSIM/Steering/Used for all curved backing scenarios except parallel parking/Curved Segment BackingSIM/Steering/Used for all parallel parking scenarios/Curved Segment *PlannedBackingDistance* BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2 BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2/Coasting to Planned Distance/Coasting1 BackingSIM/Vehicle Kinematics/Used for Vehicle Scenario 3 BackingSIM/Vehicle Kinematics/Used for Vehicle Scenario 3/Coasting to Planned Distance/Coasting1 BackingSIM/Vehicle Kinematics/Used for all except Pedestrian Scenario 2 and Vehicle Scenario 3 BackingSIM/Vehicle Kinematics/ Used for all except Pedestrian Scenario 2 and Vehicle Scenario 3/Coasting to Planned Distance/Coasting1
MeanBackingDuration SDBackingDuration	Mean and standard deviation (in seconds) of the duration of the backing maneuver. These are treated as μ and σ parameters of a normal distribution in finding the particular duration applicable to each simulation iteration. LUMCM: N/A
BackingDurationDither	The time (in seconds) from reverse gear shift engagement to the first backward movement. Calculated for each simulation iteration. LUMCM: BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2/Time/Speed2
MaxSpeed	The maximum speed (in m/s) that the vehicle will reach during the backing maneuver. Calculated for each iteration using the MeanMaxSpeed and SDMaxSpeed normal distribution parameters

	LUMCM: N/A
BackingDuration	The duration (in seconds) that the backing maneuver will last for. Calculated for each iteration using the MeanBackingDuration and SDBackingDuration normal distribution parameters LUMCM: N/A
MeanMinTTC SDMinTTC	Mean and standard deviation (in seconds) of the minimum TTC allowed by the driver during a backing maneuver towards a target (again a wall, street, parking barrier, etc.). These are treated as μ and σ parameters of a normal distribution in finding the particular minimum TTC applicable to each simulation iteration. LUMCM: N/A
StraightBackingSegmentDistance	Defines the distance (in meters) in the initial stage of a curved backing maneuver that will be composed of straight backing. Constant for any particular scenario where the variable is applicable. LUMCM: BackingSIM/Steering/Used for all curved backing scenarios except parallel parking BackingSIM/Steering/Used for all curved backing scenarios except parallel parking/Curved Segment BackingSIM/Steering/Used for all parallel parking scenarios BackingSIM/Steering/Used for all parallel parking scenarios/Curved Segment
AfterCoastingAccel	The acceleration (in *g*) that the vehicle will undergo once it has finished coasting. Calculated for each iteration. LUMCM: BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2/Coasting to TTC/Coasting1 BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2/Time/After Coasting Speed BackingSIM/Vehicle Kinematics/Used for Vehicle Scenario 3/Time/After Coasting Speed BackingSIM/Vehicle Kinematics/Used for all except Pedestrian Scenario 2 and Vehicle Scenario 3/Time/After Coasting Speed
CoastingDecel	The deceleration (in *g*) that the vehicle will

	undergo while it coasts. Calculated for each iteration. LUMCM: BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2/Coasting to Warning BackingSIM/Vehicle Kinematics/Used for Vehicle Scenario 3/Coasting to TTC/Coasting1 BackingSIM/Vehicle Kinematics/Used for Vehicle Scenario 3/Coasting to Warning BackingSIM/Vehicle Kinematics/Used for all except Pedestrian Scenario 2 and Vehicle Scenario 3/Coasting to Warning
MU SHIFT SIGMA SpeedMult	Parameters used to define the speed profile employed in the simulation when the speed profile can be pre-defined as a single bell-shaped curve. MU captures the value of the simulation time at which the maximum speed will be reached (if no external factors intervene beforehand). SHIFT contains the value of the distribution at time 0, and is used to offset the values so that speed at time T=0 is equal to 0. SIGMA captures the value of the standard deviation of the distribution, which is calculated to ensure that the planned backing distance is traveled given a pre-specified backing duration and maximum speed. SpeedMult is a calibration factor so that the mode of the bell-shaped curve is scaled to represent vehicle speed. LUMCM: BackingSIM/Vehicle Kinematics/Used for Vehicle Scenario 3/Time/Speed2 BackingSIM/Vehicle Kinematics/Used for all except Pedestrian Scenario 2 and Vehicle Scenario 3/Time/Speed1 BackingSIM/Vehicle Kinematics/Used for all except Pedestrian Scenario 2 and Vehicle Scenario 3/Time/Speed1
MinTTC	The minimum TTC (in sec) that the driver will reach when backing towards a known target. Calculated for each iteration using the MeanMinTTC and SDMinTTC normal distribution parameters LUMCM: BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2/TTC Check BackingSIM/Vehicle Kinematics/Used for Vehicle Scenario 3/TTC Check

MovementDuration	List of values representing the different movement durations (in sec) for parallel parking maneuvers that require more than one successive backing movement. LUMCM: BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2/Time/Speed2/Single Accel
MaximumSpeed	List of values representing the different maximum speeds (in m/s) for parallel parking maneuvers that require more than one successive backing movement. LUMCM: BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2/Time/Speed2/Single Accel
PauseDuration	List of values representing the different pauses between successive backing movements (in sec) for parallel parking maneuvers that require more than one successive backing movement. LUMCM: BackingSIM/Vehicle Kinematics/Used for Pedestrian Scenario 2/Time/Speed2/Single Accel
Logic:	
These variables are updated once for every iteration of the simulation. The variables are read directly into the Monte Carlo simulation model.	

7.2.3.8 Braking Performance Distribution

In addition to the acceleration kinematics of the vehicle, which are described in the previous table, it was also necessary to describe how the vehicle is slowed down by drivers during a backing maneuver. These values are used here to determine the most appropriate set of parameters for each iteration of the Monte Carlo simulation. The variables through which that information is transferred to the simulation are shown in the following table.

Relevant SIM Variables	
Variable	*Description/Possible Values*
BrakePeakDecelerationScale BrakePeakDecelerationShape BrakeAverageDecelerationScale BrakeAverageDecelerationShape	Braking performance parameters (in *g*) that are used to generate the shape of the deceleration profile. LUMCM: BackingSIM/Conflict Assessment and Resolution – Part 2/Driver Response to Detection/Driver Brakes

Logic:
The BrakeDataXXX variables (described in the Driver Model Parameters section) are repositories of the data that are used to define these parameters as a function of the scenario being considered. BrakePeakDecelerationXXX and BrakeAverageDecelerationXXX are read directly into the simulation model. Updates for this latter set of variables occur for every iteration of the Monte Carlo simulation model.

7.2.4 Monte Carlo Simulation Model

After all the non-variant and variant parameters have been established and the simulation control variables have been defined, the Monte Carlo simulation model is executed. At a high level, the simulation model receives as inputs all the necessary distributions and/or parameters to define the conditions of the scenario to be simulated, including driver model, vehicle kinematics, and obstacle characteristics. Note that each of these aspects is modeled in parallel within the simulation. For reference, the structure of the full Monte Carlo simulation model is shown in Figure 113.

Most of the structures represented in Figure 113 are modules that perform specific functions within the overall simulation. The lines between the modules represent data that flow from one subsystem to the next. For example, on the top right-hand corner of the figure there is a module called “Steering.” The data that are generated from the “Steering” module flow to a module named “Vehicle Kinematics” and to several other modules, including “Backing Initiation Phase” and “Active Backing Phase.”

Inputs to the model come from the control code, as has been specified in the previous sections of this document. For example, the “Brake Peak Deceleration Scale” variable, described in the previous section, is introduced into the model within the “Driver Brakes” sub-module of the “Driver Response to Detection” module, which is located inside of the “Conflict Assessment and Resolution – Part 2” module that can be observed near the center of Figure 113. This example is illustrated graphically in Figure 114, and showcases the complexity of the simulation model.

This section describes the high-level modules within the simulation model, which are shown in Figure 113. Note that although a sequential order may be inferred from the diagram, this would be misleading as the modules are processed mainly in parallel within the simulation. Sequence is determined by the simulation, which prioritizes modules based on the input and output relationships. Also note that the simulation takes time in discrete time steps of 0.01 sec. Therefore, the simulation should be seen as a representation of the overall backing maneuver, from the point where the vehicle is shifted to reverse all the way through to when a crash with the obstacle is recorded or an avoidance of the crash is achieved. In alternative terms, every 0.01 sec there is a complete recalculation of all the internal values of the simulation based on factors such as how much the vehicle has moved, how much the obstacle has moved, the speeds of vehicle and obstacle, whether the driver has spotted the object, whether the driver is decelerating, and many others. These factors are discussed in the context of the modules on which they are calculated. The modules that will be discussed are:

- Steering
- Vehicle Kinematics

- Obstacle Timing
- Calculate Relative Speed (Vehicle – Obstacle)
- Countermeasure Matrix
- False Alarm OT Type
- Backing Initiation Phase / Active Backing Phase
- Components that Support or Promote In-Vehicle Visual Search
- Conflict Assessment and Resolution – Part 1
- Conflict Assessment and Resolution – Part 2
- Keep Going / Crash / Avoidance

These modules are highlighted in orange in Figure 113. There are also other modules, not shown in the figure, which serve as data structures within the simulation. These structures are used to hold and transfer data asynchronously between different modules. For example, once the driver brakes, the “Braking Effort” variable (“Data Store Memory” module in the figure) holds the value for the current braking effort the driver is making. That value is available to any module within the simulation without the need to transfer the data directly to each module. This “data bank” simplifies the graphical depiction of the simulation and allows for flexibility in the creation of the modules.

Also note that “Vehicle Approach Phase” is not discussed as it is not exercised in the model. This phase within a backing maneuver was determined to fall outside of the project’s scope and countermeasures that may act during it were not considered in any testing.

Finally, note that there are 7 colored ovals in different spots within Figure 113. These represent outputs of the Monte Carlo simulation model that are sent back to the control code to be converted into the outputs that will be processed into estimated safety benefits. Also note two dark sets of rectangles named “Object Chars Scope” and “Kinematics Scope.” These represent indicators that can be used to observe how a piece of data changes over time (i.e., as in "oscilloscope"). For example, the “Kinematics Scope” is connected to the “Vehicle Kinematics Vector” output of the “Vehicle Kinematics” module. That scope allows the observation of variations in vehicle speed as a function of time while the simulation runs.

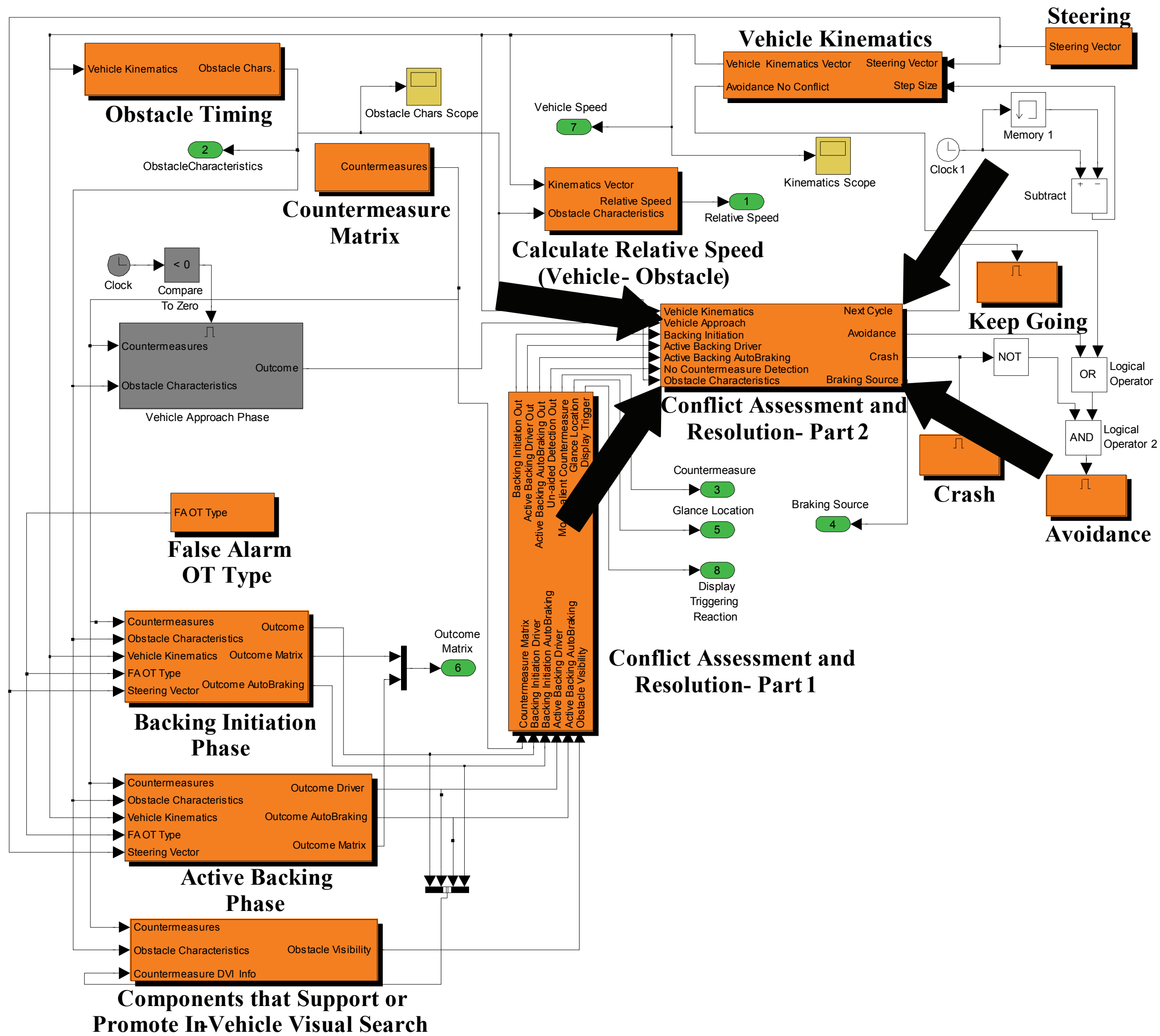


Figure 113. High-level structure of the Monte Carlo simulation model. The arrows point to the "Conflict Assessment and Resolution – Part 2" module, used as an example in the next figure.

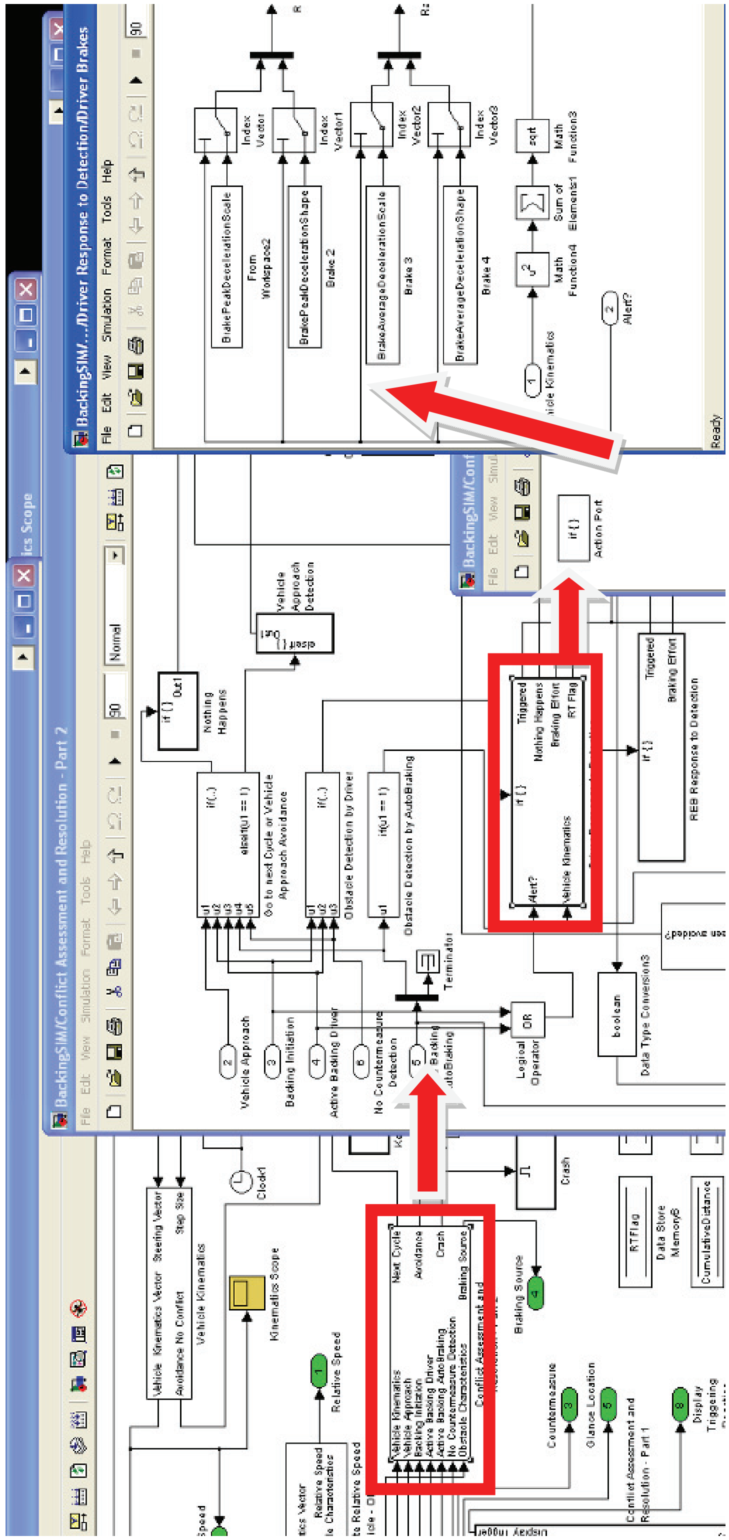


Figure 114. Example of the modularity within the SIM. Arrows point to sub-modules embedded within modules (which are enclosed in the thick-edged boxes).

Given its importance, the first simulation component that will be discussed is the Data Structures within the simulation. That discussion will be followed by discussion of other modules as previously listed.

7.2.4.1 Data structures within the Simulation

In order to perform its function, the simulation stores and uses a number of internal parameters. These parameters are used to transfer information between different sections of the SIM model, where one section may, for example, issue a flag that is used in parallel within, or even trigger, a different module of the SIM model. The following table provides a list of those internal parameters and a brief description of their function.

Relevant SIM Variables	
Variable	*Description/Possible Values*
AutoBraking	Time-dependent deceleration that the Automatic Braking feature produces for the driver.
BrakingEffort	Time-dependent deceleration that the driver produces when he applies the brakes
BWStage1	Random number against which the probability of activation for Cautionary Backing Warning is compared to in order to determine if this countermeasure component becomes active.
BWStage1Trust	Random number against which the expected driver belief in Cautionary Backing Warning is compared to in order to determine if the driver will respond and/or accept this countermeasure.
BWStage2	Random number against which the probability of activation for Imminent Backing Warning is compared to in order to determine if this countermeasure component becomes active.
BWStage2Trust	Random number against which the expected driver belief in Imminent Backing Warning is compared to in order to determine if the driver will respond and/or accept this countermeasure.
CumulativeDistance	Distance that the vehicle has traveled.
CumulativeDistanceVector	Distance that the vehicle has traveled, expressed in vector form.
ProximityInformation	Random number against which the probability of activation for Proximity Information is compared to in order to determine if this countermeasure component becomes active.
ProximityInformationTrust	Random number against which the expected driver belief in Proximity Information is compared to in order to determine if the driver will respond and/or accept this countermeasure.
AutomaticBraking	Random number against which the probability of activation for Automatic Braking is compared to in

	order to determine if this countermeasure component becomes active.
AutomaticBrakingTrust	Random number against which the expected driver probability of override of Automatic Braking is compared to in order to determine if the driver will respond and/or accept this countermeasure.
RTFlag	Is “1” when the driver is in the process of reacting to a countermeasure response.
TimeforNextGlance	Simulation time when the next glance will be required.
TimeforNextMotion	In parallel parking backing maneuvers, the simulation time when the next motion will be required.
TimeLastGlanceStarted	Simulation time when the previous glance started.
TimeLastMotionStarted	In parallel parking backing maneuvers, the simulation time when the last motion started.

7.2.4.2 Steering

This module (Figure 115) generates a vector describing the path that the vehicle will follow. All of its inputs are either in the form of data structures or sent from the control code, and are distributed throughout its sub-modules (Figure 116 and Figure 117). Inputs from the control code include the selected scenario (“Selected Scenarios”), the distance for which the vehicle will back in a straight line (“Straight Backing Segment Distance”), and the planned backing distances (“Planned Backing Distance X” and “Planned Backing Distance Y”). Inputs from data structures include “Cumulative Distance Vector”, and “Cumulative Distance”.

The logic of the module is as follows. The module shown in Figure 115 is used to select, based on the scenario, other modules that have appropriate settings describing the steering for the particular maneuver. One module is for all curved backing scenarios except parallel parking, one is used for parallel parking scenarios, and the third is used for straight backing scenarios. The outputs of these modules (only one will be active for each iteration) are combined into a single output.

Each of the sub-modules in Figure 115 has a structure similar to that shown in Figure 116. There, straight backing is assumed until the straight backing distance has been traveled, after that, the module to generate a curved backing path is used. Figure 117 shows the module that generates the curved backing path. The structures within that module combine to produce a path that follows the shape of a parabola based on the planned backing distances in the longitudinal and lateral dimensions for the particular backing maneuver being simulated in each iteration.

The module outputs a unitary vector describing a relationship between lateral and longitudinal travel (i.e., units of lateral travel per unit of longitudinal travel). If the vehicle is backing in a straight line, a simple [-1,0,0] vector is generated.

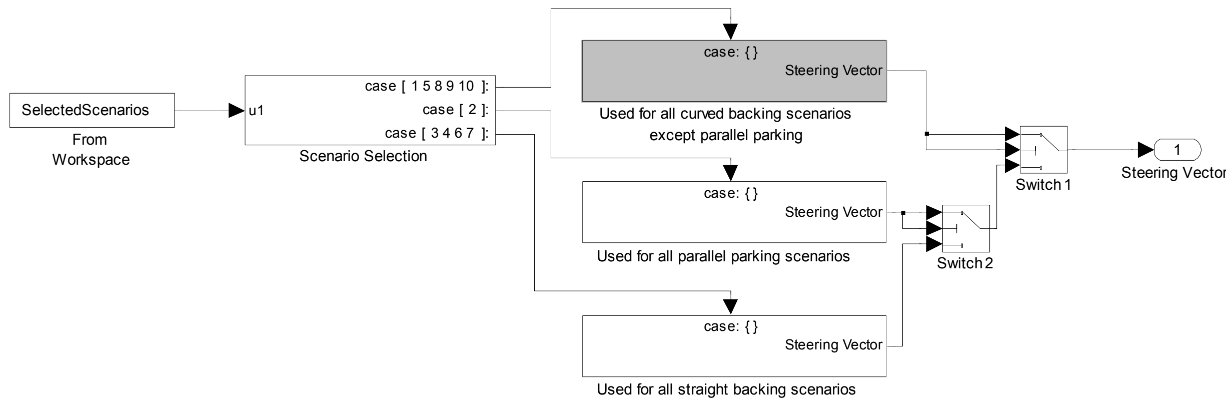


Figure 115. "Steering" module. The module highlighted in gray is expanded in the next figure.

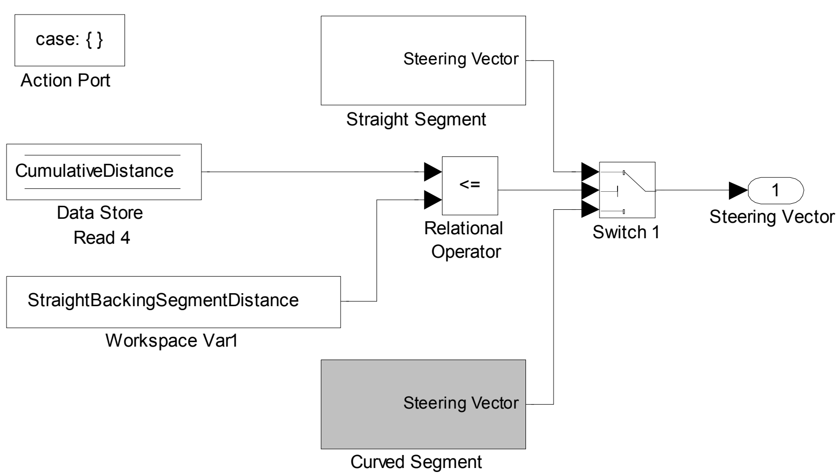


Figure 116. "Used for all curved backing scenarios except parallel parking" module under "Steering" module. The module highlighted in gray is expanded in the next figure.

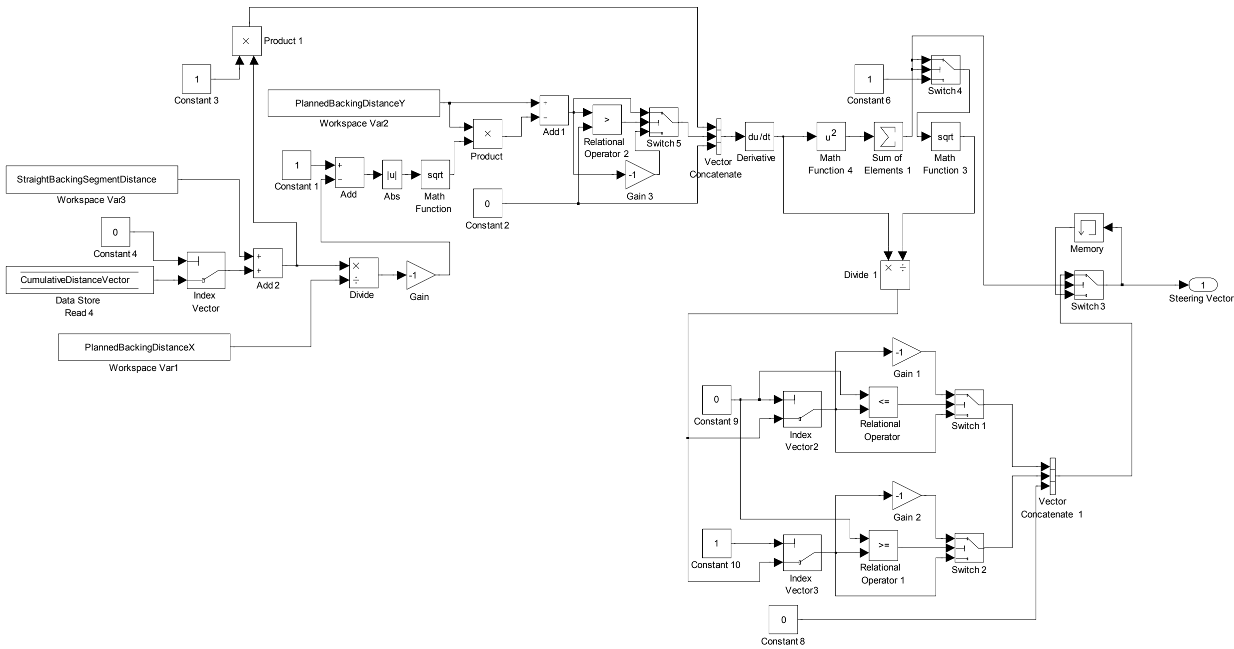


Figure 117. "Curved Segment" module under "Used for all curved backing scenarios except parallel parking" module.

7.2.4.3 <u>Vehicle Kinematics</u>

This module (Figure 118) generates the speed profile used by the vehicle for the different scenarios. The module receives inputs from other modules, from the control code, and from data structures. Inputs from other modules include the steering vector and the step size (the time that elapses between simulation steps, which is set at 0.01 seconds). Inputs from the control code include:

- SelectedScenarios
- CoastingDecel
- TargetPositionLong
- TargetPositionLat
- MinTTC
- PlannedBackingDistance
- AfterCoastingAccel
- MU
- SIGMA
- SHIFT
- SpeedMult
- BackingDurationDither
- MaximumSpeed
- MovementDuration
- PauseDuration

Inputs from data structures include:

- BrakingEffort
- AutoBraking
- RTFlag
- CumulativeDistance
- TimeforNextMotion
- TimeLastMotionStarted

The module depicted in Figure 118 selects an appropriate kinematics module based on the selected scenario. Vehicle Scenario 3 (shown in Figure 119) and Pedestrian Scenario 2 have separate modules due to peculiarities in those maneuvers. Vehicle Scenario 3 involves backing to a known target, which introduces TTC constraints to the acceleration profiles. Pedestrian Scenario 2 requires a parallel parking maneuver, and the kinematics in that case are very different from the other scenarios, as they can involve multiple start/stop maneuvers.

Once a kinematics module has been selected, the simulation uses a structure similar to that depicted in Figure 119. That module is composed of different phases of a backing maneuver. These phases are switched on and off as needed so that only one controls the kinematics of the vehicle at any point in time while providing for smooth transitions between phases. The first phase is the acceleration (the different acceleration patterns used across maneuvers were previously described in the "Vehicle Kinematics" section of this document). The acceleration module also contains components that recover from coasting maneuvers. Another phase involves coasting to avoid crossing a minimum TTC threshold. When known targets are present, it may be that the acceleration crosses a minimum TTC threshold. In that case, there is some coasting that occurs to ease the vehicle back over the minimum TTC threshold. There may also be some coasting that occurs while the driver is in the process of reacting to a countermeasure response that has been received, which is modeled as another phase. Braking represents a fourth (and very important) phase. When the driver is braking or automatic braking is engaged, the module switches over to its braking section, which introduces the required level of deceleration into the maneuver. Finally, the module also contains a phase where the vehicle is coasted to a stop within the planned backing distance. This fifth phase is used in cases where a full backing maneuver is observed, which is not possible in the current model based on the scenarios being simulated.

The module outputs a vehicle speed vector and whether the vehicle completed the backing maneuver without impacting any obstacles (again, not possible in the current model based on the scenarios being simulated). In addition, the module outputs a number of values to various data structures within the simulation, including:

- CumulativeDistanceVector
- CumulativeDistance
- TimeforNextMotion
- TimeLastMotionStarted

The final outputs for the module are "BrakeLevel", "BrakeLevel1", and "BrakeLevel2", which are sent back directly to the control code.

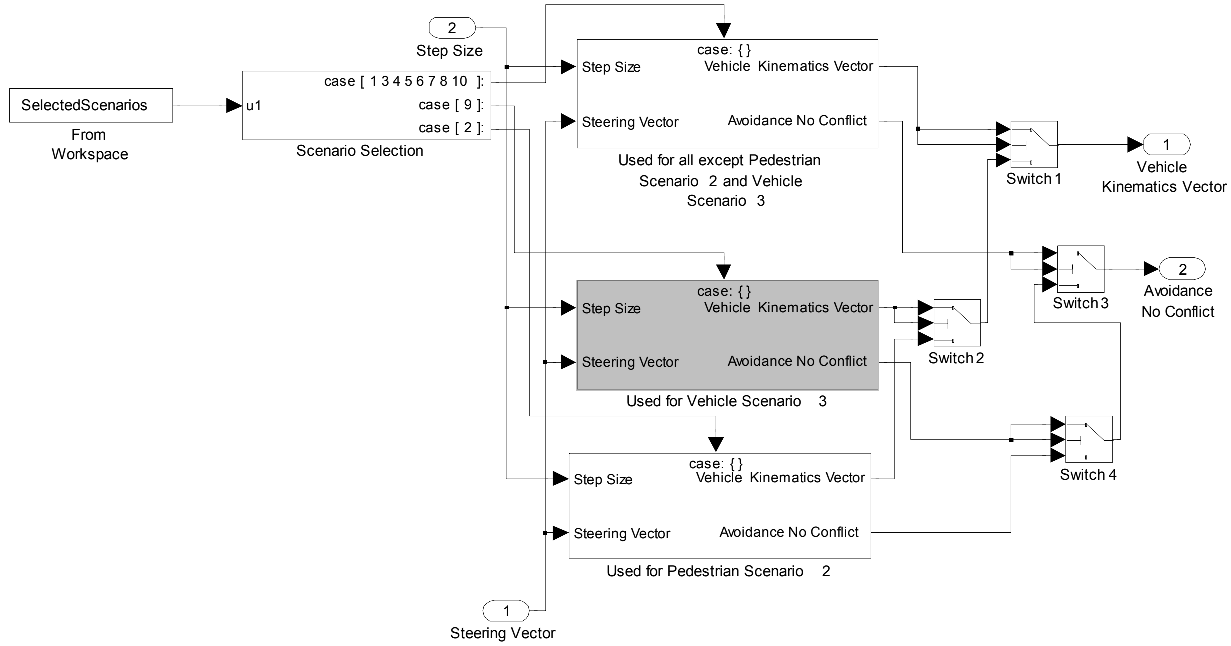


Figure 118. "Vehicle Kinematics" module. The module highlighted in gray is expanded in the next figure.

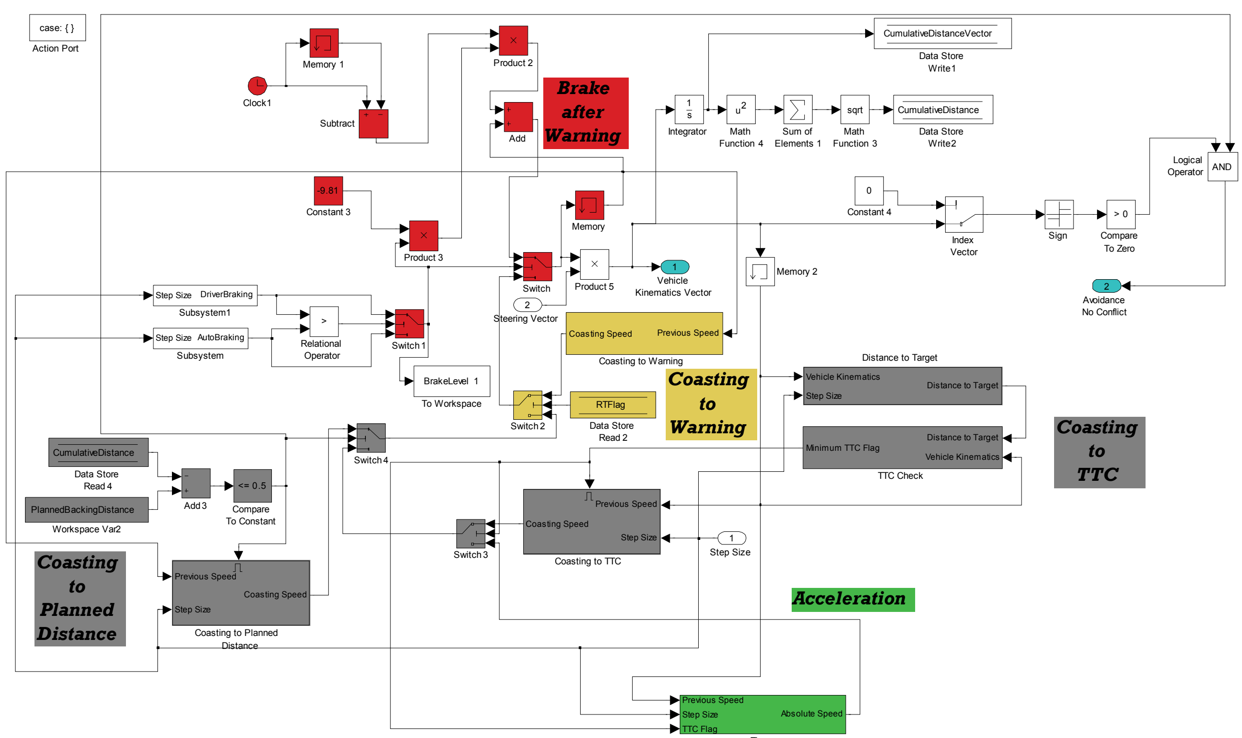


Figure 119. "Used for Vehicle Scenario 3" under "Vehicle Kinematics" module.

7.2.4.4 Obstacle Timing

The obstacle timing module (Figure 120) integrates information about the obstacle to place it within the simulation. The module receives "ObstacleType", "ObstacleStatic", "ObstaclePositionLong", "ObstaclePositionLat", "ObstacleSpeedLong", and "ObstacleSpeedLat" from the control code. The vehicle kinematics are received from another module in the simulation. Obstacle dimensions are embedded within a look-up table in the model ("Obstacle Height and Width Cross-Sectional, in meters", see Figure 120).

The module operates by first using the type of obstacle to pull data about the obstacle dimensions from a look-up table. If the obstacle is static, then the initial obstacle location and vehicle kinematics are used throughout the simulation to calculate the obstacle's longitudinal and lateral positions relative to the vehicle. If the obstacle is dynamic (Figure 121), then obstacle kinematics are also considered in the calculation of obstacle position. The obstacle position throughout the simulation is obtained by mathematically integrating the relative obstacle and vehicle kinematics to obtain distance traveled. The relative distance traveled is subtracted from either the initial (if the obstacle is static) or the last calculated (if the obstacle is moving) obstacle position to generate the new obstacle position.

The module outputs a vector of obstacle characteristics, which include the obstacle height and width, the obstacle type, the obstacle speed vector, and a vector describing the relative distance between the vehicle and the obstacle.

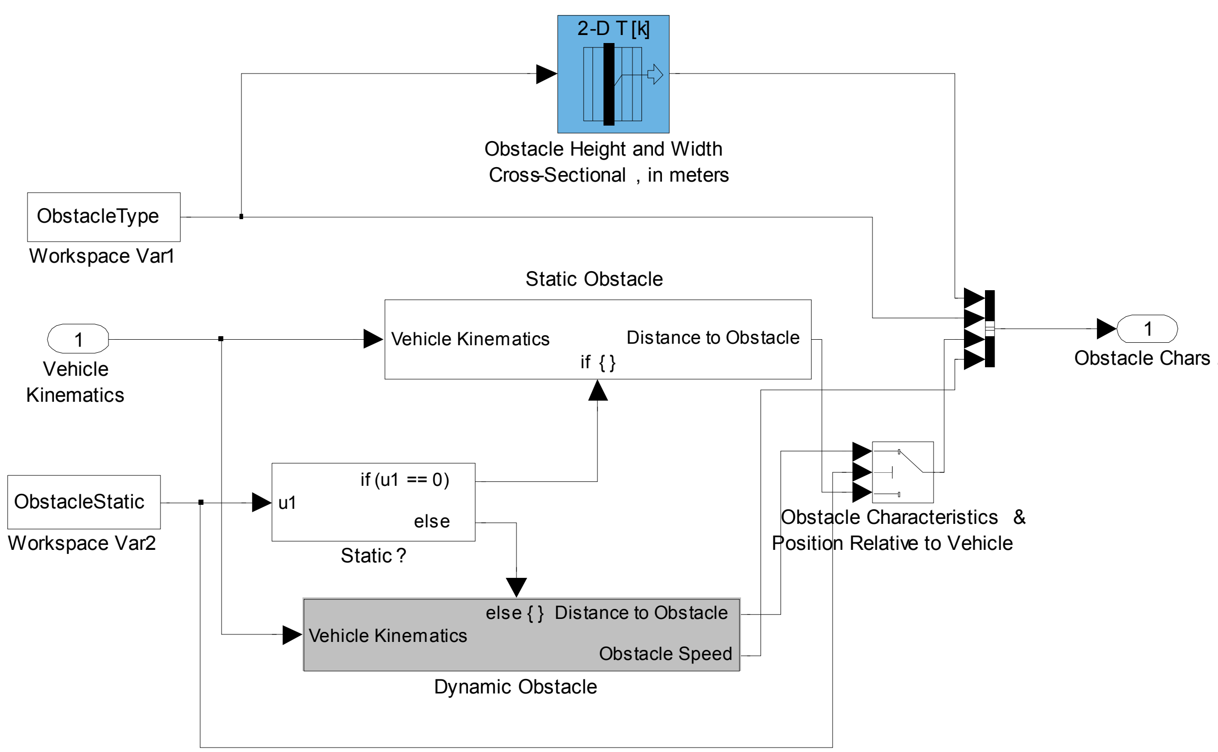


Figure 120. "Obstacle Timing" module. The module highlighted in gray is expanded in the next figure.

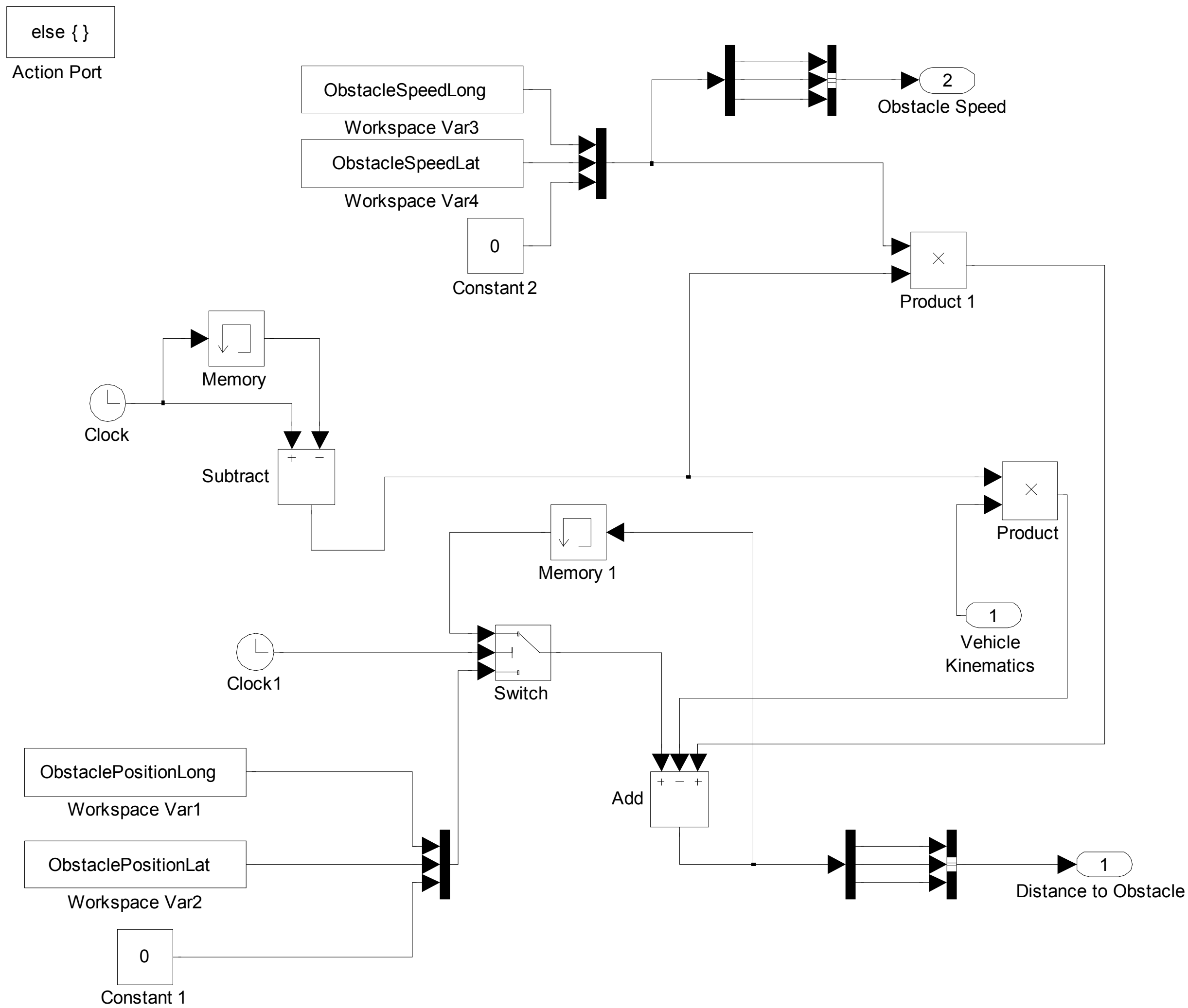


Figure 121. "Dynamic Obstacle" module within "Obstacle Timing" module.

7.2.4.5 <u>Calculate Relative Speed (Vehicle – Obstacle)</u>

This module (Figure 122) receives as inputs the obstacle characteristics and the vehicle kinematics. Obstacle speed is extracted from the obstacle characteristics vector and subtracted from the vehicle kinematics vector to obtain relative speed between vehicle and obstacle, which is then output.

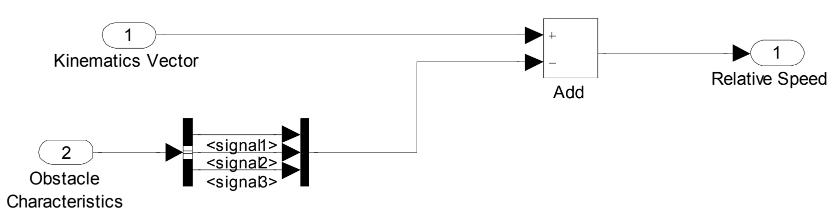


Figure 122. "Calculate Relative Speed (Vehicle-Obstacle)" module.

7.2.4.6 Countermeasure Matrix

The countermeasures matrix module (Figure 123) takes the “Vehicle Approach”, “Proximity Information”, “WarningStage1”, “WarningStage2”, “Automatic Braking”, and “Enhanced Visibility” inputs from the control code and outputs a vector combining those countermeasure availability values.

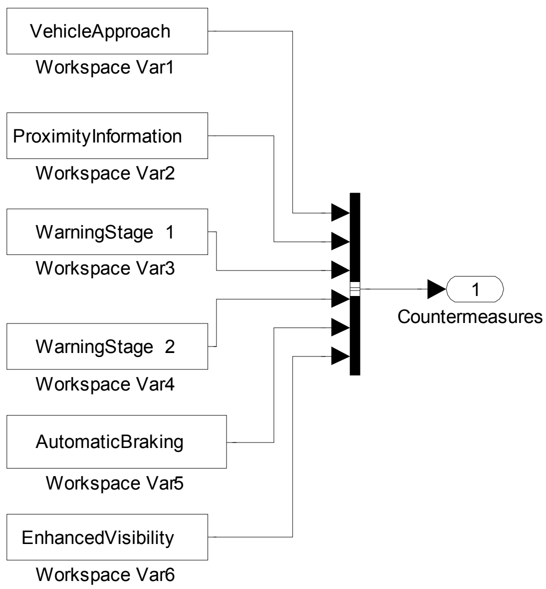


Figure 123. “Countermeasure Matrix” module.

7.2.4.7 False Alarm OT Type

This module (Figure 124) takes as input the “Selected Scenarios” from the control code. Based on that variable a type of false alarm environment (e.g., Driveway – Residential) that is most appropriate for the scenario being simulated is selected. The selection, in the form of a value of 1, 2, or 3, is the output of the module.

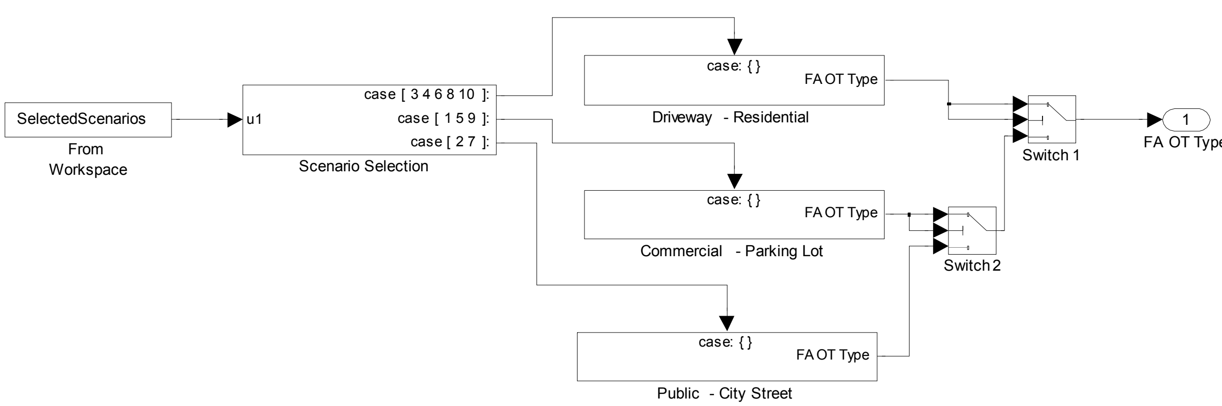


Figure 124. “False Alarm OT Type” module.

7.2.4.8 Backing Initiation Phase and Active Backing Phase

While separate in the high-level structure (Figure 113), these modules have a very similar underlying structure. They are coded as separate entities to allow for potentially different sets of countermeasures being active in different phases of the backing maneuver. For example, for the countermeasure system being tested, there is a clear distinction in that Proximity Information is available at low speeds (<4 mph), whereas Cautionary and Imminent Warnings are not. The availability of these systems reverses for speeds over that threshold. Therefore, the only difference between the modules is that these warnings are possible in one and not possible in the other. Automatic Braking is possible in both modules since it is always available regardless of speed.

The "Active Backing Phase" module is illustrated for the discussion of how these modules operate (Figure 125). The module receives inputs from the simulation model in the form of the vector of countermeasures, the vector of obstacle characteristics, the vehicle kinematics, the type of false alarm environment most appropriate for the scenario being simulated, and the steering vector. Variables obtained from the control code include:

- BackInitSpeedThreshold
- SelectedScenarios
- Latency
- FalseAlarmOT
- XXXTrustValue (where XXX can be, for example, AutomaticBraking)
- XXXOTProxGrid (where XXX can be, for example, ActiveBackingAutomaticBraking)

Data structures accessed include:

- AutomaticBraking
- AutomaticBrakingTrust
- BWStage1
- BWStage1Trust
- BWStage2
- BWStage2Trust
- ProximityInformation
- ProximityInformationTrust

These modules simulate the response performance and activation characteristics of those countermeasures that are available during each of these different backing phases. The first step taken in the module (Figure 125) is to determine which countermeasures are available and applicable to the backing phase being considered. Typically, only a subset of countermeasures will be applicable at each phase. If any countermeasure is available, the module for that countermeasure is triggered (note that there may be more than one countermeasure whose modules are triggered at the same time step). Prior to triggering the modules for any countermeasure, however, the module also determines whether the present kinematic conditions allow for operation of the countermeasures (e.g., a minimum speed threshold has been achieved). If these two conditions are satisfied (i.e., minimum speed threshold and countermeasure is available), then the module for the countermeasure is triggered.

Within the module for the countermeasure (Figure 126), the logic first finds the necessary inputs for the look-up table that will determine the likelihood of countermeasure response to an obstacle. The factors that are considered have been described previously in this document, when the variables that are used to store the data for the look-up tables were discussed. They include the distance to the obstacle, the obstacle type, the obstacle speed, the vehicle speed, the direction the obstacle is incurring from, and the steering vector. The look-up table generates a probability of response based on all of these inputs, which must exceed a pre-determined (and constant through each iteration) threshold to result in a response of the countermeasure. Assuming any latency in the system activation has also elapsed, any responses are recorded and maintained for the remainder of the iteration (i.e., once a countermeasure is activated, that activation remains). Parallel to this process, there is also a determination of the trust that the driver will have in the countermeasure for the particular scenario, and that level of trust is also compared in a later module to a different pre-determined threshold (also constant through each iteration). After that process is complete, the countermeasure identifier, response status, level of trust, trust threshold, and DVI identifiers are combined into a single output of the countermeasure module. If the countermeasure is inactive then there is a default outcome of no detection that is output from the module.

As the output from the countermeasure modules is combined, interactions between countermeasure components are considered and executed. For example, it may be that some countermeasure components turn off if other countermeasure components become active (e.g., activation of automatic braking trumps the activation of the Imminent Backing Warning). Once that process is complete, the countermeasure identifier of the most salient countermeasure active within a phase is added to the output vectors. Three vectors are output from each main module: the activation state of countermeasures that depend on driver response, the activation state of countermeasures that are autonomous, and the activation state of all countermeasures within the backing phase.

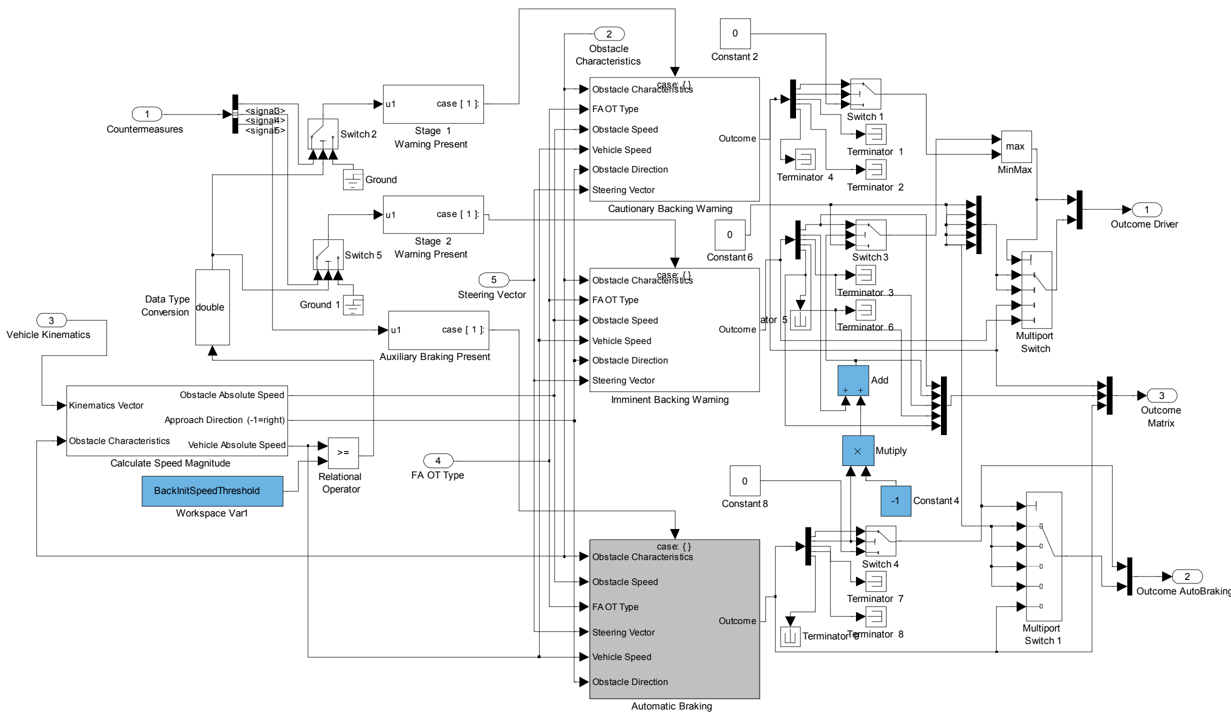


Figure 125. “Active Backing Phase” module. The module highlighted in gray is expanded in the next figure.

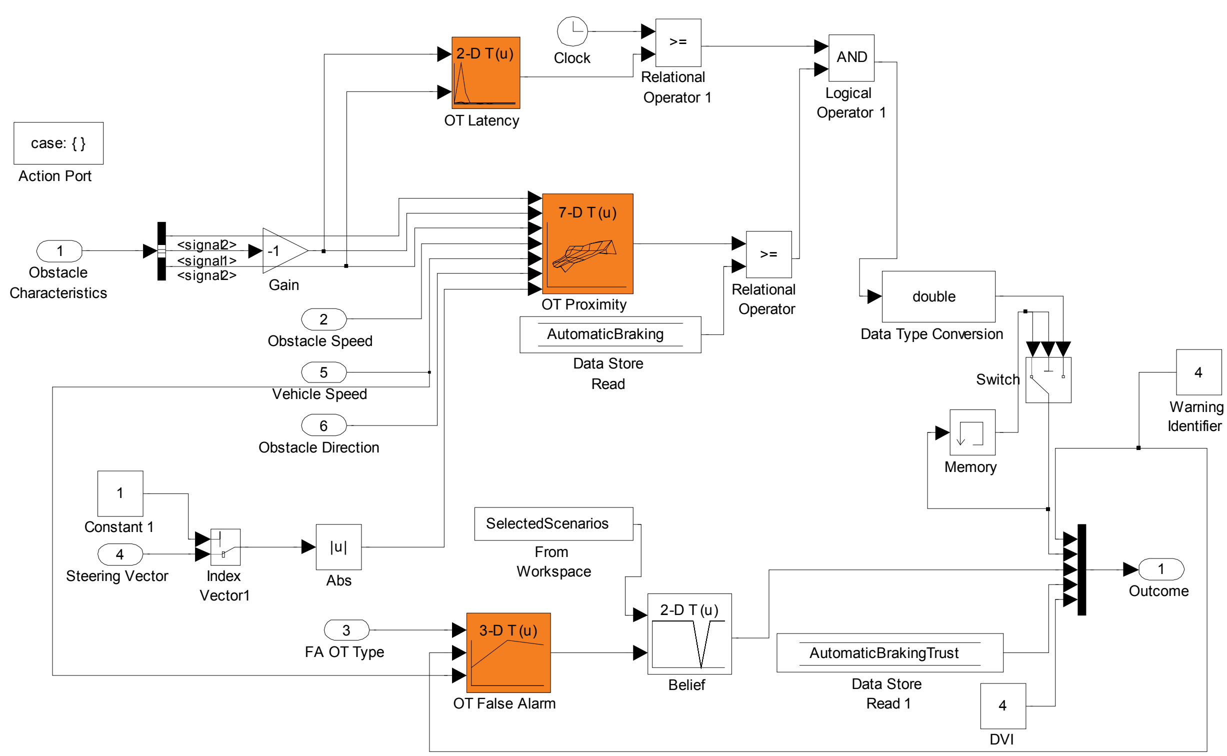


Figure 126. “Automatic Braking” module within “Active Backing Phase” module.

7.2.4.9 <u>Components that Support or Promote In-Vehicle Visual Search</u>

This module (Figure 127) estimates the visibility of the obstacle within the different displays available in the vehicle. Note that "visibility" implies that a glance to that display may result in obstacle detection; however, that detection is not guaranteed. The module takes in as inputs from the model the countermeasures that are available, the obstacle characteristics, and a code for the DVIs that the countermeasures trigger when responding to an obstacle. Inputs from the control code include "EnhancedVisionLatency" (look-up table), "LookedDidNotSeeXXX" (where XXX can be any of the visual displays, e.g., EnhancedVision), "VisualDVIOTProxGrid" (look-up table), and an array of look-up tables (XXXOTProxGrid, where XXX can be any of the visual displays, e.g., EnhancedVision; see *Visibility Model* section) that define the probability of obstacle visibility in the different visual displays as a function of factors such as the distance to the obstacle, the type of obstacle, and the DVI accompanying a countermeasure.

The module acts by first determining which displays are available to the driver in the particular iteration being simulated. Once that is determined, available display modules are activated (Figure 128). Within those modules, the look-up tables for each individual display are used to obtain a probability of visibility as the object location and other parameters (as previously described in the presentation of the look-up table characteristics) change through the simulation. That probability is compared to a pre-determined threshold (which remains constant for each iteration). If the probability exceeds the threshold, any latencies on the display have elapsed (where applicable), and the probability of look-did-not-see exceeds another pre-determined threshold, then the obstacle is considered visible within the display. Once visibility within all available displays is determined, the module collects those visibilities into a vector.

The output of the module consists of a vector of obstacle visibilities within all the different displays available to the driver.

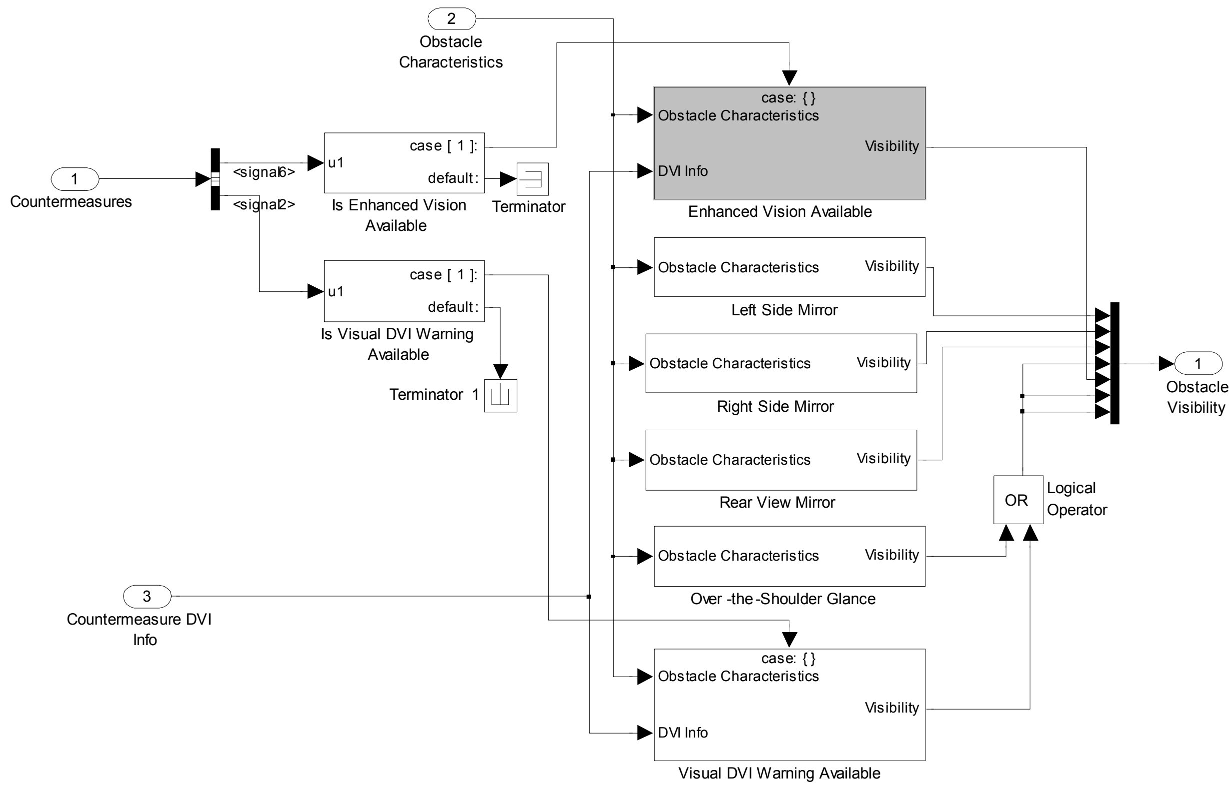


Figure 127. "Components that Support or Promote In-Vehicle Visual Search" module. The module highlighted in gray is expanded in the next figure.

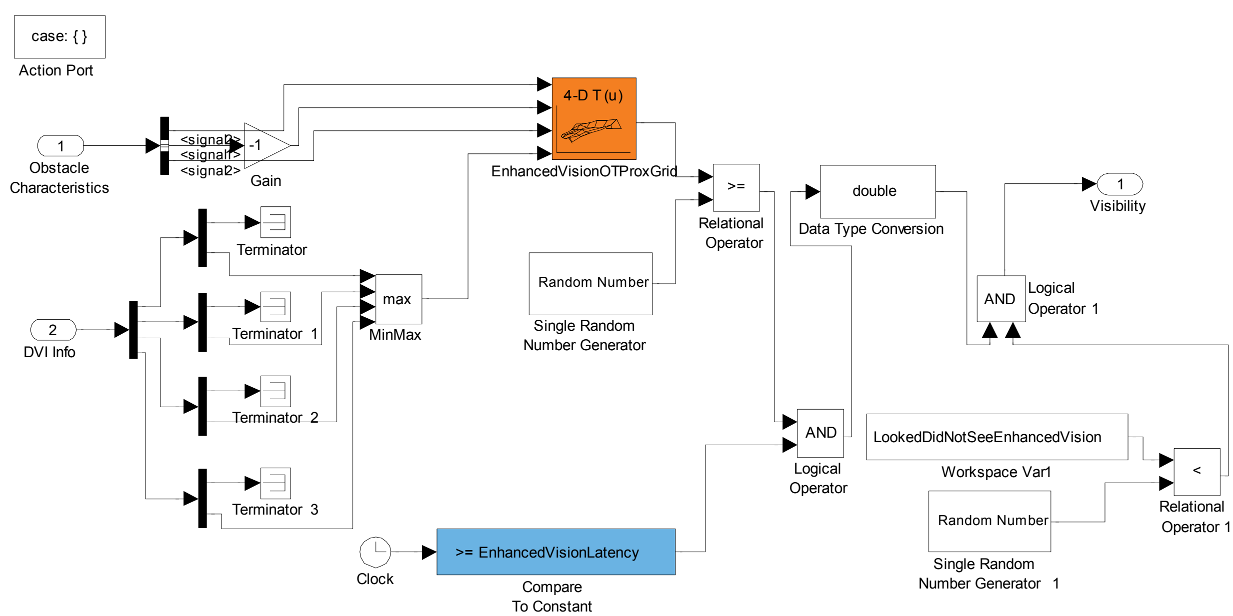


Figure 128. "Enhanced Vision Available" module within "Components that Support or Promote In-Vehicle Visual Search" module.

7.2.4.10 Conflict Assessment and Resolution – Part 1

This module (Figure 129) represents the first stage of the conflict assessment and resolution phase of backing. Components of the module are only accessed when there is a conflict in the backing maneuver. The inputs to this module from the model are the countermeasures that are available to the driver, the vector of characteristics for countermeasures that are active within the backing initiation and active backing phases (countermeasures that require driver intervention and those that are autonomous are considered separately), and the vector describing obstacle visibility among the available displays. Inputs from the control code include "Transition Scale", "Transition Shape", "Eye Glance Sequence", "XXX Location", "XXX Scale", and "XXX Shape" (where XXX can be any of the glance displays available, e.g., Over Left Shoulder, Left Mirror, see description on *Glances Distributions*). The final set of inputs, which are also written-to in some sections of the module, are the data structures "Time for Next Glance" and "Time Last Glance Started".

The initial step in the module is to determine whether any active countermeasures are trusted. If trust in the countermeasure is not sufficient to exceed pre-determined thresholds, the countermeasure is not considered to yield any crash-avoidance effect. The most salient countermeasure is then provided to the "Glance Behavior" module (Figure 130), which considers the availability of enhanced vision, the vector of obstacle visibility, and the activation of proximity information to generate the driver glances and determine whether the obstacle has been detected by the driver.

The "Glance Behavior" module accomplishes these goals by generating glances and keeping track of when new glances should be generated (based on their pre-determined duration). The module generates a glance at time zero or when the clock is greater or equal to the time when the previous glance expired and a new glance was scheduled to begin. If countermeasures become active, however, they may trigger a quicker transition than scheduled by adjustments to the "Time for Next Glance" and the "Time Last Glance Started" data structures. These adjustments occur within the "Transition to new glance on DVI activation" sub-module.

If the "Glance Behavior" module determines that a new glance is needed, then the "Glance" module (Figure 131) is activated. That module uses information from the availability of enhanced vision, the DVIs active, a random number, the duration of the previous glance, and the location of the previous glance to determine where the next glance will be directed. Once a glance location has been determined, the duration of that glance is generated based on the distribution parameters provided by the control code. Finally, the data structures are updated with new time values. The output of the "Glance" module is the current glance location.

That glance location is then used by the "Glance Behavior" model (Figure 130) to compare against the vector of obstacle visibilities. If a glance is directed towards a display where the obstacle is visible, then driver detection is assumed to occur. That detection is then provided back to the "Conflict Assessment and Resolution – Part 1" module, which uses it to determine which countermeasure(s) resulted in that detection.

Outputs from the module include whether the obstacle was detected in response to a countermeasure activation (separated by backing phase), whether autonomous braking is active (and not overridden), whether the driver detected the obstacle without the need for a countermeasure response (e.g., by looking at the mirrors), the most salient countermeasure that is active, the glance location, and which display, if any, triggered a driver reaction to the obstacle.

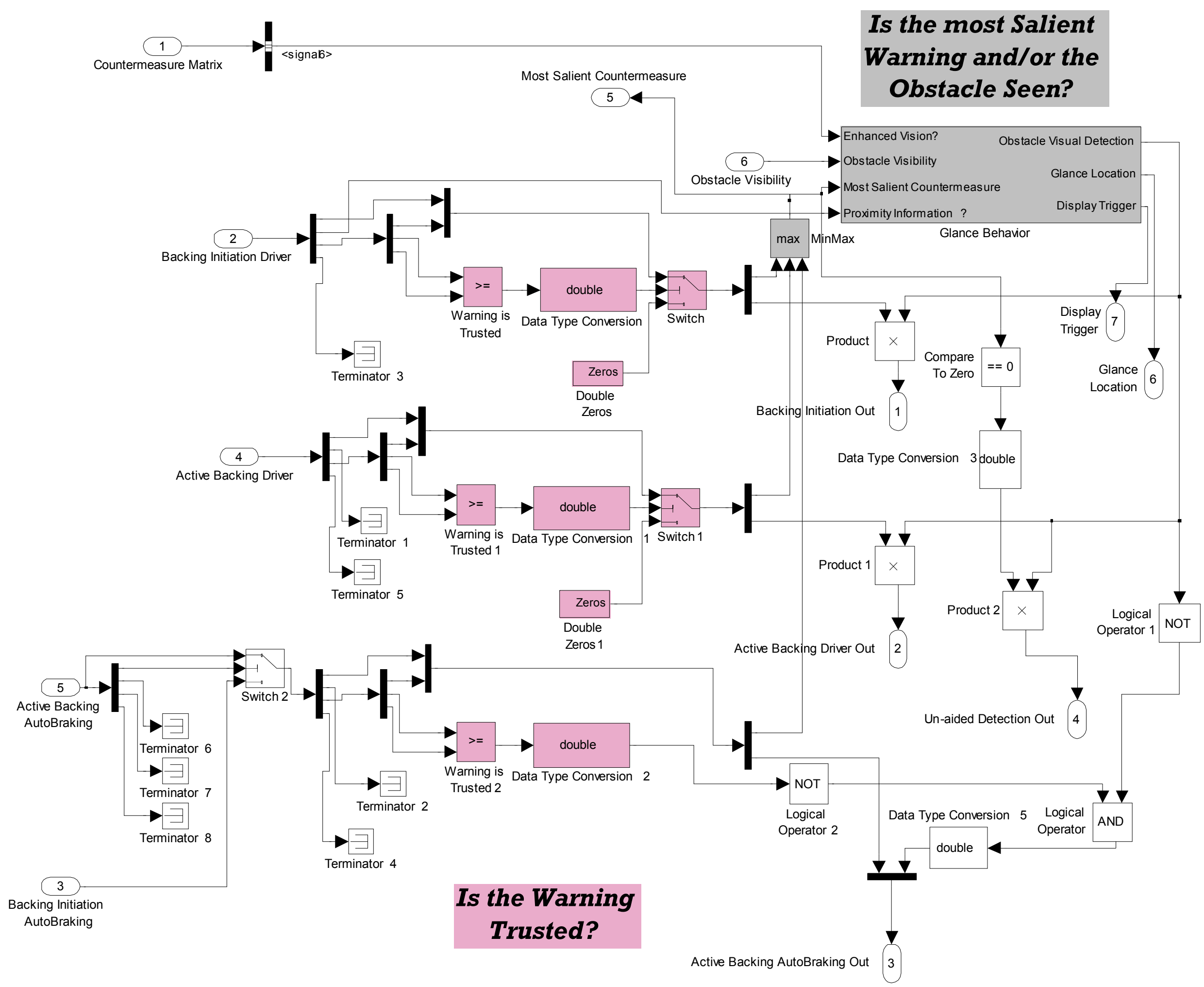


Figure 129. "Conflict Assessment and Resolution – Part 1" module. The module highlighted in gray is expanded in the next figure.

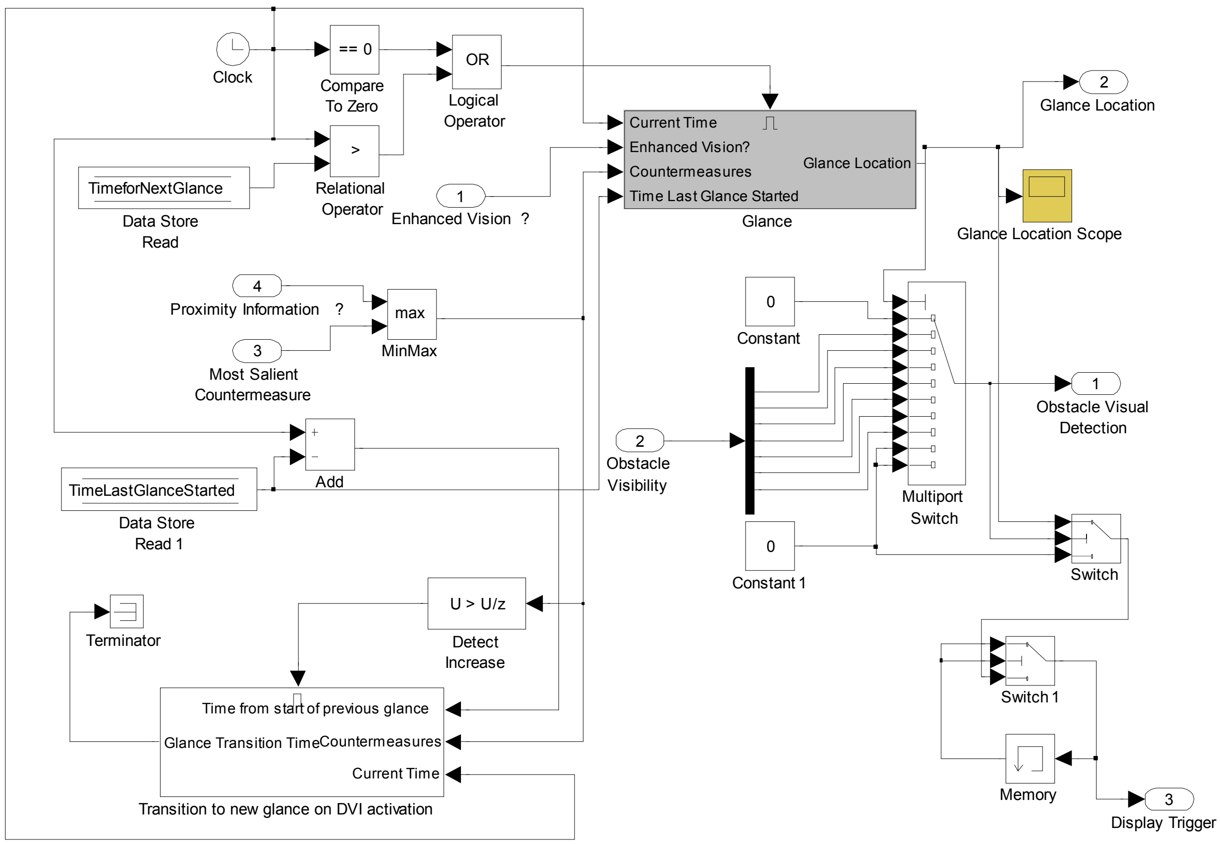


Figure 130. "Glance Behavior" module within "Conflict Assessment and Resolution – Part 1" module. The module highlighted in gray is expanded in the next figure.

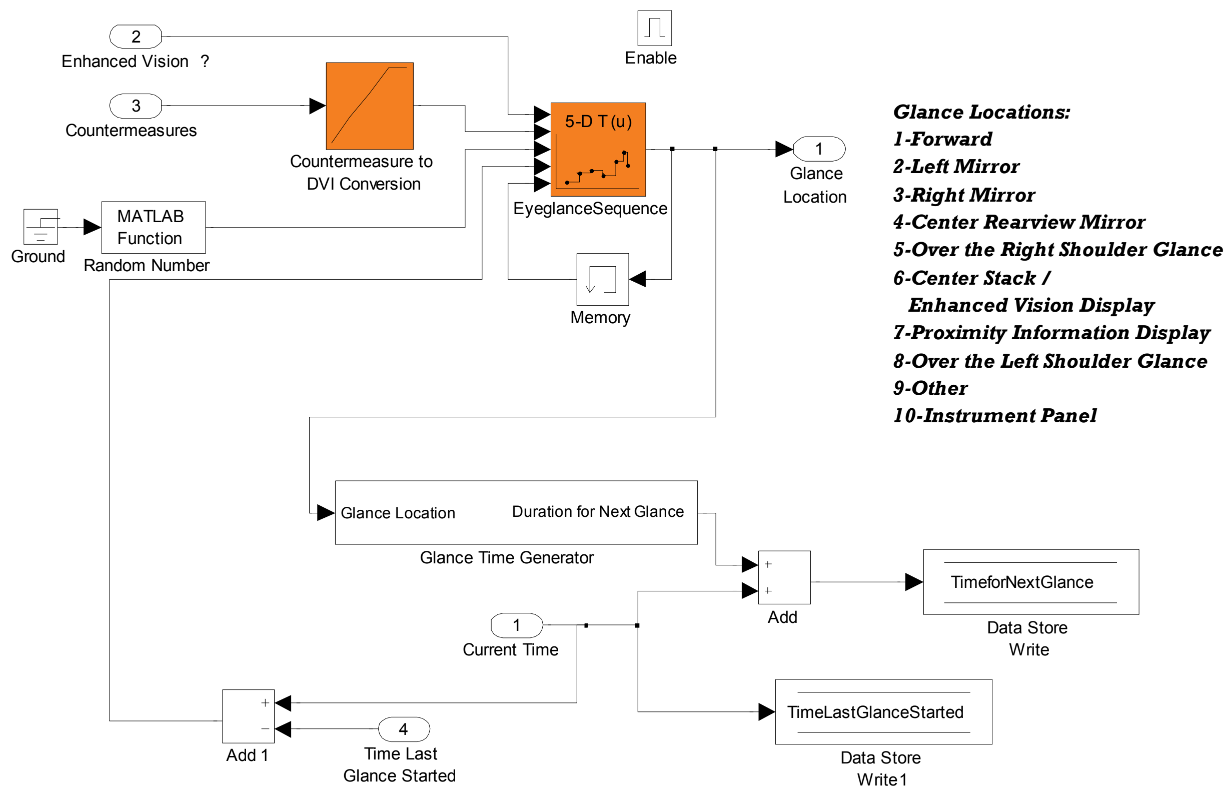


Figure 131. "Glance" module within "Glance Behavior" module

7.2.4.11 Conflict Assessment and Resolution – Part 2

The second stage of conflict assessment and resolution (Figure 132) takes the information from the first stage to determine when an outcome has been reached for the simulation and defines the presence, type, and level of driver or automated response to obstacle detection. Inputs to this module from the model are the vehicle kinematics, whether the driver has detected the obstacle in the vehicle approach, backing initiation, or active backing phases, whether automatic braking has responded to the obstacle, whether there is driver detection that is not due to a countermeasure activation, and the obstacle characteristics. Inputs from the control code include "Max Time", "RT Alerted Scale", "RT Alerted Shape", "RT Non Alerted Scale", "RT Non Alerted Shape", "Auto Brake Maximum", "Auto Brake Slope", "Selected Scenarios", "Brake Peak Deceleration Scale", "Brake Peak Deceleration Shape", "Brake Average Deceleration Scale", "Brake Average Deceleration Shape", and "Vehicle Width." Code within the module first determines if the driver has detected and/or countermeasure(s) have responded to the obstacle. If no detection or response has occurred, the simulation proceeds to the next time step. If the driver has detected or a countermeasure responded to the obstacle and a driver response is appropriate, the reaction time and braking effort values are generated (braking is triggered once the reaction time has elapsed). This occurs in the "Driver Response to Countermeasure" module. Once generated, these parameters remain fixed throughout the particular iteration (i.e., a braking maneuver continues until the vehicle comes to a complete stop or an impact occurs). Similarly, if the automatic braking countermeasure responds, there is a determination of the level of automated braking response and immediate braking. This is accomplished by the “REB Response to Detection” module. At every time step, there are two separate determinations of outcome. First, whether avoidance has occurred, which is specified if the maximum simulation time has elapsed, if there is detection in the vehicle approach phase (not possible in this case, since the Vehicle Approach Phase is outside of the scope of the project), or if the vehicle has reached a stop before impacting the obstacle. The latter is detected in the “Determine if Avoidance is Achieved by Driver or Emergency Braking” module. The second separate determination is whether a crash has occurred. This is considered to be the case if the obstacle is within the vehicle’s width, if the obstacle is past the rear bumper, or if the vehicle speed is zero due to automatic braking, but an override occurred.

“Reaction Time” and “Reaction Time Left” are output back to the control code. In addition, three data structures affecting the kinematics of the vehicle are also updated: “Braking Effort”, “RT Flag”, and “Auto Braking”. Outputs of the module include whether there is no resolution to the backing scenario in the current time step (therefore, the simulation continues), whether a crash has been avoided, the source of any braking that is occurring (i.e., driver-initiated, automatic braking, or both), and whether a crash has occurred.

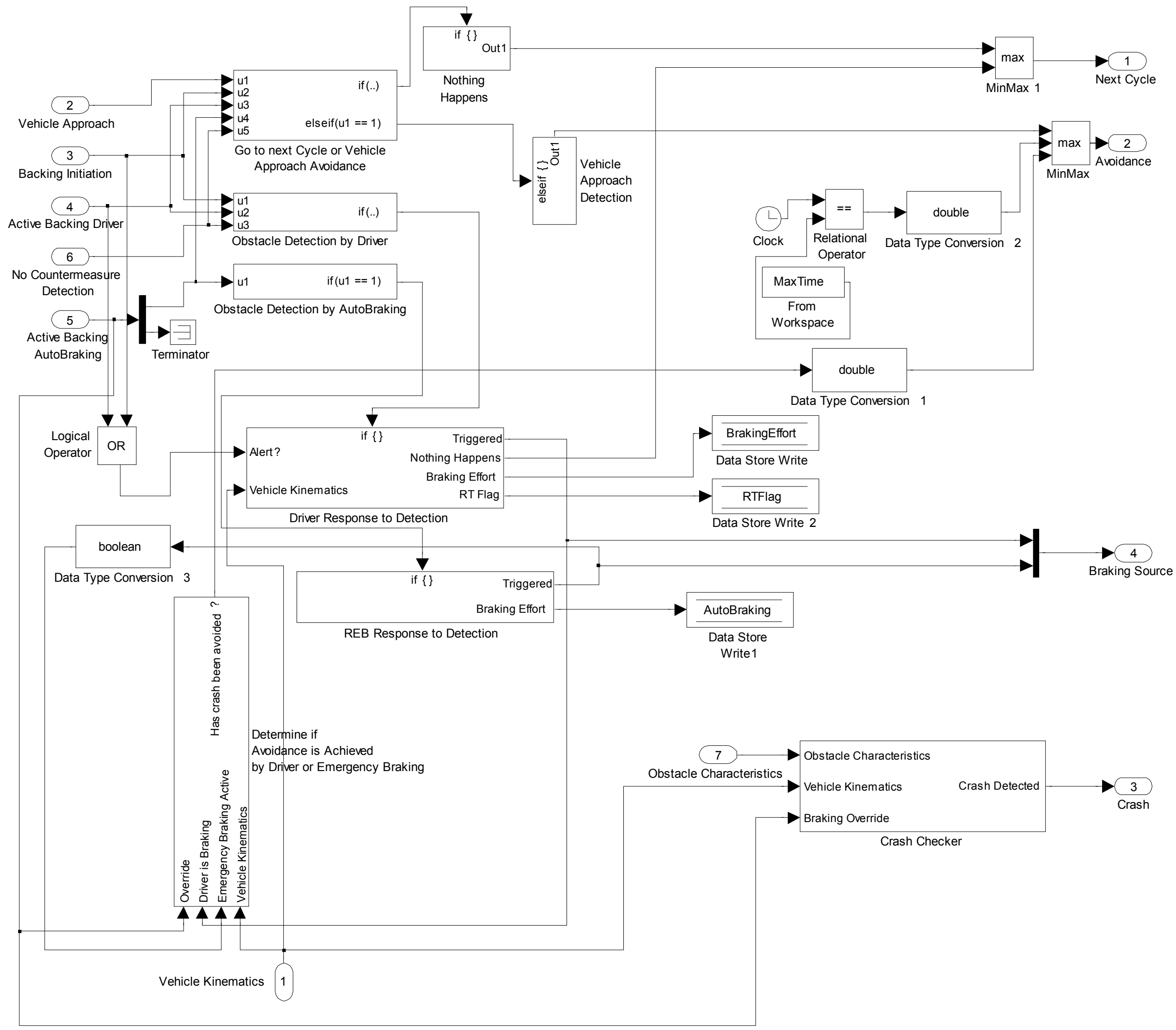


Figure 132. "Conflict Assessment and Resolution – Part 2" module

7.2.4.12 Keep Going, Crash, Avoidance

These three modules are in charge of advancing the simulation to the next time step ("Keep Going") or stopping the simulation and sending to the control code an output that characterizes the overall outcome of the iteration ("Crash" or "Avoidance", Figure 133). The "Keep Going" module does not perform any action, but serves as the last node in the current simulation time step, and therefore its execution (in lieu of any other command to stop the simulation) triggers the next time step to begin. As that new time step begins, note that all the components that have been described in this section are updated based on the new conditions of the iteration (e.g., where the vehicle is, where the obstacle is, where the driver is looking, whether the driver has responded, whether automatic braking has responded), and the process continues until an outcome is achieved.

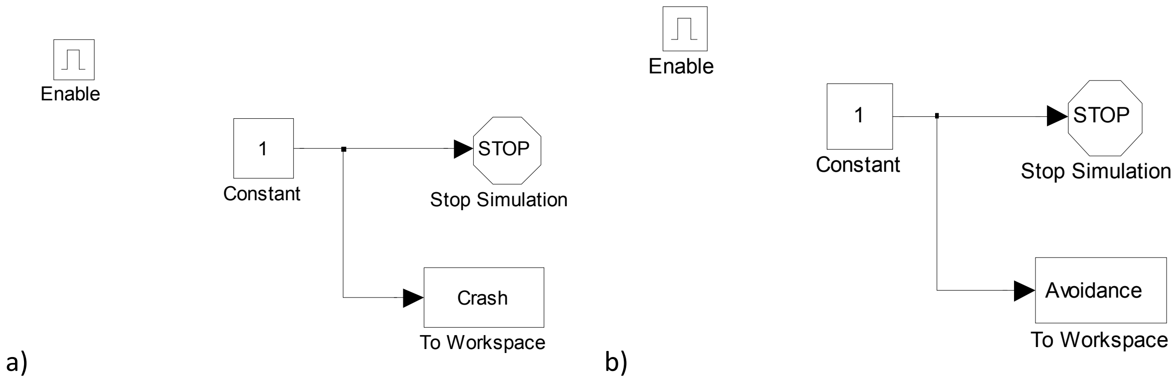


Figure 133. "Crash" (a) and "Avoidance" (b) modules

7.2.5 Simulation output

All of the parameters, inputs, logic, and outputs described thus far in this document are designed to provide a series of aggregate outputs that can be used to estimate system effectiveness measures for the countermeasure suite of interest. These outputs have been described in previous sections as part of the explanation of the different outputs that exist within the Monte Carlo simulation model. Note that one set of the values included in the table below is generated for each iteration (e.g., each time the Monte Carlo simulation is executed). These values are the only data retained from each simulation run. Remaining data (e.g., vehicle and obstacle trajectories) are reinitialized (and lost) when the new iteration begins.

Relevant SIM Variables	
Variable	*Description/Possible Values*
OutcomeMatrix	Retains the results of each simulation iteration so that it can be later used in safety benefits calculations. The columns in this matrix represent: 1 - Crash (1 if it is) 2 - Avoidance (1 if it is, mutually exclusive from 1) 3 4 5 - Final relative speed (m/s; negative implies vehicle and object getting closer) 6 7 8 - Final relative location (m; positive implies contact between object and vehicle) 9 – Most salient countermeasure that was active at the end of the trial (0-None, 1-Proximity, 2-Cautionary Backing Warning, 3-Imminent Backing Warning, 4-Emergency Braking) 10 - Type of Braking at trial end (0 for none, 1 for driver, 2 for emergency braking, 3 for both) 11 - Last braking level (*g*; driver + automatic braking) prior to outcome 12 - Final glance location 13 14 15 16 17 - Countermeasures that were active at some point (1 indicates active; column 12 is Proximity Information, 13 - Automatic Braking during Backing Initiation, 14 – Cautionary Backing Warning, 15 – Imminent Backing Warning, 16 - Automatic Braking during Active Backing) 18 - Did the vehicle move during the trial? (1 means yes) 19 - Selected Scenario 20 - Was there an obstacle in the travel path of the vehicle? 21 - Reaction Time remaining at outcome (sec; if not fully elapsed) 22 23 24 - Final vehicle speed (m/s) 25 - Maximum longitudinal vehicle speed 26 - Display that triggered object detection by driver LUMCM: N/A

Logic:
After every iteration, another row is added to this matrix with the results for the particular iteration. Once all iterations for a run are complete, the results are transferred to the aggregate matrix and the variable is cleared to make room for the new run.

These outputs are then aggregated across runs and countermeasure/no countermeasure conditions as detailed on the following table.

Relevant SIM Variables	
Variable	*Description/Possible Values*
FullOutcomeMatrix FullOutcomeMatrixNC	Three-dimensional matrices, with number of dimensions equal to Number of Runs X Number of Iterations per Run X Number of Columns in OutcomeMatrix. FullOutcomeMatrix contains results for runs where the countermeasure is available/active. FullOutcomeMatrixNC contains results for runs where the countermeasure is unavailable/inactive.
Logic:	
After every run, another level is added to this matrix with the results for the particular run.	

Details concerning the process by which these outputs are converted into estimates of safety benefits are discussed as part of Chapter 9.

8 MODEL CALIBRATION AND VALIDATION TO CONTROLLED TEST DATA

8.1 OVERVIEW

The model calibration and validation to controlled test data process was comprised of two separate efforts. First, outputs from different sections of the model were monitored to ensure that the results obtained were valid and in line with the inputs that were received. As part of this process, some areas for future improvement of the model and the data that feeds it were found. Second, inputs to the SIM model were adjusted to represent the knowledge gained through the objective tests. This required translation of the results of these tests into data structures that the SIM model could assimilate and utilize.

8.2 Model Monitoring

The necessity for a SIM model arises from the lack of real-world data on the effectiveness of the countermeasures of interest. Therefore, direct validation of the outputs of the model is not possible. That leaves model validation to be accomplished via indirect assessments of the validity of internal model outputs. Other validation alternatives, such as sensitivity analyses, were outside of the scope of this effort and were thus not attempted.

In order to perform these internal checks, two different tools were used, and are available to users of the model. The first tool is the graph indicators of internal model performance, which can provide the user with time histories of the vehicle speed, driver's eyeglance behavior, and vehicle and object trajectories on an iteration-by-iteration basis. These plots were used early in the validation process, as the output and outcome of each iteration were scrutinized (Figure 134). Since the plots can be used to monitor any internal signal within the Monte Carlo simulation, they can be very useful in ensuring that the signals that are being provided to a particular module are appropriate and valid. Since multiple signals can be plotted on the same graph, they are also useful in assessing their timeliness and synchronization. Throughout the model building process, these graphs were invaluable in testing piece-wise components of the overall SIM model.

Whereas the plots provide information for a single iteration, it was also important to ensure that the distribution of inputs and outputs to and from the SIM model were appropriately defined and reflected the scenario of interest. To assist in this verification, the second set of tools resulted from the storage, across iterations and runs, of a wide array of variables that were monitored within the simulation. Most of these variables were not essential for the estimation of safety benefits, and were observed post hoc. The list of variables available for monitoring is described in Section 7.2.5. For example, the maximum vehicle velocities could be collected for each iteration, and histograms generated to compare against the expected range of vehicle velocities based on the known distributions that were provided for the model and the scenario characteristics. Similarly, knowledge of certain countermeasure characteristics (e.g., some countermeasures were not active at speeds lower than 4 mph) allowed for verification of their inactivity in conditions where the activation thresholds and criteria were not met.

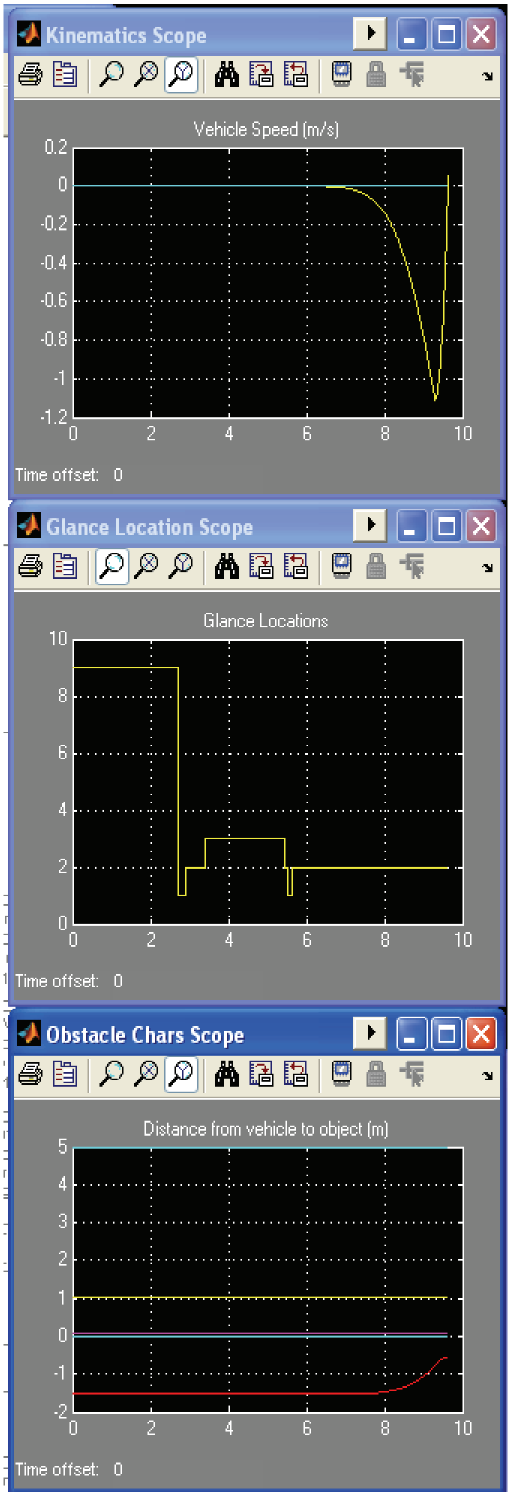


Figure 134. SIM model plots, from top to bottom, vehicle speed, glance locations, and distance between vehicle and obstacle

In general, the validation process followed the following steps:

1) Initial validation: as the model was being built, graphs were used to determine the validity and appropriateness of signals within the model. Examples include:
    a. Vehicle speed profiles (these were heavily tested, as they could be influenced by a number of factors including TTC, where applicable, the distance backed, coasting, and braking)
    b. Glance locations: ensure that durations were sufficiently long and correctly related to the location, that certain sequences of glances were more prevalent (as suggested by the empirical data), and that the timing was appropriate (e.g., certain countermeasures were very likely to trigger new glances)
    c. Vehicle-Obstacle kinematics: monitored that the obstacle and vehicle were getting nearer in paths that were compatible with the scenario and that conflicts were present
2) Subsequent monitoring
    a. Crash and Avoidance: monitored that the kinematic variables were compatible with the outcomes. For example, that avoidance outcomes were the result of a stopped vehicle and some distance left between the obstacle and the vehicle.
    b. Last Countermeasure: monitored how often countermeasures were active at the end of a scenario and correlated with the expectancies based on objective test results.
    c. Braking: monitored how often the driver and/or automatic braking engaged the brakes. Compared to expectancies based on the known driver model distributions and countermeasure operation within the objective tests.
    d. Peak deceleration levels: compared to known distributions
    e. Final glance location: correlated to driver actions; locations where the obstacle was visible would be expected to trigger a reaction more often than locations where this was not the case
    f. Countermeasures active at some point in the simulation: allowed for verification of appropriate activation sequences and checks against known countermeasure characteristics (e.g., particular activation criteria)
    g. Scenario type: monitored to ensure that different scenarios were equally likely to be simulated (exposure was accounted for as part of the benefits estimation process)
    h. Display that triggered obstacle detection by driver: monitored to ensure that only appropriate displays triggered detection, and that they did so with frequencies compatible with the expectancies based on the data available

An example of the validation process, specifically the monitoring aspect, can be found in the discussions of the results for different scenarios that are shown in Chapter 10. More specifically, maximum speed attained during the backing maneuver was examined to ensure that it supported the pre-determined characteristics of each scenario. Pedestrian Scenario 1, for example, only allowed 5 ft of distance between the rear of the vehicle and the obstacle. Pedestrian Scenario 3 allowed 15 ft of distance. A properly-working representation of vehicle kinematics in these situations would show a larger average maximum speed attained for Pedestrian Scenario 3, since it allowed for further travel distance before a crash was possible. Monitoring the maximum speed attained showed that a higher average maximum speed was indeed attained for Pedestrian Scenario 3.

As further example of the use of maximum speed attained for model validation, this variable was also used in interpreting the activation potential for different countermeasures. Pedestrian Scenario 1, for example, showed little or no activation of Backing Warnings. The reason for this lack of activation was traced back to vehicle speeds that did not exceed the 4 mph threshold for the activation of these types of countermeasure components. As expected, increased rates of Backing Warning activations were observed in scenarios that allowed for higher speeds.

Throughout the model creation process, these and other verifications and validations were invaluable in ensuring the appropriate operation of portions of the SIM whose performance could be verified. The next section describes how the model was calibrated to accurately represent the available objective test results.

8.3 Calibration to Objective Test Results

The objective test results are used to infer characteristics of the backing crash countermeasure and its expected performance in the simulated scenarios. These objective test results had to be integrated into the SIM model. This process represents a key part of the calibration process the SIM should undergo as new countermeasures are developed and tested.

The different section headings represent each of the different objective tests. Within each section, there is a description of the data that were synthesized into the SIM model for that test. Note that in most cases, the amount of data precludes inclusion into this document, even as an Appendix. The data, however, are available to the reader in the discussion of objective test results (Chapter 6), and are also included within the control code of the SIM model.

Prior to discussing the objective test integration, there was a separate minor data-gathering effort to provide information concerning the enhanced vision system latency. The results are provided in the following table. This data-gathering effort was not an objective test since it was treated as information that would be obtained from performance specifications for the countermeasure of interest.

Monitor Latency	
SIM Module Locations (Look-up tables; note that look-up tables are data structures within the simulation that produce as an output the content of the cell that represents the intersection of all its input values. Interpolation or extrapolation within the tables may be used as necessary):	▪ Backing SIM/Components that Support or Promote In-Vehicle Visual Search/Enhanced Vision Available/Compare to Constant ▪ Backing SIM/Components that Support or Promote In-Vehicle Visual Search/Visual DVI Warning Available/Compare to Constant
Variable Name:	▪ Enhanced Vision Latency. Represents the time it takes for the rear vision screen to become available to the driver. Two values were obtained, 2.08 sec when the

	driver shifts immediately after turning the ignition on, and 0.75 sec when that shift occurs after the screen has initialized (a few seconds after ignition). The former value is used when the participant is involved in hurried backing (as denoted by the Hurried Backing variable, see the section on Vehicle Kinematics). Both times are counted from the time when the reverse lights are illuminated.

In addition to monitor latency, a look-up table was created to define obstacle representation within the DVI of the countermeasure suite. The look-up table is provided for future situations where an automatic countermeasure may be active but the DVI may not reflect that activation (e.g., if multiple alerts had to be prioritized). This look-up table serves as a placeholder, and currently indicates that an active countermeasure DVI always represents the obstacle (or an indication of the obstacle) whenever that countermeasure is active.

Obstacle Representation within the DVI	
SIM Module Locations (Look-up tables):	▪ BackingSIM/Components that Support or Promote In-Vehicle Visual Search/Visual DVI Warning Available
Variable Name:	▪ VisualDVIOTProxGrid (Matrix size is 6X110X70X5, initialized to ones). Represents the likelihood that the obstacle will be represented within the DVI (0…1).
Data	
Look-up Table with 4 dimensions and corresponding anchor points: 1. Obstacle Type – 1…6 (1=2-yr. old pedestrian standing; 2=2-yr. old pedestrian sitting; 3=2-yr. old pedestrian lying prone; 4=5-yr. old standing pedestrian; 5=vehicle; 6=pole) 2. Longitudinal distance to the obstacle (in m) – [-5.94 : 0.3048 : 27.2796] (minimum : interval : maximum) 3. Lateral distance to the obstacle (in m) – [-10.5156 : 0.3048 : 10.5156] (minimum : interval : maximum) 4. DVI Type active – [0,1,2,3,4] (0 implies No DVI, 1 is Audible and Visual for Proximity Information, 2 is Audible and Visual for Backing Warning, 3 is the Audible, Visual and Haptic Brake Pulse Warning, 4 is Audible, Visual, and Automatic Braking). Provides information on which countermeasure (if any) is responding so that the availability of a visual DVI for that countermeasure can be correctly assessed and employed in the simulation. Linear interpolation is allowed within the endpoints of each dimension. However, extrapolation is not permitted. Input values outside the endpoints of any dimension receive the value corresponding to the endpoint of the out-of-bounds dimension.	

The following sections describe the use of objective test results, on a test-by-test basis.

8.3.1 Test 1: Proximity-Based, Camera Field of View

Test 1 determined the likelihood of visibility of different obstacles within the enhanced vision countermeasure across the testing grid. Results were available in the form of a matrix of grid locations (i.e., rows and columns), broken down by obstacle type, indicating whether an obstacle was visible within the enhanced vision countermeasure when located at a particular grid square.

SIM Module Location (Look-up table):	▪ BackingSIM/Components that Support or Promote In-Vehicle Visual Search/Enhanced Vision Available/ OT Proximity Grid – Enhanced Vision
Variable Name:	▪ EnhancedVisionOTProxGrid (Matrix size is 6X26X53X5, initialized to ones). Represents the likelihood that the obstacle will be visible (0…1).

Data
Look-up Table with 4 dimensions and corresponding anchor points: 1. Obstacle Type – 1…6 (1=2-yr. old pedestrian standing; 2=2-yr. old pedestrian sitting; 3=2-yr. old pedestrian lying prone; 4=5-yr. old standing pedestrian; 5=vehicle; 6=pole) 2. Longitudinal distance to the obstacle (in m) – [0.1725 : 0.345 : 8.7975] (minimum : interval : maximum) 3. Lateral distance to the obstacle (in m) – [-8.97 : 0.345 : 8.97] (minimum : interval : maximum) Linear interpolation is allowed within the endpoints of each dimension. However, extrapolation is not permitted. Input values outside the endpoints of any dimension receive the value corresponding to the endpoint of the out-of-bounds dimension.

8.3.2 Test 2: Proximity-Based, Static Field of Response

In this test, the response for different static obstacles was assessed for a static vehicle. Objects were tested across the grid, to the extent that response was still occurring, in order to determine a "response envelope" for each obstacle. Results were available in the form of a matrix of grid locations (i.e. rows and columns), broken down by obstacle type, indicating the probability that an obstacle was responded to by the proximity information countermeasure. The probability was derived as the number of responses for an obstacle divided over the number of trials performed for each grid location.

SIM Module Location (Look-up table):	▪ BackingSIM/Backing Initiation Phase/Proximity Information/OT Proximity Grid
Variable Name:	▪ BackingInitiationProximityInformationOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle response (0…1).

Data
Look-up Table with 7 dimensions with corresponding anchor points: 1. Object Type – 1…6 (1=2-yr. old pedestrian standing; 2=2-yr. old pedestrian sitting; 3=2-yr. old pedestrian lying prone; 4=5-yr. old standing pedestrian; 5=vehicle; 6=pole) 2. Longitudinal distance to the obstacle (in m) – [0.1725 : 0.3450 : 9.8325] (minimum : interval : maximum) 3. Lateral distance to the obstacle (in m) – [-2.415 : 0.3450 : 2.76] (minimum : interval : maximum) 4. Obstacle Speed (in m/s) – [0,0.89408,1.78816] 5. Vehicle Speed (in m/s) – [0,1.78816,3.57632,6.7056] 6. Obstacle Incurring Direction – [-1,0,1] (-1 implies incurring from the left, 0 implies static obstacle, 1 implies incurring from the right) 7. Lateral Steering Vector – [0,0.707106781186547] (0 implies wheels straight, 0.707106781186547 implies full lock) Linear interpolation is allowed within the endpoints of each dimension; linear extrapolation is allowed outside of those endpoints.

A subset of test 2 (using the static pole) was used to gather latency data for the proximity information countermeasure.

SIM Module Location (Look-up table):	▪ BackingSIM/Backing Initiation Phase/Proximity Information/OT Latency ▪ BackingSIM/Backing Initiation Phase/Automatic Braking/OT Latency ▪ BackingSIM/Active Backing Phase/Backing Warning Stage 1/OT Latency ▪ BackingSIM/Active Backing Phase/Backing Warning Stage 2/OT Latency ▪ BackingSIM/Active Backing Phase/Automatic Braking/OT Latency
Variable Name:	▪ Latency (Matrix size is 13X16, initialized to 0.18 sec, which was the average of all recorded latencies). Represents the time (in sec) that the countermeasure takes to respond to an obstacle as a function of its location.

Data

Look-up Table with 2 dimensions with corresponding anchor points:

1. Longitudinal distance to the obstacle (in m) – [0.1725 : 0.3450 : 4.3125] (minimum : interval : maximum)
2. Lateral distance to the obstacle (in m) – [-2.415 : 0.3450 : 2.76] (minimum : interval : maximum)

Linear interpolation is allowed within the endpoints of each dimension. However, extrapolation is not permitted. Input values outside the endpoints of any dimension receive the value corresponding to the endpoint of the out-of-bounds dimension.

This latency matrix is used throughout all the countermeasures, with two assumptions: 1) since latency was not measured for all objects, it is assumed that other objects will be responded to with similar latency patterns, and 2) the latency for grid squares that were not measured is similar to the latency for those squares that were measured.

8.3.3 Test 3: Proximity-Based, Field of Response

In this test, incurring obstacles approached the sides of a static vehicle and the timing of the proximity information countermeasure response was noted. The test consisted of two trials for each condition (which included two encroachment approaches, driver's left and driver's right). The distance (both lateral and longitudinal) to obstacle at response was the main result from the objective test. This distance was compared across the trials available for each condition. Probabilities of response were determined according to the following heuristic:

1) For each longitudinal distance, the lateral distance to the obstacle up to the minimum distance recorded was assigned a probability of 1, unless there were non-responses for any of the trials.

In the latter case, the assigned probability was the number of trials where response occurred divided by the total number of trials.

2) Subsequent distances were assigned a probability equal to the number of response observations smaller or equal to the lateral distance divided by the total number of trials.

SIM Module Locations (Look-up tables):	BackingSIM/Backing Initiation Phase/Proximity Information/OT Proximity Grid ▪ BackingSIM/Backing Initiation Phase/Automatic Braking/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Backing Warning Stage 1/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Backing Warning Stage 2/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Automatic Braking/OT Proximity Grid
Variable Names:	(in order of location, as specified above) ▪ BackingInitiationProximityInformationOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle detection (0…1). ▪ BackingInitiationAutomaticBrakingOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle detection (0…1). ▪ ActiveBackingBWStage1OTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle detection (0…1). ▪ ActiveBackingBWStage2OTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle detection (0…1). ▪ ActiveBackingAutomaticBrakingOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle detection (0…1).

Data

Look-up Tables with 7 dimensions with corresponding anchor points:

1. Object Type – 1…6 (1=2-yr. old pedestrian standing; 2=2-yr. old pedestrian sitting; 3=2-yr. old pedestrian lying prone; 4=5-yr. old standing pedestrian; 5=vehicle; 6=pole)
2. Longitudinal distance to the obstacle (in m) – [0.1725 : 0.3450 : 9.8325] (minimum : interval : maximum)
3. Lateral distance to the obstacle (in m) – [-2.415 : 0.3450 : 2.76] (minimum : interval : maximum)
4. Obstacle Speed (in m/s) – [0,0.89408,1.78816]
5. Vehicle Speed (in m/s) – [0,1.78816,3.57632,6.7056]
6. Obstacle Incurring Direction – [-1,0,1] (-1 implies incurring from the left, 0 implies static

obstacle, 1 implies incurring from the right) 7. Lateral Steering Vector – [0,0.707106781186547] (0 implies wheels straight, 0.707106781186547 implies full lock) Linear interpolation is allowed within the endpoints of each dimension; linear extrapolation is allowed outside of those endpoints.

8.3.4 Test 4: Warning-Based, Dynamic Longitudinal

In this test, static obstacles were approached by a moving vehicle and the type and timing of countermeasure responses noted. To integrate the results into the SIM, some manipulations and assumptions were necessary:

1) To obtain the distance to the obstacle, the alert location was subtracted from the obstacle location and half a square was added (to account for the difference in camera line-of-sight and the bumper surface where the sensors are located).
2) The response area was assumed to be as wide as the vehicle. Since the obstacle was not moving and steering input was minimal, only an obstacle in the vehicle track could be hit.

The test consisted of three trials for each condition. The distance to obstacle at response was the main result from the objective test. This distance was compared across the three trials (or the number of trials available for each condition). Probabilities of response were determined according to the following heuristic:

1) Distances to obstacle up to the minimum distance recorded were assigned a probability of 1, unless there were non-responses for any of the trials. In the latter case, the assigned probability was the number of trials where response occurred divided by the total number of trials.
2) Subsequent distances were assigned a probability equal to the number of response observations smaller than or equal to the distance divided by the total number of trials.

SIM Module Locations (Look-up tables):	BackingSIM/Backing Initiation Phase/Proximity Information/OT Proximity Grid ▪ BackingSIM/Backing Initiation Phase/Automatic Braking/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Backing Warning Stage 1/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Backing Warning Stage 2/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Automatic Braking/OT Proximity Grid
Variable Names:	(in order of location, as specified above) ▪ BackingInitiationProximityInformationOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to

	zeros). Represents the probability of obstacle alert (0…1). ▪ BackingInitiationAutomaticBrakingOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪ ActiveBackingBWStage1OTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪ ActiveBackingBWStage2OTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪ ActiveBackingAutomaticBrakingOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1).
Data	
Look-up Tables with 7 dimensions with corresponding anchor points: 1. Object Type – 1…6 (1=2-yr. old pedestrian standing; 2=2-yr. old pedestrian sitting; 3=2-yr. old pedestrian lying prone; 4=5-yr. old standing pedestrian; 5=vehicle; 6=pole) 2. Longitudinal distance to the obstacle (in m) – [0.1725 : 0.3450 : 9.8325] (minimum : interval : maximum) 3. Lateral distance to the obstacle (in m) – [-2.415 : 0.3450 : 2.76] (minimum : interval : maximum) 4. Obstacle Speed (in m/s) – [0,0.89408,1.78816] 5. Vehicle Speed (in m/s) – [0,1.78816,3.57632,6.7056] 6. Obstacle Incurring Direction – [-1,0,1] (-1 implies incurring from the left, 0 implies static obstacle, 1 implies incurring from the right) 7. Lateral Steering Vector – [0,0.707106781186547] (0 implies wheels straight, 0.707106781186547 implies full lock) Linear interpolation is allowed within the endpoints of each dimension; linear extrapolation is allowed outside of those endpoints.	

8.3.5 Test 5: Warning-Based, Dynamic Horizontal, Full Lock at Parking Speed

In this test, static obstacles were approached by a moving vehicle traveling at full steering lock. The type and timing of countermeasure system activations were noted. To integrate the results into the SIM, some manipulations and assumptions were necessary:

1) Straight-line distances to the obstacle were converted into longitudinal and lateral distances in a grid-like fashion, to make the results comparable to those of other objective tests.
2) The lateral distance observed was assumed to remain as the maximum response coverage width for longitudinal distances equal to or smaller than the longitudinal distance observed.

The test consisted of four trials for each condition (two counter-clockwise and two clockwise, but these results were collapsed unless substantial differences were observed in the results). The distance to obstacle at response was the main result from the objective test. This distance was compared across the four trials (or the number of trials available for each condition). Probabilities of response were determined according to the following heuristic:

1) Distances to obstacle up to the minimum distance recorded were assigned a probability of 1, unless there were non-responses for any of the trials. In the latter case, the assigned probability was the number of trials where response occurred divided by the total number of trials.
2) Subsequent distances were assigned a probability equal to the number of response observations smaller than or equal to the distance divided by the total number of trials.

These probabilities were then compared to similar probabilities obtained under straight-line backing conditions (Test 4). Differences in the resultant field-of-view were then extracted and used to modify (e.g., narrow, increase) the width of the response field-of-view across other objective tests when full-lock conditions were in use.

SIM Module Locations (Look-up tables):	BackingSIM/Backing Initiation Phase/Proximity Information/OT Proximity Grid ▪ BackingSIM/Backing Initiation Phase/Automatic Braking/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Backing Warning Stage 1/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Backing Warning Stage 2/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Automatic Braking/OT Proximity Grid
Variable Names:	(in order of location, as specified above) ▪ BackingInitiationProximityInformationOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪ BackingInitiationAutomaticBrakingOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪ ActiveBackingBWStage1OTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪ ActiveBackingBWStage2OTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪ ActiveBackingAutomaticBrakingOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪

Data
Look-up Tables with 7 dimensions with corresponding anchor points: 1. Object Type – 1…6 (1=2-yr. old pedestrian standing; 2=2-yr. old pedestrian sitting; 3=2-yr. old pedestrian lying prone; 4=5-yr. old standing pedestrian; 5=vehicle; 6=pole) 2. Longitudinal distance to the obstacle (in m) – [0.1725 : 0.3450 : 9.8325] (minimum : interval : maximum) 3. Lateral distance to the obstacle (in m) – [-2.415 : 0.3450 : 2.76] (minimum : interval : maximum) 4. Obstacle Speed (in m/s) – [0,0.89408,1.78816] 5. Vehicle Speed (in m/s) – [0,1.78816,3.57632,6.7056] 6. Obstacle Incurring Direction – [-1,0,1] (-1 implies incurring from the left, 0 implies static obstacle, 1 implies incurring from the right) 7. Lateral Steering Vector – [0,0.707106781186547] (0 implies wheels straight, 0.707106781186547 implies full lock) Linear interpolation is allowed within the endpoints of each dimension; linear extrapolation is allowed outside of those endpoints.

8.3.6 Test 6: Warning-Based, Dynamic Horizontal, Backing Straight with Incurring Obstacles

In this test, incurring obstacles were approached by a moving vehicle traveling on a straight path. The type and timing of countermeasure responses were noted. To integrate the results into the SIM, the lateral distance observed was assumed to remain as the response coverage width for longitudinal distances equal to or smaller than the longitudinal distance observed.

The test consisted of four trials for each condition (two from each direction). The distance to obstacle at response was the main result from the objective test. This distance was compared across the number of trials available for each condition. Probabilities of response were determined according to the following heuristic:

1) Distances to obstacle up to the minimum distance recorded were assigned a probability of 1, unless there were non-responses for any of the trials. In the latter case, the assigned probability was the number of trials where alert occurred divided by the total number of trials.
2) Subsequent distances were assigned a probability equal to the number of response observations smaller than or equal to the distance divided by the total number of trials.

Obstructed and unobstructed line-of-sight tests were input separately and selected-from based on the scenario being simulated. This selection is controlled by the ProbabilityofPreview and ProbabilityofPreviewData variables, to be discussed in a later section.

SIM Module Locations (Look-up tables):	▪ BackingSIM/Backing Initiation Phase/Proximity Information/OT Proximity Grid ▪ BackingSIM/Backing Initiation Phase/Automatic Braking/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Backing Warning Stage 1/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Backing Warning

	Stage 2/OT Proximity Grid ▪ BackingSIM/Active Backing Phase/Automatic Braking/OT Proximity Grid
Variable Names:	(in order of location, as specified above) ▪ BackingInitiationProximityInformationOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪ BackingInitiationAutomaticBrakingOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪ ActiveBackingBWStage1OTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪ ActiveBackingBWStage2OTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1). ▪ ActiveBackingAutomaticBrakingOTProxGrid (Matrix size is 6X29X16X3X4X3X2, initialized to zeros). Represents the probability of obstacle alert (0…1).
Data	
Look-up Tables with 7 dimensions with corresponding anchor points: 1. Object Type – 1…6 (1=2-yr. old pedestrian standing; 2=2-yr. old pedestrian sitting; 3=2-yr. old pedestrian lying prone; 4=5-yr. old standing pedestrian; 5=vehicle; 6=pole) 2. Longitudinal distance to the obstacle (in m) – [0.1725 : 0.3450 : 9.8325] (minimum : interval : maximum) 3. Lateral distance to the obstacle (in m) – [-2.415 : 0.3450 : 2.76] (minimum : interval : maximum) 4. Obstacle Speed (in m/s) – [0,0.89408,1.78816] 5. Vehicle Speed (in m/s) – [0,1.78816,3.57632,6.7056] 6. Obstacle Incurring Direction – [-1,0,1] (-1 implies incurring from the left, 0 implies static obstacle, 1 implies incurring from the right) 7. Lateral Steering Vector – [0,0.707106781186547] (0 implies wheels straight, 0.707106781186547 implies full lock) Linear interpolation is allowed within the endpoints of each dimension; linear extrapolation is allowed outside of those endpoints.	

8.3.7 Tests 7 through 10: False Alarm Rate Performance – Residential Driveway, Residential Garage, Commercial Parking Lot, and Public City Street

The false alarm rate tests examined unhelpful countermeasure responses in a variety of environments. The number of unhelpful countermeasure responses divided over the number of opportunities (i.e., a false alarm rate) was the main result from these different objective tests. Note that these rates are NOT intended to represent the false alarm rates that would be observable in extended use in the real world because the exposure to each of the conditions for the false alarm tests is unknown. The rates produced by the false alarm tests simply provide an initial value to a parameter within the SIM whose main use is to provide a means for examining the sensitivity of the benefits estimates to the combination of false alarm rate and driver trust that a countermeasure exhibits (see section 8.3.8, on driver-in-the-loop tests, for more information about the derivation of driver trust). The table below shows the locations of the different data structures that contain the false alarm objective test data.

SIM Module Locations (Look-up tables):	BackingSIM/Backing Initiation Phase/Proximity Information/OT False Alarm BackingSIM/Backing Initiation Phase/Automatic Braking/OT False Alarm BackingSIM/Active Backing Phase/Backing Warning Stage 1/OT False Alarm BackingSIM/Active Backing Phase/Backing Warning Stage 2/OT False Alarm BackingSIM/Active Backing Phase/Automatic Braking/OT False Alarm BackingSIM/Backing Initiation Phase/Proximity Information/Belief BackingSIM/Backing Initiation Phase/Automatic Braking/Belief BackingSIM/Active Backing Phase/Backing Warning Stage 1/Belief BackingSIM/Active Backing Phase/Backing Warning Stage 2/Belief BackingSIM/Active Backing Phase/Automatic Braking/Belief
Variable Names:	FalseAlarmOT (Matrix size is 3X4X2, initialized to zeros). Represents the probability of a false alarm being present in a particular backing environment (0…1).

Data

The output of the OT False Alarm look-up tables is the corresponding false alarm rate observed in the objective tests. These look-up tables have 2 dimensions and these corresponding anchor points:

1. False Alarm Test Type – 1…3 (1 is Residential – applicable to scenarios 3,4,6,8, and 10; 2 is Commercial/Parking Lot – applicable to scenarios 1,5, and 9; 3 is Public/City Street – applicable to scenarios 2 and 7)
2. Active DVI Type – [1,2,3,4] (1 is Audible and Visual for Proximity Information, 2 is Audible and Visual for Cautionary Backing Warning, 3 is the Audible, Visual and Haptic Brake Pulse for Imminent Warning, 4 is Audible, Visual, and Automatic Braking) – indicates the DVI Type(s) that were triggered as part of the false alarm.
3. Vehicle Speed (in m/s) – [1.78816,3.57632]

For each of these look-up tables, linear interpolation is allowed within the endpoints of each dimension; linear extrapolation is allowed outside of those endpoints.

8.3.8 Tests 11 through 15: Driver-in-the-Loop Tests of Crash Avoidance – Intermediate-Static Pedestrian, Near-Incurring Pedestrian, Intermediate-Incurring Pedestrian, Near Static Vehicle, and Intermediate Static Pole

The driver-in-the-loop tests provided information on driver behavior in response to the backing countermeasure alerts. The eyeglance patterns and the amount of trust that drivers placed on the countermeasure(s) received were the main results from these different objective tests. In addition, the tests provided data on transition times between the last location before an alert and a glance to the alert display or to an area where detection is possible (which allows the Monte Carlo simulation model to properly interrupt the current glance when an alert is issued during an iteration), as well as an estimate of the rate of instances in which drivers glanced at a display of the obstacle (i.e., the enhanced vision display) but failed to respond to the obstacle, also referred to as Look-Did-Not-See.

For the derivation of driver trust in the different countermeasure suite components and Look-Did-Not-See estimates, the distribution of tests across scenarios occurred as follows:

- Intermediate – Static Pedestrian: Pedestrian Scenario 1, Pedestrian Scenario 2, and Pedestrian Scenario 3
- Intermediate – Incurring Pedestrian: Pedestrian Scenario 4 and Pedestrian Scenario 6
- Near – Incurring Pedestrian: Pedestrian Scenario 5
- Near Static Vehicle: Vehicle Scenario 1
- Intermediate Static Pole: Vehicle Scenario 2, Vehicle Scenario 3, and Fixed Object Scenario

Note that in deriving trust from these tests, trust and "override" of a vehicle control countermeasure (i.e., automatic braking) are assumed to be inversely related. That is, if a participant does not trust a vehicle control countermeasure, it is expected that it will be overridden. This assumption is implemented in the SIM. In addition to the derivation of driver trust from the objective tests, a brief literature review was conducted to further inform these results. The results of this review are summarized within the chapter on Data Sources. Only the trust for Imminent Backing Warning was obtained from the literature review and applied to the SIM, as all other trust figures could be obtained directly from driver-in-the-loop test data for one or more scenarios.

SIM Module Locations (Look-up tables):	▪ BackingSIM/Conflict Assessment and Resolution – Part 1/Glance Behavior/Glance/Eyeglance Sequence ▪ BackingSIM/Conflict Assessment and Resolution – Part 1/Glance Behavior/Transition to new glance on DVI activation/Scale ▪ BackingSIM/Conflict Assessment and Resolution – Part 1/Glance Behavior/Transition to new glance on DVI activation/Shape ▪ BackingSIM/Backing Initiation Phase/Proximity Information/Belief ▪ BackingSIM/Backing Initiation Phase/Automatic Braking/Belief ▪ BackingSIM/Active Backing Phase/Cautionary Backing Warning/Belief ▪ BackingSIM/Active Backing Phase/Imminent Backing Warning/Belief ▪ BackingSIM/Active Backing Phase/Automatic Braking/Belief
Variable Names:	(in order of location, as specified above) ▪ EyeglanceSequence ▪ TransitionScale (Matrix is one-dimensional). Provides the appropriate transition time scale parameter (Weibull distribution) based on the type of DVI that becomes active. The parameters were obtained from fits of driver-in-the-loop eyeglance data. ▪ TransitionShape (Matrix is one-dimensional). Provides the appropriate transition time shape parameter (Weibull distribution) based on the type of DVI that becomes active. The parameters were obtained from fits of driver-in-the-loop eyeglance data. For all the Belief look-up tables: XXXTrustValue (Matrix size is 10X12, initialized to zeros). Represents the probability that the countermeasure component will be trusted by the driver (0…1). XXX could be one of the following: • ProximityInformation

	• CautionaryBackingWarning • ImminentBackingWarning • AutomaticBraking
Variable	*Description/Possible Values*
LookedDidNotSeeXXXX	Probability (0…1) that a glance to a display device where the obstacle is visible will not result in detection. XXXX can be any of the following: • EnhancedVision • LeftMirror • RightMirror • RearViewMirror • OverShoulder • VisualDVI Note that, while not modeled, this parameter may be dependent on the size of the visual display, especially when the target is not close to the vehicle (except for the Visual DVI which is an abstract display). If available, this information could be input in the SIM by introducing a parameter that acts as a modifier. Preliminary data to accomplish this exists (Tsimhoni et al., 2006). LUMCM: ▪ BackingSIM/Components that Support or Promote In-Vehicle Visual Search/Enhanced Vision Available ▪ BackingSIM/Components that Support or Promote In-Vehicle Visual Search/Left Side Mirror ▪ BackingSIM/Components that Support or Promote In-Vehicle Visual Search/Over-the-Shoulder Glance ▪ BackingSIM/Components that Support or Promote In-Vehicle Visual Search/Rear View Mirror ▪ BackingSIM/Components that Support or Promote In-Vehicle Visual Search/Right Side Mirror ▪ BackingSIM/Components that Support or Promote In-Vehicle Visual Search/DVI Warning Available

Data

The description of the EyeglanceSequence variable can be found in the *Glances Distributions* section under *Driver Model Parameters*. For efficiency, it was included as part of the driver model even though driver-in-the-loop test results were used to calculate it.

Transition means (and standard deviations) for the different countermeasures are:

- Proximity Information: 0.95 (0.58) sec
- Cautionary Warning: 0.95 (0.58) sec
- Imminent Warning: 0.95 (0.58) sec
- Automatic Braking: 1.06 (0.55) sec

These means and standard deviations translate to matrices of Weibull distribution parameters in the model. These transition parameters have five different columns, all of which indicate the parameters that apply to the activation of a countermeasure.

- Column 1 - No DVI (there is no transition triggered)
- Column 2 - Proximity Information
- Column 3 - Cautionary Warning
- Column 4 - Imminent Warning
- Column 5 - Automatic Braking

TransitionScale=[0,1.06081,1.06081,1.06081,1.19432]
TransitionShape=[0,1.67034,1.67034,1.67034,2.01109]

For the Belief look-up table, the first dimension represented the scenario, the second the rate of false alarms. Probabilities of trust were constant as a function of the rate of false alarms (i.e., in the current implementation of the SIM, they only vary based on the scenario). Values were as follows:

- ProximityInformationTrustValue: always 0
- CautionaryBackingWarningTrustValue: always 0
- ImminentBackingWarningTrustValue: always 0.67
- AutomaticBrakingTrustValue: always 1 except for Vehicle Scenario 1, where it was 0.77.

The nearest output was used if inputs differed from the pre-defined states.

For the LookedDidNotSeeXXXX variable, values were as follows:

- Scenarios 1, 2, and 3: 0.22 (Drivers did not detect the obstacle in the Enhanced Vision display 22% of the time.)
- Scenarios 4 and 6: 0.50
- Scenario 5: 0.00
- Scenario 7: 0.00
- Scenarios 8, 9, and 10: 0.11

Note that the simplifying assumption was made that look-did-not-see rates for mirrors were the same as those obtained from the driver-in-the-loop tests for the Enhanced Vision countermeasure. Look-did-not-see rates for visual DVIs were assumed to be zero.

8.3.9 Objective Test Limitations

While integrating the objective test results into the SIM model, a number of limitations were apparent. An important limitation related to the objective tests that emerged during the project is the "coarseness" of the objective test data. This coarseness is evident on several fronts; first, in the range of speeds that was tested in the objective tests. Typically, the first two speeds tested were 0 mph (i.e., vehicle static) and 4 mph. The issue with these speeds is that a substantial portion of the scenario simulations unfolded at speeds slower than 4 mph. While the response of the countermeasures may not have been linear in this speed range (e.g., the true response rate at 2 mph may be 100% of the response rate at 4 mph, as opposed to the 50% that would be predicted by linear interpolation), this information is not available to the SIM. Instead, the SIM is forced to linearly interpolate in that region. Potential solutions could be to examine more speeds in the range between 0 and 4 mph, or develop tests where the vehicle is accelerating from stand-still to the test speed in a manner that more closely resembles the test scenario.

A second objective test limitation identified is related to the accuracy with which incurring obstacles are modeled. In the objective tests, those obstacles were nominally timed (recall the vehicle was also moving during these tests) so that in the absence of countermeasure activation, impact occurred at the rear bumper along the vehicle centerline. This provided a single response data point to the SIM and constrains its ability to model responses to obstacles that would have nominal impact at a point before the vehicle centerline. A more comprehensive approach could be to examine countermeasure responses at nominal impact points that are located all along the rear bumper, which would allow for some interpolation of countermeasure responses and rates.

A third objective test limitation identified is the limited number of trials that were used to assess probabilities of detection. In general, once responses were broken down, based on all the factors that affected them (e.g., direction of encroachment, type of obstacle), only two or three trials per “cell” remained. Therefore, estimated response probabilities were coarse (e.g., 0%, 50%, or 100% response for cells with two trials) and very sensitive to spurious instances of non-activation, common given the probabilistic nature of active safety sensing systems. The model was also sensitive to the response distances and those instances where activation occurred unusually late. Given the low number of “repetitions,” spurious instances of late responses could sway detection rates considerably toward distances closer to the rear bumper. In turn, these late test responses had the potential to result in model-estimated responses that occurred too late for a driver to effectively apply the brakes and, in some instances, too late for the automatic braking countermeasure to brake the car while avoiding a crash.

A fourth limitation with the driver-in-the-loop tests was also noted. One of the data points obtained from these tests was the level of driver trust in the different countermeasures that the drives exhibited. Note, however, that obtaining driver trust and reaction to a countermeasure from these tests requires experimenter judgment based on the video without an understanding of a driver’s true intentions (beyond any verbalizations they may have exhibited). Also, in a number of these tests, successive countermeasures occurred in quick succession, and it is difficult to isolate whether instances where drivers reacted were due to one countermeasure or the countermeasure that followed it. Furthermore, trust estimates were based on only a limited number of participants, on the order of 8 or 9. Driver-in-the-loop test drivers were also naïve to the presence and activation of some of the countermeasures, specifically automatic braking. It is possible that this level of naiveté yielded trust figures that misestimated trust in countermeasures that are well understood by drivers (which may be lower or higher than the figures obtained). Additionally, the project uncovered a strong sensitivity of driver behaviors to small details in the protocols used to conduct the driver-in-the-loop tests. While better judgments were made about which protocol was likely to bring out driver behaviors most representative of natural behaviors, this adds uncertainty to the results of the tests. Finally, the model was unable to capture the full range of driver responses to receiving the countermeasures. For example, some drivers, upon being stopped by the automatic braking function, simply drove forward and tried the maneuver again. This behavior is not synthesized in the current version of the SIM.

9 SAFETY BENEFITS ESTIMATION

9.1 Introduction

The last stage in the SIM is the calculation of safety benefits. This chapter describes the theoretical underpinnings of, and the SIM variables used in, the calculations performed to generate these estimated safety benefits. Before describing the theory, however, it is necessary to describe how the outputs of the simulation are aggregated to obtain the necessary inputs to the safety benefits estimation process. As described in Section 7.2.5, a series of outputs are aggregated by iteration and runs and made available to generate the safety benefits estimates. Some of these outputs are only relevant to monitoring of appropriate SIM behavior (as described in Section 8.2). The following inputs (discussed in further detail later in this chapter) are required from the simulation model to determine the safety benefits that are calculated as part of the backing SIM:

1) Was there an obstacle in the vehicle's travel path? (this is used to determine whether there was a conflict and the number of total opportunities for conflict)
2) Did the vehicle move during the trial? (used in conjuction with 1 to determine the presence of a conflict)
3) Did a crash occur, or was there an avoidance? (used to determine the number of crashes)
4) What was the final vehicle speed? (used to determine potential harm due to a crash)
5) Given final vehicle kinematics, would the vehicle stop before the obstacle reached the rear axle? (used to determine potential harm due to a crash)

Values for each of these required inputs are available for each iteration and each run, both with and without countermeasures present. For example, suppose a single scenario was executed for five runs, and each of these runs had 200 iterations. There would be 2000 numbers that would need to be accounted in the final calculations. For each run, there would be 200 iterations with the countermeasure present and 200 iterations with no countermeasure (a total of 400). Multiplied by 5 runs, this yields 2000 total values. An example of how these numbers are used to calculate the estimates of safety benefits is presented at the end of this chapter. The following discussion presents a theoretical discussion of how these benefits are calculated.

The estimation of safety benefits is based on equations developed by Najm, Burgett, and others (W. Najm, Mironer, & Yap, 1997; Wassim G. Najm, 2003; Wassim G. Najm, daSilva, & Wiacek, 2000; Wassim G. Najm, Stearns, Howarth, Koopman, & Hitz, 2006; Wasim G. Najm, Wiacek, & Burgett, 1998; NHTSA Benefits Working Group, 1996), which have been used extensively for the past decade in the evaluation of numerous automotive collision avoidance technologies. The main outcome of the safety benefits estimation process is the predicted number of crashes potentially avoided annually following the deployment of a particular crash countermeasure, as follows:

$C_A = C_{wo} \times D_C \times SE$ (Equation 1)

Where:

C_A = annual number of the type of crashes of interest predicted to be avoided with a countermeasure's deployment

C_{wo} = annual number of the type of crashes of interest prior to a countermeasure's deployment

D_C = potential countermeasure deployment rate in the vehicle fleet

SE = System Effectiveness – proportion of relevant crashes expected to be prevented by the countermeasure of interest

Another potential safety benefit is related to crash mitigation, and re-expresses equation 1 in terms of the reduction in harm due to those crashes that occur.

$$H_R = H_{wo} \times D_C \times SR \quad \text{(Equation 2)}$$

Where:

H_R = predicted annual reduction in harm for the type of crashes of interest with a countermeasure's deployment (***for the purposes of the backing crash estimates, reductions in harm are calculated based on reductions in fatalities***)

H_{wo} = annual total harm for the type of crashes of interest prior to a countermeasure's deployment (***i.e., for the backing crash estimates, the total number of annual fatalities due to these crashes***)

D_C = potential countermeasure deployment rate in the vehicle fleet

SR = System Harm-Reduction Effectiveness – estimated total effectiveness of the countermeasure in reducing the harm caused by the types of crashes of interest

Equations 1 and 2 provide estimates of changes in crash frequency and crash severity, whose generation represents the main goal of the SIM. Estimation of the change in associated societal value related to changes in crash frequency and severity requires a substantial number of subjective assumptions and estimates. Therefore, SIM users would need to develop these estimates, if desired, based on their own value systems.

It is important to note the distinction between false and nuisance alerts provided by a properly functioning countermeasure system and the potential for unintended consequences resulting from unforeseen interactions between the driver, countermeasure system and the external environment. False alerts are typically the result of countermeasure system misclassification of some element in the environment as a potential threat when none really exists. For example, responding to a manhole cover as an in-path threat. Nuisance alerts are conditions where the countermeasure system correctly responds to an object of interest, but the driver is already aware of the situation and finds the response unhelpful. Minimizing these aspects of countermeasure system behavior is necessary to encourage proper driver behavior when a correct helpful response does occur. Testing to assess false alert performance was conducted and the data were used in the SIM to model the balance between aggressive system performance and intended driver response. However, the potential for unintended consequences, such as increase in frequency of an unrelated crash type, driver experimentation with the system, or long term behavioral adaptation, is typically not well understood based on results of controlled test track scenario evaluations, which are the basis for this work, and therefore are not presently modeled in the SIM.

The parameters in equations 1 and 2, combined with an understanding of the backing crash problem (discussed earlier in this document), suggest that there are three primary measures of interest that may have an impact on the estimation of the potential safety benefits for backing crash countermeasures:

- System Effectiveness
- System Harm-Reduction Effectiveness
- Countermeasure Deployment Rate

The countermeasure deployment rate is beyond the scope of this effort and will be assumed to be 100%. The SIM structure, however, will allow adjustments to this figure in the interest of facilitating the generation of 'what-if' scenarios, including scenarios that consider incremental deployment over periods of time. The remaining two measures, System Effectiveness and System Harm-Reduction Effectiveness, are discussed in more detail later in this report. To frame that discussion, the following section summarizes the relevant literature that describes the extent and characteristics of backing crashes.

9.2 Characteristics of Crashes Targeted by Backing crash Countermeasures

A detailed description of the number and characteristics of backing crashes was presented in Section 2.2.1. This section discusses those findings as they relate to the estimation of safety benefits introduced in the previous section.

Generating safety benefits for backing crash countermeasures requires the aggregation of the different crash scenarios that are included within backing crashes, which will be the modeling pieces used by the SIM model. Aggregating these scenarios in turn requires information about the proportion of crashes attributable to each particular crash scenario. As previously indicated, this proportion is not directly available for many of the scenarios of interest due to a number of reasons, key among them the outside-traffic way location at which many of these crashes occur. Six of these scenarios include pedestrians as an obstacle, three include a vehicle, and one includes a fixed obstacle. A breakdown of these crashes as they fit into Eberhard's classification of backing crashes (C. D. Eberhard et al., 1994) was presented in Table 1 and general data about the magnitude of the problem discussed in Section 2.2.1.

Data from "37 crashes" (W.G. Najm, Smith, & Yanagisawa, 2006) were used to estimate the fatalities and injuries due to the vehicle and fixed-object scenarios. The extent to which these estimates exclude pedestrians is unclear. Therefore, care should be taken in assuming that these figures are exclusive from those already described for the pedestrian scenarios. The number of fatalities for the non-pedestrian scenarios was obtained using the proportion of fatal injuries observed under "37 crashes" for the "Backing up into another Vehicle" and "Road Edge Departure while Backing Up" crashes, respectively. Vehicle scenarios 1 and 2 were estimated to account for 11 fatalities every year, with vehicle scenario 3 and the fixed object scenario accounting for 91. Similarly, the number of injuries was determined by considering injury scale classifications other than “None” within each of these crash categories. Vehicle scenarios 1 and 2 accounted for 39,204 injuries, whereas vehicle scenario 3 and the fixed object scenario accounted for 11,102.

These data suggest that the opportunity for backing countermeasures may be:

- 201,583 crashes per year
- 285 fatalities
- > 57,000 injuries

Note that these figures represent the maximum safety benefit that can be attained given the data that are available. With these figures determined, the next step is to distribute them beyond the breakdowns presented on Table 1, especially for the pedestrian scenarios. The resolution within the sources examined did not allow for an indication of the relative expected frequency with which the different pedestrian scenarios would be expected to occur. Data from Patrick, Bensard, Moore, Partington, and Darrer (1998) represent one source of known information on this regard, and suggest that:

- Pedestrian scenario 1 (standing child) would be expected to occur 9.4% of the time (3 out of 32 cases)
- Pedestrian scenarios 2 and 3 would be expected to occur 59.4% of the time (19 out of 32 cases)
- Pedestrian scenarios 4. 5, and 6 would be expected to occur 31.3% of the time (10 out of 32 cases)

If the assumption is made that those breakdowns (which represent instances of injury) are also representative of the exposure to that injury and to fatalities, then those breakdowns can be used to split the aggregate figures amongst the different pedestrian scenarios. This approach still requires the assumption that pedestrian scenarios 2 and 3 are equally likely (and each represent 59.4% ÷2=29.7% of the pedestrian backing crash problem), as would pedestrian scenarios 4, 5, and 6 (each representing 31.3%÷3=10.4% of the pedestrian backing crash problem). Note that the breakdowns for pedestrian scenarios include pedestrians of all ages, whereas scenarios are based on 2- and 5-year-olds. The assumption is made, for lack of better data, that adult pedestrians are struck in similar proportions across the six different child pedestrian scenarios. Pedacyclist crashes were added to the figures for pedestrian scenarios 4, 5, and 6. While this approach differs from the scenario breakdown of pedacyclist crashes in the original analysis, in which half were apportioned to pedestrian crashes and half to vehicle-vehicle crashes, the reassignment of all pedacyclist crashes to pedestrian crashes was necessary since data to support a suitable split in these crashes (i.e., between perpendicular and in-line bicycle/subject vehicle paths) were not available. In addition, further consideration of these crashes led to the conclusion that injuries and other outcomes resulting from pedacyclist crashes may also be better represented by pedestrian crashes (confirming the mapping to pedestrian scenarios as the more appropriate choice).

An alternate source of data for these figures would be the compendium of SCI crashes that NHTSA has compiled on backing crashes, and whose examination was discussed in Section 5.3. Given the limited number of available SCI backing cases that could hinder the random aspect of the sampling strategy potentially resulting in non-representative proportional distributions of backing crashes, it was expected that Patrick, Bensard, Moore, Partington, and Darrer (1998) would represent a more precise source for the proportional distribution of backing crashes across subtypes.

Figures for vehicle scenarios 1 and 2 were split proportionally based on the proportion of crashes each represents (Table 1), as were vehicle scenario 3 and the fixed object scenario. These breakdowns, combined with the aggregate fatality, injury, and crash frequencies, result in the per-scenario distributions shown in Table 54.

Table 54. Distributions of crashes, fatalities, and injuries across the backing scenarios

Backing crash Scenario	Number of Crashes	Percentage of Crashes	Fatalities	Injuries**
Pedestrian Scenario 1: 2-year-old pedestrian standing ~5' directly behind vehicle backing out of a parking space	263	0.13%	17	630
Pedestrian Scenario 2: 2-year-old pedestrian sitting on curb ~ 30' behind parallel parking vehicle departing roadway	831	0.41%	54	1990
Pedestrian Scenario 3: 2-year-old pedestrian lying prone 2' offset from center line on driveway ~ 15' behind vehicle backing out of a driveway	831	0.41%	54	1990
Pedestrian Scenario 4: 5-year-old pedestrian incurring from the right ~ 15' behind vehicle backing out of driveway	556	0.28%	19	697
Pedestrian Scenario 5: 5-year-old pedestrian incurring from the left ~ 5' behind vehicle backing out of parking space	556	0.28%	19	697
Pedestrian Scenario 6: 5-year-old pedestrian incurring from the left ~ 30' behind vehicle driving in reverse down alleyway or long driveway	556	0.28%	19	697
Vehicle-to-Vehicle Scenario 1: Vehicle protrudes into roadway; driver decides to rectify but strikes a parallel path vehicle directly behind	23,297	11.56%	2*	7364
Vehicle-to-Vehicle Scenario 2: Vehicle backing out of driveway strikes a vehicle in motion on roadway	100,738	49.97%	9*	31840
Vehicle-to-Vehicle Scenario 3: Vehicle backing out of parking space strikes vehicle parked behind	64,703	32.10%	80*	9713
Vehicle-to-Fixed Object Scenario 1: Vehicle backing out of driveway strikes a utility pole	9,253	4.59%	11*	1389

* While these fatalities come from the crash databases, their causes are unclear. It would be inappropriate to make inferences (e.g., that they are due to excessive speeds) about these fatalities without analyzing case reports where these fatalities occurred.

** Injuries for pedestrian crashes are based on an aggregate figure of 6700 pedestrian injuries per year suggested as a lower bound by NHTSA (2006).

Given the number of assumptions and uncertainty that is associated with these figures, their distribution amongst the scenarios and the figures themselves were coded as user-adjustable parameters within the SIM. The values provided in this document, however, were used as default values for these parameters.

The next section describes the process used to estimate the number of these crashes and fatalities that may be prevented by a backing crash countermeasure. This process employs the outputs of the SIM in a series of calculations. Before describing the process used to estimate the potential safety benefits of a backing countermeasure, however, it is important to clarify the relationship between the scenarios that have been previously described and the conflicts that will be introduced as part of the benefits estimation equations in the next section. When sufficient crash-causal data are available, any crash type can be described in terms of one or more pre-crash maneuvers. As a whole, the characteristics of these maneuvers can be summarized in the form of one or more conflict types that may result in the crash of interest. These conflicts can then be used in the estimation of potential safety benefits, as is described in the next section. The scenarios that have been described in this document are situations that capture the most influential factors describing or characterizing particular conflicts. Given the limitations on the crash data available for backing crashes, the assumption is made that the scenarios that have been described are representative of those conflicts that lead to backing crashes. Therefore, it is assumed that the results of a simulation process that provides information about crash outcomes for different scenarios will be applicable to the assessment of a countermeasure's effects on one or more conflict types. Consequently, when the term *conflict* is used in the next section, a direct reference is made to each of the 10 scenarios previously described.

9.3 Benefits Estimation

The benefits estimation process is directly based on the outputs obtained from the Monte Carlo simulation within the SIM. These outputs are in the form of a system effectiveness estimate and a system harm-reduction effectiveness estimate, which result from a comparison of the outcomes of the simulation with and without the countermeasures present. With enough simulation runs, average values for each of these parameters are obtained, along with their associated confidence intervals. Note that the outputs from the SIM are stochastic in nature since the inputs to the simulation contain probabilistic components. To make references back to the SIM easier, the equations in this section are accompanied by the SIM variable names that represent them, where applicable.

System Effectiveness (*SE*) is calculated as follows:

$$SE = 1 - \frac{P_W(C)}{P_{WO}(C)}$$ (Equation 3, **SIM Variables: AverageSE, StDevSE**)

Where:

$P_w(C)$ = probability of the type of crashes of interest occurring with the countermeasure present

$P_{wo}(C)$ = probability of the type of crashes of interest occurring without the countermeasure present

The *SE* can also be re-expressed to consider two separate proportions as a function of the conflict(s) of interest, one dealing with the probability of exposure to a particular conflict, the other one representing the probability of a crash given that the driver is involved in a particular conflict. The first proportion is typically known as the exposure ratio, the second as a prevention ratio. These proportions are combined with the probability that a particular conflict is encountered prior to a crash. Written on an individual conflict basis:

$$SE_i = P_{wo}(S_i|C) \times \left(1 - \frac{P_w(S_i)}{P_{wo}(S_i)} \times \frac{P_w(C|S_i)}{P_{wo}(C|S_i)}\right) \quad \text{(Equation 4)}$$

Where:

$P_{wo}(S_i|C)$ = probability that, given there is a crash, it resulted from conflict *i* if the countermeasure is not present (**SIM Variable: PwoSiC**)

$P_w(S_i)$ = probability that conflict *i* occurs if the countermeasure is present (**SIM Variable: PwSi**)

$P_{wo}(S_i)$ = probability that conflict *i* occurs if the countermeasure is not present (**SIM Variable: PwoSi**)

$P_w(C|S_i)$ = probability that conflict *i* results in a crash if the countermeasure is present (**SIM Variable: PwCSi**)

$P_{wo}(C|S_i)$ = probability that conflict *i* results in a crash if the countermeasure is not present (**SIM Variable: PwoCSi**)

At a top level, the System Harm-Reduction Effectiveness (*SR*) is based on a comparison of the estimated relative harm associated with the crashes that occur while the countermeasure is present to the estimated relative harm when there is no countermeasure present.

$$SR = 1 - \frac{P_w(C) \times \bar{H}_w}{P_{wo}(C) \times \bar{H}_{wo}}$$ (Equation 5, **SIM Variables: AverageSR, StDevSR**)

Where:

$\bar{H}_w$ = average harm for the type of crashes of interest occurring with the countermeasure present

$\bar{H}_{wo}$ = average harm for the type of crashes of interest occurring without the countermeasure present

As done for the SE, the SR can also be calculated on an individual conflict basis. The calculation uses the prevention and exposure ratios for each conflict to modify the average harm observed with and without the countermeasure for crashes preceded by a particular conflict type. Harm is calculated based on the number and/or type of fatalities within particular conflict categories and countermeasure states. This ratio is then weighted by the relative harm represented by different conflict types, which considers both the severity of injuries (***only fatalities in this case***) and their frequency. Equation 5 can be expressed as:

$$SR_i = H_{wo}(C|S_i) \times \left(1 - \frac{P_w(S_i)}{P_{wo}(S_i)} \times \frac{P_w(C|S_i)}{P_{wo}(C|S_i)} \times \frac{\bar{H}_w(C|S_i)}{\bar{H}_{wo}(C|S_i)}\right) \quad \text{(Equation 6)}$$

Where:

$H_{wo}(C|S_i)$ = relative harm for the type of crashes of interest occurring without the countermeasure present in conflict *i* (**SIM Variable: HwoCsi**)

$\bar{H}_w(C|S_i)$ = average harm for the type of crashes of interest occurring with the countermeasure present in conflict *i* (**SIM Variable: HbarwCsi**)

$\bar{H}_{wo}(C|S_i)$ = average harm for the type of crashes of interest occurring without the countermeasure present in conflict *i* (**SIM Variable: HbarwoCsi**)

The overall SE and SR values can then be obtained by summing equation 5 values and equation 6 values, respectively, across conflict types that collectively represent the complete crash problem. These estimates for SE and SR can then be input into equations 1 and 2 to obtain prediction of potential crashes avoided and crash mitigation (reduction in harm). Calculation of the different components of each equation is completed within the SIM, using either pre-determined parameters or the output of the simulation process. The next sections describe this calculation process.

9.4 Estimation of System Effectiveness

As the SIM is exercised for each of the 10 scenarios, data to estimate SE will be generated as follows:

- $P_{wo}(S_i|C)$: obtained from the "Percentage of Crashes" column in Table 54
- $P_w(C|S_i)$: obtained directly from the Monte Carlo simulation as follows:

$$P_w(C|S_i) = \frac{Number\ of\ crashes\ observed\ in\ a\ simulation\ run\ with\ the\ countermeasure\ present}{Number\ of\ conflicts\ in\ a\ simulation\ run}$$ (Equation 7, **SIM Variables: Numerator – NumberofCrashes; Denominator – NumberofConflicts**)

- $P_{wo}(C|S_i)$: obtained directly from the Monte Carlo simulation as follows:

$$P_{wo}(C|S_i) = \frac{Number\ of\ crashes\ observed\ in\ a\ simulation\ run\ with\ the\ countermeasure\ absent}{Number\ of\ conflicts\ in\ a\ simulation\ run}$$ (Equation 8, **SIM Variables: Numerator – NumberofCrashes; Denominator – NumberofConflicts**)

- $P_w(S_i)$: obtained directly from the Monte Carlo simulation as follows:

$$P_w(S_i) = \frac{Number\ of\ conflicts\ occurring\ in\ a\ simulation\ run\ with\ the\ countermeasure\ present}{Number\ of\ iterations\ in\ a\ simulation\ run}$$ (Equation 9, **SIM Variables: Numerator – NumberofConflicts; Denominator – NumberofOpportunities**)

- $P_{wo}(S_i)$ =obtained directly from the Monte Carlo simulation as follows:

$$P_{wo}(S_i) = \frac{Number\ of\ conflicts\ occurring\ in\ a\ simulation\ run\ with\ the\ countermeasure\ absent}{Number\ of\ iterations\ in\ a\ simulation\ run}$$ (Equation 10, **SIM Variables: Numerator – NumberofConflicts; Denominator – NumberofOpportunities**)

Note that a conflict is defined as a situation that exists when the path of a backing vehicle *already moving in reverse* intersects with the point at which an obstacle is or will be located. The obstacle will be struck if there are no changes in the vehicle or obstacle path or kinematics. One of the key aspects of this definition is that the vehicle must have begun to travel in reverse. Therefore, it is possible for some potential countermeasure components (e.g., rear video) and some of the mirrors and other traditional backing aids to aid in decreasing $P_w(S_i)$ and $P_{wo}(S_i)$ differentially within the simulation. This effect will depend directly, among other factors, on the glance pattern that is selected for any particular simulation iteration. In other words, it is possible that a driver's glance pattern in some scenarios yields a reduction in exposure to conflict (as defined), since detection of the obstacle may occur before the vehicle begins its travel. Therefore, the number of conflicts within a simulation run will be less than or equal to the number of iterations in that run.

Although the probabilities just described represent the output of the Monte Carlo simulation process, the simulation process itself cannot occur without a substantial amount of data regarding the operation of the countermeasure and the behavior of the driver. Data concerning the operation of the countermeasure was obtained from the objective tests. For example, the different grid tests map the ability of the countermeasure's sensor and signal processing algorithms to respond to different static and moving obstacles. Driver behavior data came from two main sources. Driver behavior data when the countermeasure is available were obtained from driver-in-the-loop tests. In contrast, driver behavior data when there was no countermeasure were obtained from previous research that has studied typical driver behaviors while backing.

Note that both when countermeasures are present and absent, data to generate the SE estimates will always come from the simulation's output. The difference in the outcomes between both situations will depend on two main factors. The first factor is if and when the countermeasure responds (in the form of an alert being issued and/or some level of automatic control being assumed) to the obstacle-in-path (this is not the case for a 'baseline' condition where the countermeasure is, of course, absent). The second factor is the driver response to detecting the obstacle, either unaided (in situations where the countermeasure is absent) or with the aid of one or more countermeasure responses. The extent to which driver behaviors change, specifically in the form of glance pattern, speed profile, response time, and braking and/or steering effort, will determine the difference in outcomes between countermeasure-present and countermeasure-absent situations.

An important consideration in the estimation of SE (and SR, as well as the estimation of crashes prevented and crashes mitigated) is the extent to which nuisance and false alarms may influence the effectiveness of any particular countermeasure. While there is some empirical evidence that a certain frequency of nuisance alarms may be beneficial to drivers in the forward collision warning context (Abe & Richardson, 2006; Lees & Lee, 2007; Maltz & Shinar, 2004), there are limits to the extent to which these benefits may be attained. For example, a countermeasure that continuously presents nuisance alarms may be ignored or turned off by a driver, rendering it ineffective when an actual threat presents itself.

The SIM model uses results from the false alarm rate objective tests to establish expected false alarm rates for the countermeasure being studied. These false alarm rates, however, are not used to modulate the likelihood of the driver choosing to ignore or override (e.g., in the case of automated control countermeasures) the countermeasure, since these estimates are obtained directly from the driver-in-the-loop tests. Conversion between false alarm rates and ensuing driver behavior (in terms of trust) remains an area where more research and data could further the state of the art, and may benefit from future work. However, it is noteworthy that false alarm rates are specified in the model, and the mechanism to tie these rates to the trust exhibited by drivers are in place to use as needed, be it to reflect additional data collected outside the scope of the ACAT project, or to perform sensitivity analyses on that relationship.

9.5 Estimation of System Harm-Reduction Effectiveness

The estimation of SR is similar to the estimation of SE, but considers the extent of fatalities that crashes within different conflicts result in, with and without the "countermeasure." Calculating equation 6 fully (i.e., considering injuries in addition to fatalities) for backing crashes is currently infeasible, given limitations in the data available. While the breakdown of injuries is available in the "37 Crashes" document for "Backing up into another Vehicle" and "Road Edge Departure while Backing Up" crashes (represented by three vehicle scenarios and the fixed object scenario in this analysis), there are no such detailed injury data that would encompass all pedestrian scenarios. Furthermore, crash database data, on which "37 Crashes" is based, do not contain sufficiently detailed information concerning the kinematics of backing crashes to allow for a breakdown of injuries and fatalities due to backing crashes based on meaningful criteria (e.g., equivalent to Δv in a rear-end crash).

Given these limitations of the data, the current estimation of harm for pedestrians is performed in a dichotomous fashion, with crashes assumed to either result in a fatality or no fatality. A pedestrian crash is assumed to be fatal if one or two conditions occur: the impact speed is greater than 10 mph (4.5 m/s) (stopping the vehicle before the pedestrian reaches the rear wheels or the space between the rear wheels would require a deceleration over 1 *g*) or the vehicle is not stopped prior to the obstacle reaching the rear wheels or the space between the rear wheels. Any crash not fulfilling either of these conditions is considered a non-fatal crash. This classification system is based on the set of SCI cases previously analyzed, which suggested a much higher probability of fatality when contact with the rear wheels or other vehicle parts located between the rear wheels was present. To simplify the calculations for this analysis, the vehicle-to-vehicle scenarios are assumed to never result in a fatality.

These assumptions make the estimation of $\bar{H}_w(C|S_i)$ and $\bar{H}_{wo}(C|S_i)$ possible, as follows:

$$\bar{H}_w(C|S_i) = P_w(F|C|S_i) \times w(F) + P_w(I|C|S_i) \times w(I) \qquad \text{(Equation 11)}$$

Where:

$P_w(F|C|S_i)$ = probability of a fatality given a crash occurring in conflict *i* with the countermeasure present (**SIM Variable: Fatal/NumberofConflicts**)

$w(F)$ = coefficient of maximum fatality severity, set at 1, since a fatality is considered the maximum possible injury severity (**SIM Variable: FatalWeight**)

$P_w(I|C|S_i)$= probability of a non-fatality given a crash occurring in conflict *i* with the countermeasure present (**SIM Variable: 1 - Fatal/NumberofConflicts**)

$w(I)$ = coefficient of maximum non-fatality severity, assumed at 0.00, indicating that non-fatalities have no additional improvement in harm beyond the prevention of that fatality (**SIM Variable: NonFatalWeight**)

$$\bar{H}_{wo}(C|S_i) = P_{wo}(F|C|S_i) \times w(F) + P_{wo}(I|C|S_i) \times w(I) \quad \text{(Equation 12)}$$

Where:

$P_{wo}(F|C|S_i)$= probability of a fatality given a crash occurring in conflict *i* with the countermeasure absent (**SIM Variable: Fatal/NumberofConflicts**)

$P_{wo}(I|C|S_i)$= probability of a non-fatality given a crash occurring in conflict *i* with the countermeasure absent (**SIM Variable: 1 - Fatal/NumberofConflicts**)

$P_w(F|C|S_i)$ and $P_w(I|C|S_i)$ are estimated based on fatality data for each iteration of each conflict; that is, each crash that results for each conflict is categorized as either fatal or non-fatal. The number of crashes in each category is then divided by the total number of crashes recorded for each particular conflict and iteration of the simulation.

9.5.1 Estimation of Number of Crashes Prevented

Once SE is estimated, the prediction of the number of crashes is relatively straightforward, using equation 1. The C_{wo} parameter is determined directly from the first data column on Table 54 (**SIM Variable: Crashes**). As previously described, modeling of the D_c parameter is beyond the scope of this effort, and is assumed to be 100%.

9.5.2 Estimation of Harm Reduction

Estimation of the harm reduction, or crash mitigation, is also straightforward once estimates for SR are calculated. The annual total harm estimated using previously stated assumptions is 182 fatalities (**SIM Variable: WeightedHarm**). This estimate was established by applying equation 13 to each of the scenarios based on the aggregate fatality and injury data from Table 54.

9.6 Applied Example of these Calculations

For this example, consider a potential set of simulation results for Scenario #1. A total of 5 runs with 1000 iterations each was used, but these iterations were divided randomly amongst 10 possible scenarios. Therefore, the number of actual iterations for this particular scenario will not be exactly the same across different runs.

Starting with the estimation of the number of crashes, the first calculations that need to be completed are those probabilities expressed in equations 7 through 10. To generate those probabilities, it is necessary to know the number of crashes, number of conflicts, and number of opportunities present for each run. Number of crashes is determined by counting, within the output, the number of iterations where the outcome was a crash and there was an obstacle in the vehicle's path (Columns 1 and 20, respectively, of the output matrix as described in Section 7.2.5). This is completed once for cases where there was a countermeasure, and once when there was no countermeasure. Resultant numbers for the example are:

Countermeasure present (for each run): 43, 54, 52, 47, 50
Countermeasure absent (for each run): 91, 83, 93, 96, 98

Number of conflicts is determined by counting the number of iterations where there was an obstacle in the vehicle's path and the vehicle moved, again calculated with and without a countermeasure present. Results are:

Countermeasure present (for each run): 89, 98, 105, 97, 103
Countermeasure absent (for each run): 91, 83, 93, 96, 98 (note all conflicts resulted in crashes, above, for this condition)

The last estimate needed for the calculation of probabilities is the number of opportunities, which were:

Countermeasure present (for each run): 94, 107, 112, 100, 108 (note some opportunities did not result in conflict, suggesting the countermeasure had some exposure reduction effects)
Countermeasure absent (for each run): 91, 83, 93, 96, 98 (note all opportunities resulted in conflicts, above, for this condition)

With these values available, the probabilities in equations 7 through 10 can be calculated directly. Resultant values are:

PwCS: 0.4831, 0.5510, 0.4952, 0.4845, 0.4854
PwoCS: 1.0000, 1.0000, 1.0000, 1.0000, 1.0000
PwS: 0.9468, 0.9159, 0.9375, 0.9700, 0.9537
PwoS: 1.0000, 1.0000, 1.0000, 1.0000, 1.0000

The calculation of SE is straightforward at this point, following equation 4:

SE (note these are adjusted for the relative weight of this scenario in respect to the overall crash problem): 0.0007, 0.0006, 0.0007, 0.0007, 0.0007
SE (if this were the only scenario modeled): 0.5426, 0.4953, 0.5357, 0.5300, 0.5370

Once the SE is available, the number of crashes is calculated using equation 1. If the assumption is made that scenario 1 was the only one modeled (so numbers for other scenarios don't have to be introduced and weighted), the number of crashes potentially prevented are: 143, 130, 141, 139, 141. Note that the number of crashes that were represented by this particular scenario was 253. To obtain summary measures, means and standard deviations for the results of interest are calculated across runs.

Calculation of potential harm reduction is similar once the number of fatal crashes in each run is determined. For the backing crash cases, fatal crashes were assumed to occur if:

1) The vehicle was traveling over 10.3 mph at impact;
2) There was vehicle braking present at impact, but the braking would not be sufficient to prevent the obstacle from reaching the rear axle;
3) The driver is in the process of reacting at impact, but the combination of reaction time and braking effort would not be sufficient to prevent the obstacle from reaching the rear axle.

For the example, these are the results of that addition:

Countermeasure present (fatal for each run): 8, 13, 9, 11, 10
Countermeasure absent (fatal for each run): 25, 19, 27, 26, 29

Equations 11 and 12 are then used to calculate the average proportion of fatalities; with the countermeasure: 0.0899, 0.1327, 0.0857, 0.1134, 0.0971; and without the countermeasure: 0.2747, 0.2289, 0.2903, 0.2708, 0.2959.

These values are input into equation 6 to obtain SR, and equation 1 to obtain the estimated reduction in harm. For SR, values were (assuming scenario 1 was the only one modeled): 0.8503, 0.7075, 0.8629, 0.8032, 0.8481. Corresponding fatalities reduction was: 15, 12, 15, 14, 14 (out of 17 fatalities).

Repeating this process across scenarios yields the overall results for the model execution, which are discussed in the next chapter.

10 SAFETY BENEFITS RESULTS

10.1 Overview

This chapter describes the results obtained when the SIM was used to attempt to estimate the potential reduction in crashes represented by the crash scenarios when a simulated backing crash countermeasure suite was active. As previously described, the countermeasure suite, which was simulated, included Enhanced Vision, Proximity Information, Cautionary Warnings, Imminent Warnings, and Automatic Braking.

Results were obtained by executing five independent runs of the simulation model, each of which had 100 iterations (individual backing cases) with the countermeasure suite active and 100 iterations with no countermeasures present. The potential safety benefits were estimated using the approach described in the previous chapter and the results are summarized in this chapter. As previously specified, benefits were estimated in terms of potential crash reduction and potential fatality reduction.

As indicated in various sections of the SIM description, several assumptions are necessary in the SIM. These assumptions were the following for the SIM analysis described in this chapter:

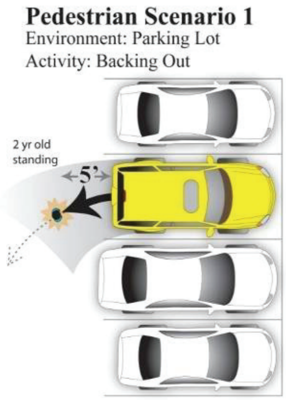
- Probability of 'hurried' backing: 0.10
- Backing Initiation to Active Backing changeover speed: 1.79 m/s (4 mph)
- Vehicle width: 2.01 m (79 in.)
- Maximum simulation time (per iteration) for maneuver: 90 sec
- For driver and vehicle model parameters, refer to the descriptions provided in the respective sections of this document
- Deployment / Market Penetration are not considered in the estimates; 100% penetration in the existing fleet is assumed
- False alarm rates do not factor in the estimation of driver trust in the countermeasures
- Trust is mostly derived from the driver-in-the-loop objective tests
    - Trust values for imminent backing warnings are derived from archival data (no such warnings observed in DIL tests)

The results are discussed first by scenario, and then on the aggregate as the scenarios are weighted by their prevalence in the overall backing crash problem as estimated in Table 54. The following table presents a description of the results that will be summarized for each scenario.

Picture of the Scenario being Described	- Brief description of the scenario characteristics - Percentage of crashes (and the total number) potentially prevented by the combination of countermeasures, **only for the scenario being discussed.** The SE is also presented. - Percentage of fatalities potentially prevented, **only for the scenario being discussed**
This section describes the proportion of iterations where a countermeasure was active. For example, if Proximity Information has a value of 50%, it indicates that this countermeasure component issued a warning in 50% of the iterations tested. Note that the activation of a countermeasure does not imply that it will be acknowledged. This cell also contains information about the proportion of drivers that detected the obstacle in the Enhanced Vision System	**Proximity Information** | **Cautionary** | **Imminent** | **Automatic Braking**
This cell describes the percentage of iterations where the driver braked on his/her own, where automatic braking was active without additional driver braking, and where both the driver and automatic braking were actively attempting to stop the car prior to hitting an obstacle.	**Driver Only** | **Automatic Braking Only** | **Both**

Results for Pedestrian Scenario #1 are presented on the following table.

10.2 Individual Scenario-Based Results



- 2-year-old pedestrian standing ~5' directly behind vehicle backing out of a parking space
- 53% (SD*=1.9%) of 263 annual crashes potentially prevented (SE_i=0.0007)
- 81% (SD=6.4%) potential reduction in fatalities out of 17 annually

*SD – Standard Deviation

Countermeasures Active: (28.9% detected on Enhanced Vision)	Proximity Information	Cautionary	Imminent	Automatic Braking
	100.0%	0.0%	0.0%	43.0%

Braking Behavior:	Driver Only	Automatic Braking Only	Both
	14.3%	42.8%	0.2%

For this scenario, Proximity information was always active, but the model estimated 0% driver reaction to proximity information cues (i.e., no driver trust in proximity information) for this scenario. The model estimated a 40% response rate for Automatic Braking and 30% driver detection of the pedestrian on enhanced vision. These response rates, however, do not add up to result in 70% (i.e., 40% + 30%) crash avoidance. Some potential reasons include some overlap between countermeasures, the finding from the driver-in-the-loop tests of a 22% look-did-not-see rate for enhanced vision, and the findings of objective tests that are relevant to this scenario. Specifically, based on these objective tests, 1 out of 3 automatic braking responses do not occur until the obstacle is at or inside 1.7 ft from the rear bumper; 2 out of 3 occur at or inside 2.9 ft. Therefore, the objective tests did not find perfect detection in the range at which this scenario unfolds. In addition, these automatic braking activations are being interpolated between 0 mph (where NO detections occur, since the vehicle is static) and 4 mph, where there is 100% detection close to the rear bumper. Speeds in the scenario tend to be low (< 4 mph), so there is considerable interpolation close to the zero-detection region, which drives the simulated detection rates down. Cautionary and imminent warnings were not observed because the model speeds remained below the threshold where they were available.

The following table presents the results obtained for Pedestrian Scenario 2, which involves a parallel parking maneuver and a 2-year-old pedestrian.

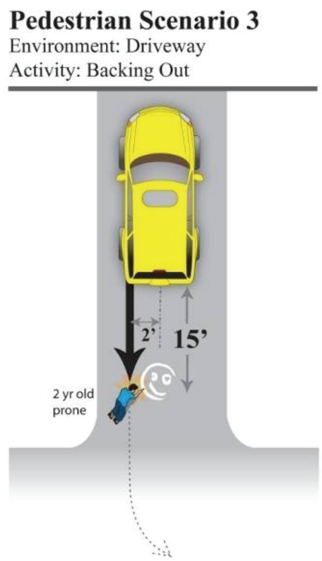
- 2-year-old pedestrian sitting on curb ~ 30' behind parallel parking vehicle departing roadway
- 41% (SD=4.0%) of 831 annual crashes potentially prevented (SE_i=0.0017)
- 65% (SD=11.0%) potential reduction in fatalities out of 54 annually

Countermeasures Active: (35.9% detected on Enhanced Vision)	Proximity Information	Cautionary	Imminent	Automatic Braking
	36.1%	15.4%	7.2%	25.7%

Braking Behavior:	Driver Only	Automatic Braking Only	Both
	33.2%	21.6%	4.1%

For this scenario, driver-in-the-loop tests indicated that neither proximity information nor cautionary backing warnings were associated with driver trust in the context of avoiding a pedestrian. The model estimated a combined ~70% driver detection/response rate for enhanced vision, imminent warning, and automatic braking, with the resultant level of crash prevention being ~41%. Among the reasons for this discrepancy are the overlap between countermeasures and the complexity of the detection environment. In the environment for this scenario, the obstacle is not immediately in the backing path. Additionally, the vehicles provide visual occlusion. Other reasons for the discrepancy are the interpolation issue noted for Pedestrian Scenario #1 and the results of the objective tests applicable to this scenario. For the former, although speeds were higher than those for Pedestrian Scenario 1, the model predicted that ~70% of trials were within 0 and 4 mph, requiring interpolation of objective test results without knowledge of countermeasure behaviors between these speeds. For the latter, objective tests applicable to this scenario showed one missed detection, with the remaining detections occurring at or inside 1.7 ft.

The next scenario modeled was Pedestrian Scenario #3, where a 2-year-old static pedestrian is laying on the path of a backing vehicle at an intermediate distance. The results are shown on the following table.



- 2-year-old pedestrian lying prone 2' offset from center line on driveway ~ 15' behind vehicle backing out of a driveway
- 33% (SD=7.4%) of 831 annual crashes potentially prevented (SE_i=0.0014)
- 53% (SD=8.9%) potential reduction in fatalities out of 54 annually

Countermeasures Active:	Proximity Information	Cautionary	Imminent	Automatic Braking
(29.6% detected on Enhanced Vision)	28.1%	52.7%	18.2%	20.0%

Braking Behavior:	Driver Only	Automatic Braking Only	Both
	25.6%	20.0%	0.0%

For this scenario, driver-in-the-loop tests suggested that neither proximity information nor cautionary backing warnings had any associated driver trust. Model-estimated speeds for this scenario were higher than for Pedestrian Scenarios 1 and 2, and crossed the threshold to allow for cautionary and imminent warnings more often in this scenario than for previous scenarios. The objective tests applicable to this scenario recorded no automatic braking responses for this particular obstacle under 8 mph, which represents ~80% of the range of speeds estimated in the model, which may partly explain the 20% estimated Automatic Braking response rate. In some instances of braking, the braking level was estimated to be insufficient or not timely enough to avoid the crash; the model estimates that driver-initiated braking, when present by itself, resulted in a crash ~25% of the time (i.e., instances where there was some crash mitigation, but the vehicle was not successfully stopped prior to impact). In addition, ~15% of cases where automatic braking responded also were estimated to result in a simulated crash.

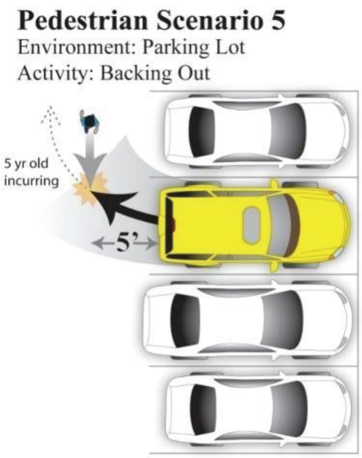
The following table presents the results for Pedestrian Scenario 4, where a pedestrian encroaches at an intermediate distance.

<table>
<tr><td>
</td><td>
- 2-year-old pedestrian lying prone 2’ offset from center line on driveway ~ 15’ behind vehicle backing out of a driveway
- 33% (SD=7.4%) of 831 annual crashes potentially prevented (SE_i=0.0014)
- 53% (SD=8.9%) potential reduction in fatalities out of 54 annually
</td></tr>
<tr><td>Countermeasures Active:

(10.4% detected on Enhanced Vision)</td><td>
<table>
<tr><th>Proximity Information</th><th>Cautionary</th><th>Imminent</th><th>Automatic Braking</th></tr>
<tr><td>14.9%</td><td>35.9%</td><td>6.7%</td><td>37.9%</td></tr>
</table>
</td></tr>
<tr><td>Braking Behavior:</td><td>
<table>
<tr><th>Driver Only</th><th>Automatic Braking Only</th><th>Both</th></tr>
<tr><td>25.7%</td><td>34.8%</td><td>3.1%</td></tr>
</table>
</td></tr>
</table>

The circumstances for this scenario were similar to those for Pedestrian Scenario #3. Note, however, that driver-in-the-loop tests suggested a 50% look-did-not-see rate for this scenario. In addition, the objective tests applicable to this scenario: 1) showed detection inside of 2.9 ft. and, perhaps more importantly, were designed for a vehicle-centerline impact if no response occurred. Since only one nominal impact point was used in the objective tests, no interpolation of responses in different impact points along the rear bumper is possible based on the available data. Therefore, responses while the obstacle travels along the incurring side of the rear bumper are not represented in the model, which in turn may mischaracterize actual system performance.

Pedestrian Scenario #5, the results for which are shown in the following table, had a near-pedestrian incurring in a perpendicular backing scenario.



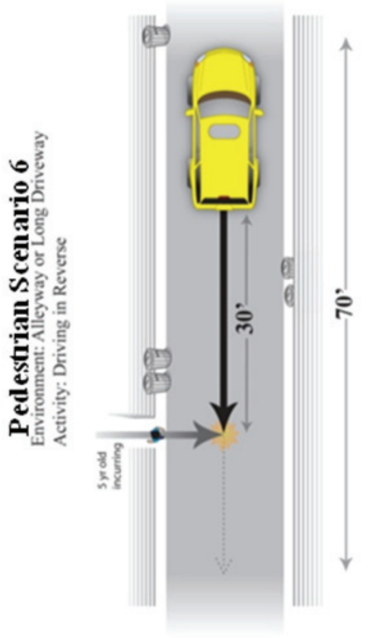
- 5-year-old pedestrian incurring from the left ~ 5' behind vehicle backing out of parking space
- 20% (SD=3.0%) of 556 annual crashes potentially prevented (SE_i=0.0006)
- 45% (SD=11.1%) potential reduction in fatalities out of 19 annually

	Proximity Information	Cautionary	Imminent	Automatic Braking
Countermeasures Active: (21.4% detected on Enhanced Vision)	13.5%	0.2%	0.0%	23.9%

	Driver Only	Automatic Braking Only	Both
Braking Behavior:	12.5%	22.9%	1.0%

As for Pedestrian Scenario #2, Pedestrian Scenario #5 had a complex detection environment. For this scenario, the obstacle was incurring and the lines of sight to the obstacle were blocked for part of the encroachment. Given the proximity of the obstacle to the rear bumper, model-estimated speeds generally remained below the threshold to allow for cautionary and imminent warnings. In interpreting the results obtained, note that the objective test results used to model this scenario combine the issues described for Pedestrian Scenario #1 (i.e., interpolation between 0 and 4 mph) and those described for Pedestrian Scenario #4 (i.e., objective test designed for vehicle-centerline impact).

Pedestrian Scenario #6 involved an incurring long-range obstacle, and its results are shown on the next table.



- 5-year-old pedestrian incurring from the left ~ 30' behind vehicle driving in reverse down alleyway or long driveway
- 42% (SD=7.0%) of 556 annual crashes potentially prevented (SE_i=0.0012)
- 75% (SD=7.0%) potential reduction in fatalities out of 19 annually

Countermeasures Active:

(22.4% detected on Enhanced Vision)

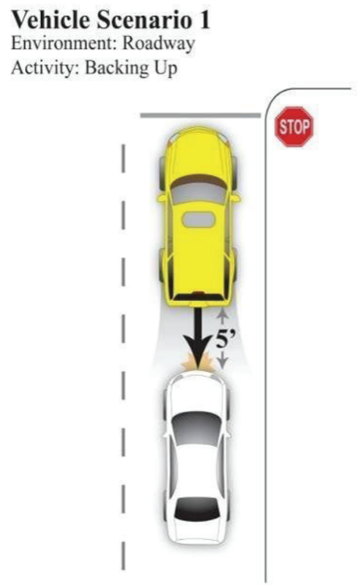
Proximity Information	Cautionary	Imminent	Automatic Braking
13.9%	37.6%	2.1%	48.7%

Braking Behavior:

Driver Only	Automatic Braking Only	Both
11.7%	46.0%	2.7%

Similar to some previously discussed scenarios, the detection environment for Pedestrian Scenario #6 is complex. For this scenario, the obstacle is both incurring and occluded. In addition, the automatic braking response is estimated to be hindered by the objective test vehicle-centerline-impact issue, which has previously been discussed. In some cases, applied braking levels were estimated to be insufficient and/or not timely enough. The model estimated that driver-initiated braking, when present by itself, resulted in a simulated crash ~20% of the time (i.e., instances where there was some crash mitigation, but the vehicle was not successfully stopped prior to impact). Similarly, ~30% of cases where automatic braking responded were estimated to result in an impact.

The first of the vehicle scenarios considers a stop bar scenario, where a vehicle which overshoots the stop bar backs into another vehicle behind it. The results for this scenario are shown in the next table.



- Vehicle protrudes into roadway; driver decides to rectify but strikes a parallel path vehicle directly behind
- 52% (SD=3.9%) of 23,297 annual crashes potentially prevented (SE_i=0.0607)

Countermeasures Active:

(29.0% detected on Enhanced Vision)

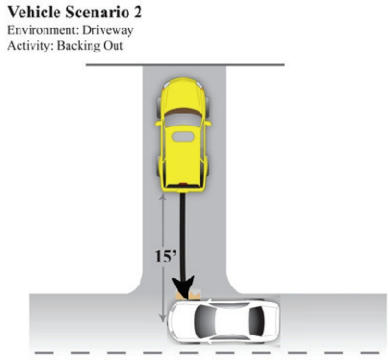
Proximity Information	Cautionary	Imminent	Automatic Braking
100.0%	7.6%	0.8%	82.5%

Braking Behavior:

Driver Only	Automatic Braking Only	Both
9.6%	82.1%	0.4%

The model estimates that for Vehicle Scenario #1, the obstacle is detected ~100% of the time (either by the driver or countermeasure suite). The model also estimates, however, that ~10% of instances where driver-initiated braking occurred by itself resulted in a crash; the corresponding figure is ~50% for automatic braking. This is directly related to the objective test results applicable to this scenario. Note that 1 in 3 objective test detections applicable to this scenario did not occur until the obstacle was inside 1.7 ft from the rear bumper. In addition, for this scenario, the driver trust for automatic braking in the model drops from 100% to 77% based on the driver-in-the-loop test results. Therefore, the model estimated that ~23% of the automatic braking responses were overridden by the driver and resulted in a crash.

The second Vehicle Scenario consisted of a vehicle backing out of a driveway and striking a vehicle on the roadway. Results for this scenario are shown on the next table.



- Vehicle backing out of driveway strikes a vehicle in motion on roadway
- 9.0% (SD=10.0%) of 100,738 annual crashes potentially prevented (SE_i=0.0451)

Countermeasures Active:

(11.0% detected on Enhanced Vision)

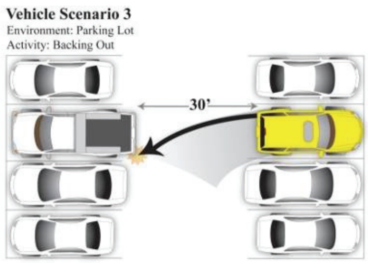
Proximity Information	Cautionary	Imminent	Automatic Braking
0.0%	29.4%	0.0%	34.0%

Braking Behavior:

Driver Only	Automatic Braking Only	Both
8.9%	27.1%	6.9%

Different from other scenarios considered by the model, this scenario exhibited ~20 mph delta-Vs which were larger than the incurring-obstacle speeds considered in the objective tests. The test obstacles in these tests did not incur at more than 4 mph. Although the model allows extrapolation in obstacle speeds when determining countermeasure response to the obstacle, in this case that extrapolation occurs over a large speed gap (4 mph to ~25 mph). In addition, objective tests showed one missed response at 8 mph vehicle speeds for the pole obstacle, which was used to represent the vehicle in the model. Finally, it is noteworthy that potential evasive maneuvers for the vehicle traveling on the roadway were not modeled.

The final vehicle-to-vehicle crash scenario considers a parking lot environment, where backing is occurring towards a vehicle whose location is known, but another vehicle that is not noticed by the driver is impacted. Results for this scenario are shown in the next table.



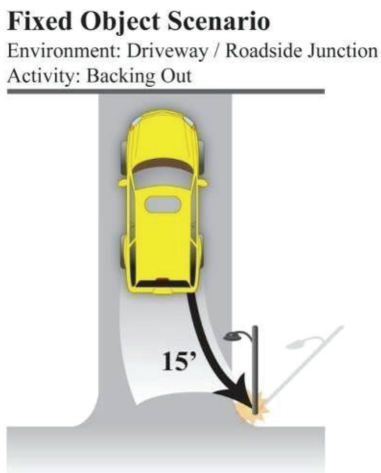
- Vehicle backing out of parking space strikes vehicle parked behind
- 55% (SD=5.7%) of 64,703 annual crashes potentially prevented (SE_i=0.1772)

	Proximity Information	Cautionary	Imminent	Automatic Braking
Countermeasures Active: **(25.0% detected on Enhanced Vision)**	29.4%	35.4%	15.7%	47.4%

	Driver Only	Automatic Braking Only	Both
Braking Behavior:	34.6%	40.6%	6.8%

For this scenario, driver-in-the-loop tests suggested that neither proximity information nor cautionary backing warnings should have any associated driver trust in the model. In addition, the look-did-not-see rate from driver-in-the-loop tests is 11% for this scenario. As for other previous scenarios, there were instances where braking levels were estimated to be insufficient and/or timely enough to avoid a crash, although some braking was initiated. The model estimated that ~15% of instances where driver-initiated braking occurred by itself resulted in a crash. A similar situation was estimated ~25% of the time for automatic braking.

The final scenario considered a crash where a vehicle impacted a fixed obstacle. Results for that scenario are shown in the next table.

<table>
<tr>
<td>
</td>
<td colspan="4">

- Vehicle backing out of driveway strikes a utility pole
- 71% (SD=4.1%) of 9,253 annual crashes potentially prevented (SE_i=0.0324)

</td>
</tr>
<tr>
<td rowspan="2">Countermeasures Active:

(38.8% detected on Enhanced Vision)</td>
<td>Proximity Information</td>
<td>Cautionary</td>
<td>Imminent</td>
<td>Automatic Braking</td>
</tr>
<tr>
<td>36.9%</td>
<td>52.2%</td>
<td>15.4%</td>
<td>81.3%</td>
</tr>
<tr>
<td rowspan="2">Braking Behavior:</td>
<td>Driver Only</td>
<td>Automatic Braking Only</td>
<td>Both</td>
<td></td>
</tr>
<tr>
<td>16.0%</td>
<td>76.4%</td>
<td>4.9%</td>
<td></td>
</tr>
</table>

Similar to the previous scenario, driver-in-the-loop tests for this Vehicle-Fixed Object scenario suggested that neither proximity information nor cautionary backing warnings should have any associated driver trust in the model. In addition, the look-did-not-see rate from driver-in-the-loop tests is 11% for this scenario. As for other previous scenarios, there were instances where braking levels were estimated to be insufficient and/or timely enough to avoid a crash, although some braking was initiated. The model estimated that ~5% of instances where driver-initiated braking occurred by itself resulted in a crash. A similar situation was estimated ~30% of the time for automatic braking.

10.3 Aggregated Scenario Results

The results obtained for these scenarios can be aggregated based on assumptions of relative exposure to theses crash scenarios from Table 54. Table 55 shows the aggregate results obtained utilizing these exposure assumptions for each of the five independent runs that composed the simulation.

Table 55. SIM aggregate predictions in terms of estimated SE and estimated percentage reduction in fatalities

Run:	1	2	3	4	5
SE	0.3108	0.3490	0.3170	0.2414	0.3896
Fatality Crash Redux	61.9%	62.2%	62.8%	57.2%	66.1%

These aggregate results translate to an average SE of 0.3216 (SD=0.0547). This SE figure indicates, given previously stated assumptions about 100% countermeasure penetration in North American vehicles and crash scenario exposure assumptions, that an opportunity space of ~32% of backing crashes represented in the scenarios is estimated to be potentially prevented. Such a reduction would amount to 64,823 (SD=11,021) annual crashes possibly prevented, assuming an overall backing crash figure of 201,583 crashes per year. The corresponding average potential estimated reduction in fatalities with these assumptions was 62.0% out of 182 annual fatalities considered in the model (SD=3.2%), which was only estimated for pedestrian crashes.

11 SUMMARY AND CONCLUSIONS

SIM modeling results estimate that the implementation of the prototype backing crash countermeasure suite examined during the project deployed in 100% of the U.S. vehicle fleet could theoretically result in up to a 32% overall reduction in backing crashes. This figure translates into approximately 64,823 annual crashes possibly prevented, assuming an overall backing crash figure of 201,583 crashes per year. However, a number of limitations were identified which impact the ability of the SIM to accurately predict potential countermeasure effectiveness in real-world deployment.

The SIM model provides value in bringing together a wide variety of research efforts which provide piece-wise information about backing crashes, but which are unable to separately present a complete picture. However, a number of limitations were identified in its structure, operation, and in the data that were used to generate the safety benefits estimates. Given the limits in project scope, these limitations could not be addressed, and required assumptions to be made. General limitations and the future work needed to address them are discussed below. The more specific assumptions necessary to make the SIM operational are discussed throughout the document, accompanying the discussion of the specific SIM elements.

One key limitation of the current backing crash SIM model is that it does not completely account for "exposure ratio." This ratio requires information about the frequency of occurrence of the conditions for each particular conflict scenario, which is presently unknown. Data to populate this portion of the model would need to come from a large scale statistically-valid study of naturalistic backing behaviors and the presence of potential conflict objects in the environment. Without this information, predictions of absolute safety benefit are not possible for some types of countermeasures.

The use of the modeling estimates to predict benefits is also hindered by lack of data on the potential for unintended consequences related to the presence backing crash countermeasures in the vehicle. These unintended consequences would emerge once such a system was deployed and data related to its use in naturalistic conditions obtained. Data to simulate these unintended consequences would need to come from FOTs or other similar test paradigms involving extensive naturalistic exposure of the countermeasures.

Data on the influence that false alarm frequency may have on individual driver use of these systems during prolonged exposure in the real world are also missing. While the objective tests in this report obtain some standardized data on frequency of false alarms for certain proposed specific environmental situations, the frequency of the conditions that trigger those false alarms is unknown. This exposure is expected to be dependent on individual driving patterns and geographic location. The influence of false alarms on driver trust is also likely to vary by individual. While the SIM model contains structures that could assimilate these data were it to become available, the current analysis is unable to accurately account for these variables. Therefore, the SIM model currently examines only those scenarios where a conflict situation is present and does not analyze potential unhelpful countermeasure activations in situations where no conflict is present. Data to simulate these variables would need to come from FOTs or other similar test paradigms involving extensive naturalistic exposure of the countermeasures.

Countermeasure responses in the SIM are a direct function of the objective test results. An important limitation related to the objective tests that emerged during the project is the “coarseness” of the objective test data. A second objective test limitation identified is related to the accuracy with which incurring obstacles are modeled. A third objective test limitation identified is the limited number of trials that were used to assess probabilities of detection. A fourth limitation with the driver-in-the-loop tests was also noted, and was related to the reliability of the estimates of driver trust in the different countermeasures that were derived from these tests. In most or all of these cases, collecting more data within the objective tests may reduce the magnitude of these issues. That additional data collection, however, was outside of the scope of the current effort. Furthermore, the extent to which that additional data collection would achieve improved levels of accuracy is unknown.

All of these limitations affect the SIM differently. While the direction and magnitude of some effects could be obtained via sensitivity analyses, additional data and research needs identified include:

- Model validation activities to independently verify the accuracy and reliability of model predictions and outputs.
- Further characterization of driver interactions with countermeasure features to include drivers with a range of system usage experience and exposure.
- Naturalistic data to examine the potential for unintended consequences associated with system usage. Real-world experiences associated with the use of advanced in-vehicle backing crash technologies are needed in order to assess how drivers come to learn, use and interact with these devices under naturalistic conditions.
- Data on exposure, including the base rate of occurrence for various backing conflicts and maneuvers; this includes characterizing the full range of potential situations and objects drivers are likely to encounter, and the number of times any particular driver may experience these conditions under normal use. This type of data would be particularly useful in understanding and modeling false alarm rates.
- Modifications to the Objective Test procedures to allow for a wider range of testing conditions and trials to increase data stability and reliability. At present, tests are constrained to a limited range of vehicle speeds and backing profiles.
- Application of the SIM model and process for use in evaluating alternative countermeasure approaches, implementations, and solutions

In summary, while the SIM serves as a useful tool to bring together data from a wide array of research into a unified simulation, the limitations identified constrain its usefulness in predicting potential real-world safety benefits of emerging crash avoidance systems. Benefit estimates from the SIM should be considered preliminary indications of countermeasure performance useful in studying the interaction of technology with driver behavior at various stages along the crash timeline.

The ACAT program was a proof-of-concept effort that sought to determine the feasibility of developing estimates of effectiveness for specific safety technologies in the absence of data from real-world or field operational tests. This project was successful at developing and demonstrating a methodology that could be used to estimate the safety effectiveness of the particular backing crash countermeasure evaluated in this research project. In addition, the project used data that was publicly available at the time of development. Therefore data from additional backing crashes that were investigated by NHTSA after 2006 and the new Not-in-Traffic Surveillance (NiTS) data source are not included in this effort. A follow-on effort would be needed to incorporate any new data and would change the effectiveness estimates generated in this study.

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APPENDIX A:

OBJECTIVE TEST PROTOCOLS

Advanced Crash Avoidance Technologies Program (ACAT)
Backing crash Countermeasures Project

PURPOSE

This appendix describes a set of objective test procedures designed to characterize the performance of vehicle-based backing crash countermeasures for input to a computer-based SIM model. Three basic types of objective tests are specified: 1) Grid Tests of System Response Performance, 2) Tests of False Alarm Performance, and 3) Driver-in-the-Loop Performance Tests. All tests are conducted under daylight conditions on level, dry surfaces. In addition, two special sections are included at the end of the Appendix: a Vehicle Alignment Procedure, and a Depiction of the Test Objects.

Overview of Specific Tests

In all, 15 specific tests are prescribed across the three basic test types to include the following:

(Grid Tests)

1. Proximity-based, camera field of view
2. Proximity-based, static field of response
3. Proximity-based, field of response with incurring obstacles
4. Warning-based, dynamic longitudinal
5. Warning-based, dynamic horizontal, full lock
6. Warning-based, dynamic horizontal, incurring obstacles

(False Alarm Performance Tests)

7. Residential driveway
8. Residential garage
9. Commercial parking lot
10. Public city street

(Driver-in-the-Loop Tests)

11. Pedestrian, intermediate static
12. Pedestrian, near incurring
13. Pedestrian, intermediate incurring
14. Near, static vehicle
15. Intermediate, static pole

Table 1 lists each specific objective test and associated test conditions, including the number of trials to be performed.

Table 1. Summary of Objective Tests and Testing Conditions

Test Class	Test Type & Number	Test Name & Purpose	Test Objects and Conditions
Grid Test	**Trained Observer (Driver Out Of Loop)**	**Grid Test of System Response Performance over Coverage Zone.** Evaluate the performance of the countermeasure's obstacle detection system in responding to objects to establish the zone of coverage.	
Proximity-Based	1. Camera Field of View (FOV)	Assess camera Field of View FOV	Test Object ○ Cardboard Cylinder. 1 meter tall (40 inches), 30.5 cm diameter (12 inches) **(Total of 2 Testing Conditions)**
	2. Static Field of Response	Static vehicle and static obstacles positioned in squares moving horizontally and lengthwise across test grid	Test Objects ○ PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches) ○ Surrogate Test Mannequins ▪ 2 yr old Standing ▪ 5 yr old Standing ▪ Sitting ▪ 5 yr old Prone ○ Both Objects and Vehicle Stationary **(Total of 5 Testing Conditions)** **(Total of 15 Trials)**
	3. Field of Response with Incurring Obstacles	Static Vehicle, Incurring Obstacles	Test Objects ○ PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches) ○ Surrogate Test Mannequins ▪ 2 yr old Standing Upright Walking ▪ 5 yr old Standing Upright Walking Test Object Movement Rates ○ Two speeds of 2 and 4 mph (3.2 and 6.4 km/h respectively) **(Total of 6 Testing Conditions)** **(Total of 24 Trials)**
Warning-Based	4. Dynamic Longitudinal	Dynamic Vehicle, Static Obstacles. Vehicle backing on straight path toward object	Test Objects ○ PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches) ○ Surrogate Test Mannequins ▪ 2 yr old Standing ▪ 5 yr old Standing ▪ Sitting ▪ 5 yr old Prone Vehicle Movement Rates ○ Three backing speeds of 4, 8, and 15 mph (6.4, 12.9, and 24.1 km/h) **(Total of 15 Testing Conditions)** **(Total of 45 Trials)**

Test Class	Test Type & Number	Test Name & Purpose	Test Objects and Conditions
	5. Dynamic Horizontal, Full Lock	Full Lock at Parking Speed. Identify the horizontal field of response, any path prediction	Test Objects ○ PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches) ○ Surrogate Test Mannequins ▪ 2 yr old Standing ▪ 5 yr old Standing ▪ Sitting ▪ 5 yr old Prone Vehicle Movement Rates ○ A single backing speed of 5 mph (8 km/h) **(Total of 5 Testing Conditions)** **(Total of 20 Trials)**
	6. Dynamic Horizontal, Incurring Obstacles	Backing Straight With Incurring Obstacles (with and without preview - clear vs obstructed line of sight). Identify the horizontal field of response	Test Objects ○ PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches) ○ Surrogate Test Mannequins ▪ 2 yr old Standing ▪ 5 yr old Standing Vehicle Movement Rates ○ Two backing speeds of 4, 8 mph (6.4, 12.9 mph) Object Movement Rates ○ Two speed of 2 and 4 mph (3.2, 6.4 km/h) Line-of-sight Conditions ○ Obstructed and Unobstructed **(Total of 24 Testing Conditions)** **(Total of 96 Trials)**
False Alarm	**Trained Test Driver**	**False Alarm Performance.** Characterize and estimate system false activations via use of a standardized test course.	
Residential	7. Driveway	Evaluate false alarm potential for elements commonly found in residential driveway environments.	○ 17 test objects/features in actual and simulated driveways ○ Mix of driveway types (straight and curved) ○ Mix of vehicle movement rates of 4 and 8 mph (6.4 and 12.9 km/h)
	8. Garage	Evaluate false alarm potential when backing into and out-of a residential garage.	○ 5 tests in actual garage environments (both backing into and out of garage) ○ A single vehicle movement rate of under 5 mph (under 8 km/h)
Commercial	9. Parking Lot	Assess the false alarm potential for commercial parking lot situations.	○ 6 test objects/features in actual parking lot environments ○ Mix of backing approach angles & directions ○ A single vehicle movement rate of under 5 mph (8 km/h)
Public	10. City Street	Assess the false alarm potential for driving environments on public roadways and street parking environments.	○ 12 tests in actual public street and parking environments ○ Mix of vehicle movement rates of 4 and 8 mph (6.4 and 12.9 km/h) ○ Mix of Approach directions

Test Class	Test Type & Number	Test Name & Purpose	Test Objects and Conditions
Driver-In-Loop		**Conflict Scenarios.** Evaluate countermeasure system performance in terms of the driver's interaction with the system (trust, understanding, and use) by examining driver's response in conflict situations with the system.	
Pedestrian	11. Intermediate Static Pedestrian	Pedestrian Scenario 3 with a 2-yr. old surrogate prone 15 ft behind vehicle backing out of driveway. Located off-center. Present prior to maneuver. Pedestrian object enhanced to enable system to reliably respond.	○ 8 Drivers (age 30-65, gender balanced) ○ Novice users ○ Vehicle backing out of driveway ○ Obstacle: 2-yr. old surrogate prone (or comparable object). Present at time of backing, approximately 15 ft behind vehicle.
	12. Near Incurring Pedestrian	Pedestrian Scenario 5 (scenario 5) with a 5-yr old surrogate incurring from driver's side at 5ft from vehicle backing down drive. Pedestrian object enhanced to enable system to reliably respond.	○ 8 Drivers (age 30-65, gender balanced) ○ Novice users ○ Vehicle backing from perpendicular parking space ○ Obstacle: 5-yr. old surrogate (or comparable object), incurring into the vehicle's line of travel from the driver's side, 5ft from bumper. The test object moving at a rate of 2 mph (3.2 km/h) to be consistent with pedestrian walking speeds.
	13. Intermediate Incurring Pedestrian	Pedestrian Scenario 4 with a 5-yr old surrogate incurring from passenger side at 15 ft behind vehicle when backing out of driveway. Pedestrian object enhanced to enable system to reliably respond.	○ 8 Drivers (age 30-65, gender balanced) ○ Novice users ○ Vehicle backing out of driveway ○ Obstacle: 5-yr. old surrogate incurring from passenger side at 15 ft from bumper. The test object moving at a rate of 2 mph (3.2 km/h) to be consistent with pedestrian walking speeds.
Vehicle, Fixed Object	14. Near Static Vehicle	Vehicle 1 (scenario 7) with stationary vehicle located directly behind (5ft) host vehicle (in same traffic lane).	○ 8 Drivers (age 30-65, gender balanced) ○ Novice users ○ Vehicle backing down straight path (driveway) ○ Obstacle: PVC pole (1 meter tall, 75 mm diameter) as surrogate for vehicle. Present at time of backing; located 5 ft behind vehicle
	15. Intermediate Static Pole	Fixed Object (scenario 10) with a fixed pole located 15 ft behind host vehicle while backing out of driveway; pole located along passenger side of the vehicle.	○ 8 Drivers (age 30-65, gender balanced) ○ Novice users ○ Vehicle backing down driveway or garage ○ Obstacle: PVC pole (1 meter tall, 75 mm diameter). Obstacle present at time of backing; located 15 ft behind vehicle and to the passenger side of the vehicle

GRID TESTS OF SYSTEM RESPONSE PERFORMANCE

PROXIMITY BASED TESTS:

CAMERA FIELD OF VIEW (FOV) AND STATIC FIELD OF RESPONSE

(TESTS 1 & 2)

Procedure **Test 1: Proximity-Based, Camera Field of View**

This test assesses the coverage zone for enhanced view systems (e.g., camera-based rear vision systems) using a detection grid 8 meters wide by 30 meters long, comprised of 30 x 30 centimeter cells and a two test objects: a 1 meter tall by 30.5 cm diameter cardboard cylinder, and a surrogate test mannequin representing a 2yr old standing child. Two assessment procedures are outlined. The first captures the near Field Of View adjacent to the vehicle bumper area and involves running the cylinder along the length of the vehicle's bumper to confirm that the displayed views capture the test object. The second maps the camera's longitudinal Field Of View using the same test cylinder and the 2yr old standing mannequin positioned across individual test grid rows and columns. Both tests assume a static host vehicle equipped with the backing countermeasures and a static test object. Unless otherwise noted, testing will be conducted on a straight, level, dry surface under daytime conditions.

Map out the near horizontal and longitudinal Field Of View (FOV) by following the procedures outlined below.

(Near FOV, bumper)

1. Position the vehicle so that the rear axle is over the test grid area, with the rear bumper aligned with the leading edge of one of the rows of the test grid; the vehicle should be horizontally centered on the test grid (see "Vehicle Alignment Protocol" in the back of this Appendix). This position will allow objects along the curvature of the bumper to also be precisely measured.
2. Switch the vehicle ignition to "run"
3. Once the test object is in position, place the vehicle into "reverse" gear to activate the system (note that each trial will need to start with the test object in place)
4. Place the pole (1 meter tall, 30.5 cm diameter cardboard cylinder) in the center of the rear bumper so that it is in contact with the rear bumper fascia and the ground.
5. Move the test object along the entire length of the bumper (start in one direction, then repeat in the other) following the contour of the bumper.
6. Record the grid location where the pole (any part) is no longer visible in the rear vision system display.

(Longitudinal and Lateral FOV)

1. Position the vehicle so that the rear axle is over the test grid area, with the rear bumper aligned with the leading edge of one of the rows of the test grid; the vehicle should be horizontally centered on the test grid (see "Vehicle Alignment Protocol" in the back of this Appendix).
2. Switch the vehicle ignition to "run."

3. Start by placing one of the test objects (1 meter tall by 30.5 cm diameter cylinder or the 2yr old surrogate test mannequin) in the center grid of the first test row (the one directly behind and centerline with the vehicle's rear bumper).
4. (Once the test object is in position) Place the vehicle into "reverse" gear to activate the system (note that each trial will need to start with the test object in place)
5. Record whether the test object (all or any part) is visible in the rear video display screen
6. Move the test object to the next grid cell location along the row and repeat steps 4 & 5, exposing the object for a period of 5 seconds.
7. Continue testing along the row until a point is reached where there is no part of the object visible any longer in the display.
8. Repeat the procedure moving in the opposite direction for the first row.
9. Move to the next row and repeat the process recording whether or not the test object is visible in each grid cell location.
10. Continue testing until the object is no longer visible, or the full length of the grid is exhausted.
11. Repeat the steps with the second test object.

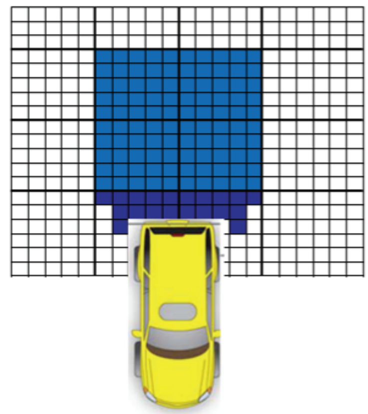
Note: The camera FOV may be wider than the grid which measures approximately 8 meters wide (26ft). In this case, the camera FOV for the passenger-side and driver's side can be gathered independently by locating the vehicle to one side of the grid (aligned with the left-most or right-most column) to measure the FOV for a given side of the vehicle. This technique allows measurement of up to a 16 meter wide FOV – 8 meters along the passenger-side and 8 meters across the driver's side.

<u>Objective Performance Measures</u>

▪ Detection	▪ Location at which no part of the test object is visible any longer in the display. Each grid cell should be coded as object "fully visible," "object partially visible," or "object not visible."
▪ Response Performance	▪ Lateral and Longitudinal Coverage

Procedure **Test 2: Proximity-Based, Static Field of Response**

This test assesses the longitudinal and lateral coverage zones for **proximity-based** systems (including systems that provide proximity information such as Park Assist) using a detection grid 8 meters wide by 30 meters long, comprised of 30 x 30 centimeter cells and a set of static test objects of varying heights and sizes (including a 1meter tall, 75 mm diameter pole; and special test mannequins representative of pedestrians). Test objects are placed in each of the squares and data is captured and recorded to indicate whether or not the system responds to the presence of the test objects. Each object is placed at the appropriate grid location and is in position before the vehicle is placed into reverse. The test assumes a static host vehicle equipped with the backing countermeasures and static test objects. Unless otherwise noted, testing will be conducted on a straight, level, dry surface under daytime conditions.



Map out the near horizontal and longitudinal field of response (FOR) by placing the test objects in each of the grid sections (across all rows) noting for each cell whether the system responds or does not respond to the test object. Follow the procedures outlined below.

1. Position the vehicle so that it is over the test grid area, with the rear bumper aligned with the leading edge of one of the rows of the test grid; the vehicle should be horizontally centered on the test grid (see "Vehicle Alignment Protocol" in Appendix B). This position will allow objects along the curvature of the bumper to also be precisely measured.
2. Switch the vehicle ignition to "run."
3. Take measurements starting in the center grid of the first test row (the one directly behind and centerline with the vehicle's rear bumper). Place the test object in the center of the first grid and activate the system (If the test object is larger than the grid square, then its "centroid" should be located over the grid square).
4. (Once the test object is in position) Place the vehicle into "reverse" gear to activate the system (note that each trial will need to start with the test object in place). Ensure vehicle does not move (engage parking brake and/or depress brake pedal).
5. Present the test object for a period of 5 seconds and record response and response latency (note that although latency data may be captured for all grid units, analysis may rely on a sample).
6. Move the test object to the next grid cell location along the row and repeat steps 4 & 5, exposing the object for a period of 5 seconds and recording system response.
7. Continue testing along the row until the system ceases to respond the object for 3 consecutive grid locations.
8. Repeat the procedure moving in the opposite direction for the first row.

9. Repeat testing with each test object. Once testing for the first test object along the first row has been completed, perform testing along the first row with the next test object. All test objects should be exposed for each row before moving to the next row.
10. Move to the next row and repeat the process recording whether or not the system responded to the obstacle, and response latency.
11. Continue across all of the rows (moving away from the vehicle) until the system does not respond to the test object for a series of 3 consecutive grid cells (rows).
12. Repeat the test 2 more times (**total of 3 trials per test object**) to establish the repeatability of the system.

Notes:

- □ Testing should proceed by rows so that all test objects are exposed before moving to the next grid row.
- □ Test should be repeated 3 times for each test object. Complete testing along all grid rows before repeating the test.

Test Objects & Conditions

The test is to be performed under the following five (5) testing conditions:

- □ PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches)
- □ Surrogate test mannequin, 2yr old standing
- □ Surrogate test mannequin, 5yr old standing
- □ Surrogate test mannequin, 5yr old prone (lying perpendicular to the vehicle bumper)
- □ Surrogate test mannequin, sitting

Objective Performance Measures

▪ Response	▪ Response versus No Response at each cell (grid unit) ▪ Response Reliability. Responses probabilities are calculated by aggregating the response performance across trials and averaging across the number of trials. ▪ Time to Respond (latency from the time the vehicle placed into reverse to onset of response)
▪ Response Performance	▪ Longitudinal & Lateral Coverage. Maps the response probability across individual grid cells for each test object.

GRID TESTS OF OBSTACLE RESPONSE PERFORMANCE

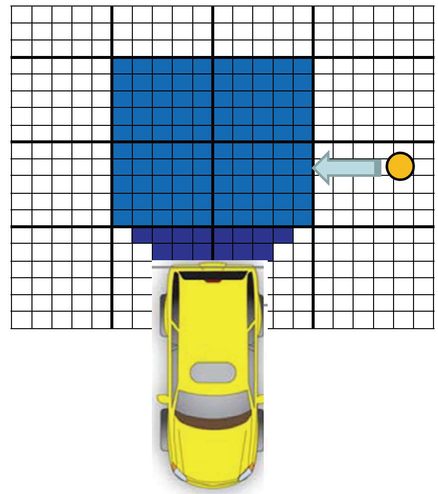
PROXIMITY BASED TESTS:

STATIC FIELD OF RESPONSE, INCURRING OBSTACLES

(TEST 3)

<u>Procedure</u> **Test 3: Proximity-Based, Field of Response for Incurring Obstacles**

This test assesses the longitudinal and lateral coverage zones for proximity-based systems (e.g., proximity information) with dynamic test objects and a stationary host vehicle. The test uses a detection grid approximately 8 meters wide by 30 meters long, comprised of 30 x 30 centimeter cells and a set of dynamic test objects of varying heights and sizes (including a 1 meter tall, 75 millimeter diameter PVC pole; and special test mannequins representative of pedestrians). The test assumes a static host vehicle equipped with the backing countermeasures and dynamic test objects moving at a rate of 2 and 4 mph (3.2 and 6.4 km/h); these speeds are consistent with a range of pedestrian walking speeds (Mazzae, 2006). Unless otherwise noted, testing will be conducted on a straight, level, dry surface under daytime conditions.



Map out the near horizontal and longitudinal Field of Response by moving the test object along each row of the grid and noting when the system first responds to the test object. Follow the procedures outlined below.

1. Position the vehicle so that it is over the test grid area, with the rear bumper aligned with the leading edge of one of the rows of the test grid; the vehicle should be horizontally centered on the test grid (refer to “Vehicle Alignment Protocol” section of this appendix for vehicle alignment procedures).
2. Start with the test object located off to the side of the grid area, positioned along the first row. The test object should be capable of being pulled or propelled through the system’s Field Of Response (FOR) at the prescribed speeds. (Note that the mechanism used to achieve the dynamic capability should not interfere with or otherwise alter the system signature of the test object). The test object should remain close to or in contact with the road surface (within 1 inch of the surface) during its course of travel.
3. Switch the vehicle ignition to “run”
4. Place the vehicle into “reverse” gear to activate the system. Ensure vehicle does not move (engage parking brake and/or depress brake pedal).
5. Move the test object along the first row (in either direction – obstacle incurring from the driver’s side, or the passenger’s side) in accordance with the prescribed speeds (2 and 4 mph, or 3.32 and 6.44 km/h). The test object should follow a straight path, perpendicular to the vehicle’s bumper (e.g., track the path outlined by the test row).
6. Record when the system first responds to the test object.
7. Repeat in the opposite direction. Trials should be counterbalanced for direction of travel.
8. Capture data for each of the test objects before proceeding to the next grid row.

9. Move to the next row and repeat the process (steps 4 thru 8). Note that if the mechanism used to move or propel the test objects is not mobile (is located in a fixed position), then the vehicle can be repositioned on the test grid and re-aligned.
10. Continue testing across all of the rows (moving away from the vehicle) until the system does not reliably respond to the test object.
11. Repeat test 3 more times (total of 4 trials) for each condition listed below.

Notes:

- Testing should proceed by rows so that all test objects are exposed (for all speed conditions) before moving to the next grid row.
- Test should be repeated 4 times for each test condition; the direction of the incurring objects should be counterbalanced (perform 2 trials for each direction of encroachment – passenger and driver's side). Complete testing along all grid rows before repeating the test.

Test Objects & Conditions

This test is to be performed under the following **6 testing conditions**, derived from combining 3 test objects and 2 movement rates (travel speeds):

- PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches)
  - 2 speeds (2 and 4 mph; 3.2 and 6.4 km/h)
- Surrogate test mannequin, 2yr old standing
  - 2 speeds (2 and 4 mph; 3.2 and 6.4 km/h)
- Surrogate test mannequin, 5yr old standing
  - 2 speeds (2 and 4 mph; 3.2 and 6.4 km/h)

Objective Performance Measures

▪ Response	▪ Response vs No Response, and Onset of Response. Identify Grid Unit In Each Row Where System First Responds. Onset of response should be expressed as a distance measure (lateral distance); may be defined as the distance from the bumper midpoint, or intrusion into the vehicle's path using the leading edge of the path to note the extent of intrusion. ▪ Response Reliability. Calculated by mapping performance across trials.
▪ Response Performance	▪ Longitudinal & Lateral Coverage. Map of lateral distances reflecting onset of response across grid rows (longitudinal distances).

GRID TESTS OF OBSTACLE RESPONSE PERFORMANCE

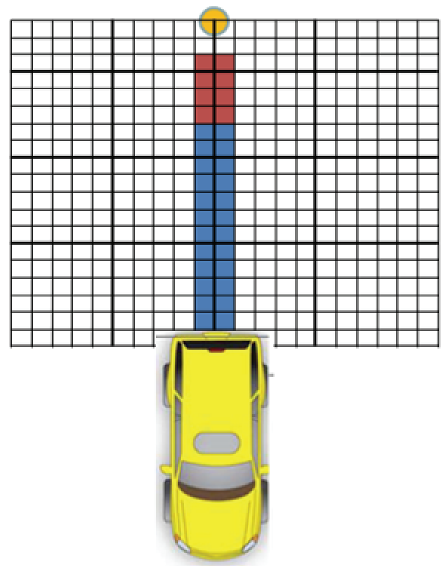
WARNING-BASED TESTS:

DYNAMIC LONGITUDINAL AND HORIZONTAL RESPONSE PERFORMANCE

(TESTS 4, 5, and 6)

Procedure **Test 4: Warning Based, Dynamic Longitudinal**

This test assesses the system's longitudinal response envelope, including the maximum longitudinal Response Performance, for **warning-based** systems (e.g., backing warning and avoidance systems) using a grid 8 meters wide by 30 meters long, comprised of 30 x 30 centimeter cells and static test objects of varying heights and sizes (including a 1meter tall, 75 mm diameter pole; and special test mannequins representative of pedestrians in a variety of positions - standing, sitting and prone). The test requires a trained driver to back the host vehicle (equipped with the backing countermeasures) towards different static test objects. Unless otherwise noted, testing will be conducted on a straight, level, dry surface under daytime conditions. Since warning-based systems are likely to rely on a complex response algorithm (e.g., speed, time-to-collision, etc.) and not merely distance, the system will need to be tested under different approach speed profiles, including high-speed approaches in order to determine the maximum longitudinal range of the system (i.e., the earliest possible point that the system will respond). This requires backing the vehicle towards the test object at various rates of speed (4, 8, and 15 mph; 6.4, 12.9, and 24.1 km/h) in order to define the longitudinal range of the response envelope. This is accomplished in accordance with the following procedures:



1. Locate the test object in the far field of the grid (approximately 30 meters away from the start of the test grid). Position the test object so it is aligned with the centerline of the vehicle's rear bumper and centered along the horizontal axis of the grid. The test object should be in contact with the ground.
2. Position the vehicle sufficiently in advance of the test grid so that the vehicle can reach the prescribed target speeds of 4, 8 and 15 mph (6.4, 12.9, and 24.1 km/h) by the time the vehicle's rear bumper reaches the start of the grid.
3. Switch the vehicle ignition to "start."
4. Place the vehicle into "reverse" gear.
5. Quickly bring the vehicle up to the maximum target speed (4, 8, and 15 mph; 6.4, 12.9, and 24.1 km/h) and maintain a constant velocity, backing along a straight path towards the test object. The vehicle should be traveling at the target speed by the time the rear bumper crosses the leading edge of the grid.
6. Record the range and vehicle speed associated with system responses (warnings, alerts, braking activity, etc). For staged systems, allow the full-range of responses (warnings or interventions) to be elicited before slowing the vehicle. Test driver should not intervene or respond to alerts, warning, or activations.

7. Repeat the test a total of 3 times under each speed profile for each test object.

Notes:

- The test includes a total of 15 testing conditions (5 test objects under 3 backing speeds).
- Tests should be repeated 3 times under each test condition.

Test Objects & Conditions

This test is to be performed under the following **15 testing conditions**, derived from combining test objects and vehicle backing speeds:

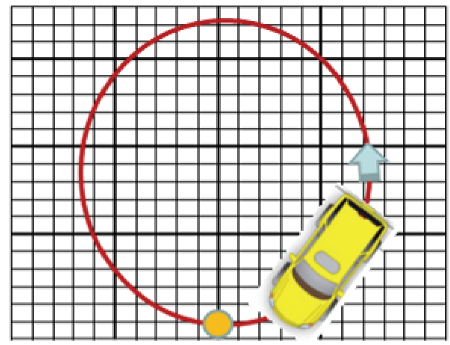
- PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches)
  - 3 speeds (4, 8, and 15 mph; 6.4, 12.9, and 24.1 km/h)
- Surrogate test mannequin, 2yr old standing
  - 3 speeds (4, 8, and 15 mph; 6.4, 12.9, and 24.1 km/h)
- Surrogate test mannequin, 5yr old standing
  - 3 speeds (4, 8, and 15 mph; 6.4, 12.9, and 24.1 km/h)
- Surrogate test mannequin, 5yr old prone
  - 3 speeds (4, 8, and 15 mph; 6.4, 12.9, and 24.1 km/h)
- Surrogate test mannequin, sitting
  - 3 speeds (4, 8, and 15 mph; 6.4, 12.9, and 24.1 km/h)

Objective Performance Measures

▪ System Activation & Response Rates ▪ Response Distances	▪ System response/activation probability for each object recorded for each type of system response, or countermeasure. Expressed as an averaged ratio over the available trials (number of activations over number of trials). ▪ Response distances. Distance from the vehicle bumper to the test object at onset of response for each speed profile. May be expressed as an average or the maximum response range for each test object under each speed profile. Record values for each type of system response.

Procedure **Test 5: Warning Based, Dynamic Horizontal, Full Lock at Parking Speed**

This is one of two tests intended to assess the edge of a system's response zone for **warning-based** systems (e.g., backing warning and avoidance systems). This test specifically identifies the **edge of the system's response zone** (including any path prediction) by simulating backing along a continuous circular path with static test objects. It captures the system's **maximum response range** when backing along a curved path. The procedure defines the edge of the response zone by having a trained test driver back the vehicle (equipped with the backing countermeasures) along a sharp curve (representing the vehicle's maximum turning radius) and identifying the point at which the system first responds to the test object. Test runs will be performed at a single backing speed of 5 mph (8 km/h). The angular coverage is captured by recording the system's response profile across the curved path. Unless otherwise noted, testing will be conducted on a straight, level, dry surface under daytime conditions. The test requires the use of a circular path overlaid on the ground which is used to delineate the vehicle's path and to position test objects; reference marks on the path itself will also allow precise distance measures to be derived down to a resolution of between 3-6 inches.



Follow the procedures detailed below.

1. Place the vehicle on the circular test path so that the turning radius of the vehicle is directly overlaid on the delineated test path; ensure that the center of the vehicle's bumper is aligned with the marked test path. The vehicle's steering wheel should be "locked" in position (turned to the maximum extent, in one direction) so that the vehicle's maximum turning radius is represented.
2. Place the test object on a point along the projected vehicle's path. Allow sufficient distance to enable the vehicle to achieve the desired speed of 5 mph before the object enters the system's Field Of Response (FOR). Placing the test object directly in front of the vehicle is suggested.
3. Back with the steering wheel "locked" in position so that the vehicle will back along the designated path at a speed of 5 mph (8 km/h).
4. The FOR is established by noting the vehicle's speed and distance to the test object at the time of system responses (warnings, alerts, interventions). Distance measures will require identifying the vehicle's precise location on the curved path associated with the onset of system responses (this information may be used to calculate the angular field of response).
5. Perform 4 trials for each test object; counterbalance trials with direction (half clock-wise and half counterclockwise).

Notes:

- □ The test includes a total of 5 testing conditions
    - o 5 test objects (pole, standing mannequin, sitting mannequin)
- □ Tests should be repeated a total of 4 times.
    - o Counterbalanced by vehicle direction (2 trials clockwise, and 2 trials counter-clockwise)

<u>Test Objects & Conditions</u>

This test is to be performed under the following **5 testing conditions**, derived from combining test objects and vehicle backing directions (all trials to be performed at 5 mph (8 km/h) backing speeds):

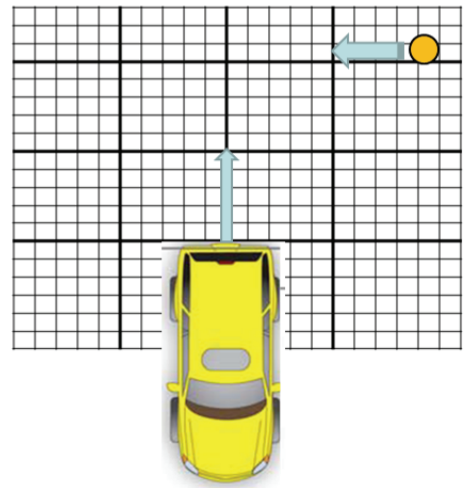
- □ PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches)
    - o Clockwise & counter-clockwise directions
- □ Surrogate test mannequin, 2 yr old standing
    - o Clockwise & counter-clockwise directions
- □ Surrogate test mannequin, 5 yr old standing
    - o Clockwise & counter-clockwise directions
- □ Surrogate test mannequin, 5 yr old prone
    - o Clockwise & counter-clockwise directions
- □ Surrogate test mannequin, sitting
    - o Clockwise & counter-clockwise directions

<u>Objective Performance Measures</u>

▪ System Activation & Response Rates ▪ Response Distances	▪ System response/activation probability for each object recorded for each type of system response, or countermeasure. Expressed as an averaged ratio over the available trials (number of activations over number of trials). ▪ Response distances. Distance from the vehicle bumper to the test object at onset of response. Two types of distances measures are used in the SIM: curve distance and straight-line distance. Curve distances denote the distance along the perimeter of the curve. Straight-line distance represents the shortest distance to the test object (may be derived mathematically). Distances may be expressed as an average or the maximum response range for each test object across trials. Record values for each type of system response.

Procedure **Test 6: Warning Based, Dynamic Horizontal, Backing Straight With Incurring Obstacles**

This is one of two tests intended to assess the horizontal field of response for **warning-based** systems (e.g., backing warning and avoidance systems). This test specifically identifies the **edge of the system's response zone** (without path prediction) by backing along a straight path with dynamic incurring test objects. The test uses a detection grid 8 meters wide by 30 meters long, comprised of 30 x 30 centimeter cells, and a set of dynamic test objects of varying heights and sizes (including a 1meter tall, 30 centimeter diameter pole; and special test mannequins representative of pedestrians). The test assumes a dynamic host vehicle equipped with the backing countermeasures and dynamic test objects moving at a rate of 2 and 4 mph (3.2 and 6.4 km/h); these speeds are consistent with a range of pedestrian walking speeds (Mazzae, 2006). The test will also be performed under two vehicle backing speeds (4 and 8 mph, equivalent to 6.4 and 12.9 km/h) for a total of 4 speed configurations (2 vehicle speeds crossed by 2 test object speeds). The test will also be conducted under two line-of-sight conditions; one with a clear line of sight and one with an obstructed line of sight (e.g., vehicle partially blocking the driver's line of sight).



Unless otherwise noted, testing will be conducted on a straight, level, dry surface under daytime conditions. Map out the dynamic horizontal Field Of Response following the procedures outlined below.

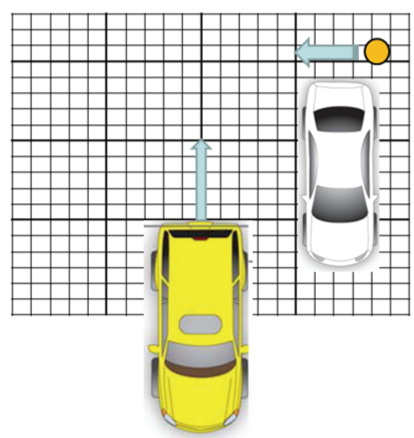
(Unobstructed Line of Sight)

1. Locate the test object in the far field of the grid, along the outside edge so that it can be moved across the vehicle's path at the prescribed time. The test object's line of travel should be perpendicular to the vehicle and should travel in a straight line (down one of the grid rows). The test object should be capable of being pulled or propelled through the system's Field Of Response (FOR) at the prescribed speeds. (Note that the mechanism used to achieve the dynamic capability should not interfere with or otherwise alter the signature of the test object). The test object should remain close to or in contact with the road surface (within 1 inch of the surface) during its course of travel.
2. Position the vehicle sufficiently in advance of the test grid so that the vehicle can reach the prescribed target speed of 4 and 8 mph (6.4 and 12.9 km/h) by the time the vehicle's rear bumper reaches the start of the grid.
3. Switch the vehicle ignition to "start."
4. Place the vehicle into "reverse" gear.
5. Quickly bring the vehicle up to the target speed (e.g., 4 or 8 mph; 6.4 or 12.9 km/h) and maintain a constant velocity, backing along a straight path towards the end of the grid. The vehicle should be traveling at the target speed by the time the rear bumper crosses the leading edge of the grid.

6. Launch the test object into the path of the vehicle, so that it intercepts the vehicle's projected path (the test object should be timed so it intersects with the vehicle at mid bumper). Some variation in timing is acceptable, but the trial should be repeated if the test object does not fall within the vehicle's wheel base at the point of intersection.
7. Record the range, vehicle speed, and the location of the test object corresponding to the onset of each system responses (warnings, alerts, braking activity, etc). Test driver should not respond to countermeasure alerts, warnings, or interventions.
8. Repeat the test 3 more times (a total of 4 trials); the direction of the incurring objects should be counterbalanced (perform 2 trials for each direction – driver and passenger side).
9. Repeat process with each test object under each speed profile (vehicle and test object speed).

(Obstructed Line of Sight)

1. Repeat procedure above, using an obstruction which blocks the system's line of sight of the incurring test object. To accomplish this, park a vehicle parallel to the vehicle's line of travel. The obstructing vehicle should be located one row ahead of the path of the moving object and approximately 8 ft laterally from the grid centerline (essentially simulating a vehicle which is parallel parked along the street, as shown in the illustration)



Notes:

- The test includes a total of 24 testing condition combinations
    - 3 test objects (PVC pole, standing mannequin 2-yr, standing mannequin 5-yr)
    - 2 vehicle backing speeds (4 and 8 mph; 6.4 and 12.9 km/h)
    - 2 obstacle speeds (2 and 4 mph; 3.2 and 6.4 km/h)
    - 2 line-of-sight conditions (clear and obstructed)
- Tests should be repeated a total of 4 times; counterbalancing for the direction of encroachment (passenger and driver side).

Test Objects & Conditions

This test is to be performed under the following **24 testing conditions**, derived from combining test objects, vehicle backing speeds, object movement speeds, and line of sight:

(Clear, Unobstructed Line of Sight)

- □ PVC Pole. 1 meter tall (40 inches), 75 mm diameter (3 inches)
  - Vehicle backing at 4 mph (6.4 km/h), object @ 2mph (3.2 km/h)
  - Vehicle backing at 8 mph (12.9 km/h), object @ 2mph (3.2 km/h)
  - Vehicle backing at 4 mph (6.4 km/h), object @ 4mph (6.4 km/h)
  - Vehicle backing at 8 mph (12.9 km/h), object @ 4mph (6.4 km/h)
- □ Surrogate test mannequin, 2 yr standing
  - Vehicle backing at 4 mph (6.4 km/h), object @ 2mph (3.2 km/h)
  - Vehicle backing at 8 mph (12.9 km/h), object @ 2mph (3.2 km/h)
  - Vehicle backing at 4 mph (6.4 km/h), object @ 4mph (6.4 km/h)
  - Vehicle backing at 8 mph (12.9 km/h), object @ 4mph (6.4 km/h)
- □ Surrogate test mannequin, 5 yr standing
  - Vehicle backing at 4 mph (6.4 km/h), object @ 2mph (3.2 km/h)
  - Vehicle backing at 8 mph (12.9 km/h), object @ 2mph (3.2 km/h)
  - Vehicle backing at 4 mph (6.4 km/h), object @ 4mph (6.4 km/h)
  - Vehicle backing at 8 mph (12.9 km/h), object @ 4mph (6.4 km/h)

(Obstructed Line of Sight)

- □ Run under same conditions as above

Objective Performance Measures

▪ System Activation & Response Rates	▪ System response/activation probability for each object recorded for each type of system response, and countermeasure. Expressed as an averaged ratio over the available trials (number of activations over number of trials). Activation rates should be expressed for each testing dimension (object type, vehicle backing speed, object movement speed, line-of-sight condition). o Provides a probability of response map for incurring objects when backing straight under vehicle and object different speed profiles (overall and for specific objects)
▪ Response Distances	▪ Longitudinal and lateral distances at onset of system response. Record values for each type of system response and by all testing factors.

FALSE ALARM PERFORMANCE TESTS

RESIDENTIAL DRIVEWAY, RESIDENTIAL GARAGE,

COMMERCIAL PARKING LOT, AND PUBLIC CITY STREET TESTS

(TESTS 7, 8, 9 and 10)

Procedure **Test 7: Residential Driveway**

This test assesses the false alarm potential when backing down a residential driveway in the presence of common road-side and roadway elements (test objects and/or features) to include, among other objects: bicycle, mailbox, parked vehicles, garden hose, basketball pole, watering can, and trash can. Aspects of the driveway itself will also be evaluated (driveway characteristics) including: discontinuities in road surface (joints, cracks, potholes), and changes in elevation or driveway transitions. The approach calls for implementing this test by: 1) locating existing real-world driveways which adequately capture the elements of interest (actual environment), as well as 2) constructing artificial driveway environments to accurately represent the desired conditions (simulated environments). The procedures for staging and performing each of the tests are detailed below.

Simulated Driveway (Straight)

1. Create a simulated straight driveway section approximately 100 ft long by 10 ft wide on an asphalt surface, with a flat grade (approximately 0 degree slope). Delineate the driveway with painted edge lines if necessary.
2. Center the vehicle in the lane with the vehicle positioned at the start of the driveway at least 25 feet in advance (upstream) of any test objects.
3. Test objects should be positioned in accordance with the diagram illustrated in the figure below.
4. Each test should be performed by exposing the vehicle to a single test object (feature or roadside element); avoid presenting multiple objects/features during a single test run.
5. Place the vehicle into "reverse" gear and back the vehicle down the driveway at one of two speeds (4 mph or 8 mph, 6.4 or 12.9 km/h). Maintain speed and keep the vehicle centered in the lane. Continue to back until the end of the driveway is reached.
6. Capture and record whether the system responded to the test object and the nature of the response (i.e., the specific countermeasure activated).
7. Repeat the test for a total of 2 trials; trials should be performed in opposite backing directions so that both sides of the test vehicle are exposed.
8. Repeat the test under the second backing speed condition.

Test Objects

- Garden hose (filled with water). Placed across driveway
- Vehicles (two vehicles, parallel to the driveway)
- Bicycle
- Fence
- Metal mailbox with metal post
- Basketball pole
- Metal trash can
- Watering can (plastic with water)
- Snow mound or bank (simulate using a 20 lb bag of ice laying on its side). Place over driveway

Notes:

- ☐ There are a total of 9 test objects for the simulated straight driveway test; each represents exposure to a single test object as detailed below.
- ☐ Tests are to be performed under two backing speed conditions: 4 mph and 8 mph (6.4 or 12.9 km/h).
- ☐ Some test objects are to be placed parallel to the driveway, and others positioned across the driveway. Test objects to be placed along-side the driveway are to be positioned so that the closest part of the object is within 1 ft of the driveway edge (refer to the figure below).

  <u>Test Objects to be Placed Parallel to Driveway</u>
  - o Vehicles (two vehicles), Bicycle, Fence, Mailbox, Basketball pole, Metal trash can, and Watering can (with water)

  <u>Test Objects to be Located Across the Driveway Surface</u>
  - o Hose (with water)
  - o Snow (simulated using bag of ice)
- ☐ Each test should be repeated for a total of 2 trials per test object. The vehicle's direction of travel should be reverse between trials to expose both sides of the vehicle to the test objects.

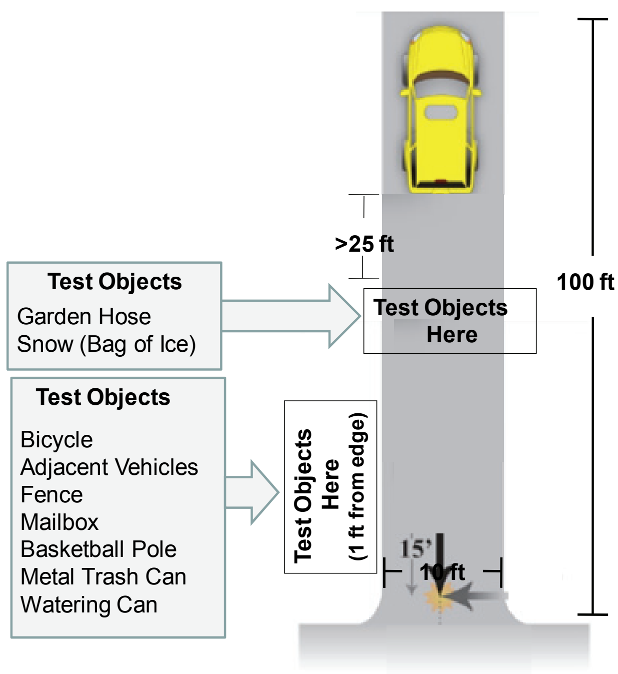


Figure 1. Diagram of Simulated Straight Driveway Test Layout for Residential Driveway

Simulated Driveway (Curved)

1. Create a simulated curved driveway section approximately 75 ft long by 10 ft wide on an asphalt surface, with a flat grade. Delineate the driveway with painted edge lines if necessary. Use a curved path with a radius of approximately 13 ft.
2. Center the vehicle in the lane with the vehicle positioned at the start of the driveway at least 25 feet in advance (upstream) of any test objects.
3. Test objects should be positioned in accordance with the diagram illustrated in the figure below.
4. Each test should be performed by exposing the vehicle to a single test object (feature or roadside element).
5. Place the vehicle into "reverse" gear and back the vehicle down the driveway at one of two speeds (4 mph or 8 mph, 6.4 or 12.9 km/h). Maintain speed and keep the vehicle centered in the lane.
6. Capture and record whether the system responded to the test object and the nature of the response (i.e., the specific countermeasure activated).
7. Repeat the test for a total of 2 trials; trials should be performed in opposite backing directions. Note that the location of the test objects will need to be adjusted for the direction of travel (refer to the figure below).
8. Repeat the test under the second backing speed condition.

<u>Test Objects</u>

- Vehicle
- Bicycle
- Metal mailbox with metal post
- Metal trash can
- Watering can (plastic with water)

Notes:

- There are a total of 5 testing conditions (subset of the 5 tested under the straight driveway) for the simulated curved driveway test; each represents exposure to a single test object as detailed below.
- Tests are to be performed under two backing speed conditions: 4 mph and 8 mph (6.4 or 12.9 km/h).
- Test objects are to be placed at the apex of the curve, outside of the actual line of travel, so no real risk of a conflict should exist. The scenario will expose the system to the test objects during the initial phase of backing and as the vehicle maneuvers along the curved path. Test objects are to be placed along-side the driveway positioned so that the closest part of the object is within 1 ft of the driveway edge (refer to the figure below).

☐ Each test should be repeated for a total of 2 trials per test object. The vehicle's direction of travel should be reversed between trials to expose both sides of the vehicle to the test objects. Test objects will need to be relocated in accordance with the vehicle's direction of travel (the figure depicts the two test object locations).

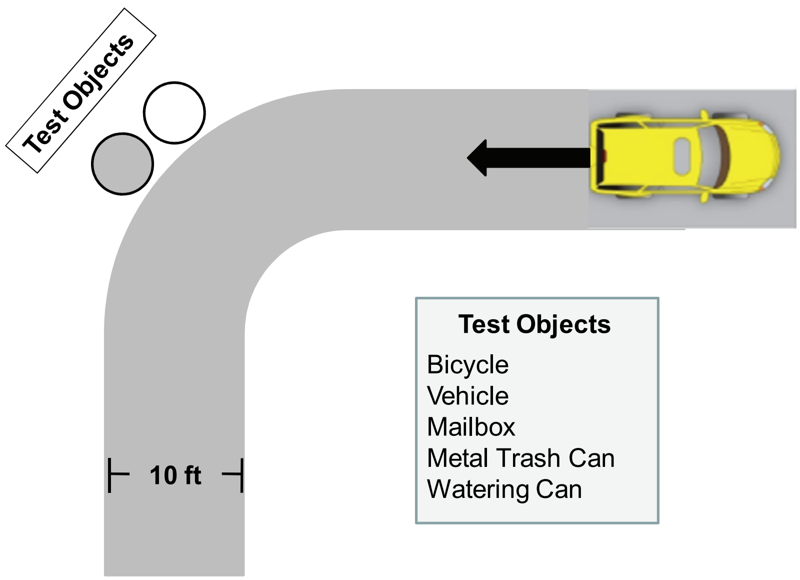


Figure 2. Diagram of Simulated Curved Driveway Test Layout for Residential Driveway. The Two Circles Represent the Test Object Locations; Select the Location Specific to the Backing Direction

Actual Driveway Environments

1. Locate actual driveways or settings that conform to the elements and environments detailed below. Parallel forms of the test element or environment should be located to allow exposure to multiple examples or cases of the same basic type of element or environment (e.g., 3 examples of steep driveways).
2. Each test should be performed by exposing the vehicle to a single test object (element or environment).
3. Position the vehicle at least 15 feet in advance (25 ft is recommended) of the element to be tested. Allow sufficient room to allow the vehicle to reach the designated backing speed. Depending on the element being tested, ensure that the vehicle is centered relative to the test element so that the vehicle passes directly over the element; avoid exposing only part of the vehicle (left or right) to the element.
4. Place the vehicle into "reverse" gear and back the vehicle down the driveway at a speed of 4 mph and/or 8mph (6.4 and 12.9 km/h), if the environment allows (it may not be feasible to

back at higher speeds for certain conditions). Maintain speed and keep the vehicle centered relative to the element.

5. Capture and record whether the system responded to the test object and the nature of the response (i.e., the specific countermeasure activated).
6. Repeat the test using each of the parallel test forms; each element or environment should have 3 examples or cases for testing.
7. If conditions allow, repeat to collect data for the two backing speeds (4 mph and 8mph, 6.4 and 12.9 km/h).

<u>Test Elements /Environments</u>

- Driveways of varying grades - transitions in incline angle between the driveway and the street.
  - Steep driveway grade (10-15% grade)
  - Moderate driveway grade (5-10% grade)
  - Flat driveway (no grade)
- Gravel driveway with ruts (backing exposure of at least 50 ft)
- Asphalt driveway with large cracks (1-3 inch wide and over 2 feet in length)
- Asphalt driveway with puddle (at least ¼ inch deep and 2 ft diameter)
- Flat driveway with moderate vertical alignment change – offset or lip between driveway and street level.
- Driveway with entrance element (e.g., gate)

Notes:

- □ There are a total of 8 test objects or features to be captured under the actual driveway tests; each represents exposure to a single test environment/driveway element. Each testing condition should be repeated three times using the parallel forms.
  - Multiple examples (or parallel forms) of each driveway element should be located and used. Testing should be performed with three examples or cases.
- □ Backing speeds should be consistent with the typical driveway backing speeds of approximately 4 mph and 8 mph (6.4 and 12.9 km/h) during steady state backing, lower when traversing transitions between the driveway and street. If possible, repeat tests under both backing speed profiles.

Examples

Driveway Element or Environment		Example
Driveways of varying grades - transitions in incline angle between the driveway and the street.		
- Steep driveway grade (10-15% grade)		
- Moderate driveway grade (5-10% grade)		
- Flat driveway (no grade)		
Gravel driveway with ruts (backing exposure of at least 50 ft)		
Driveway with large cracks (1-3 inch wide and over 2 feet in length)		

Asphalt driveway with puddle (at least ¼ inch deep and 2 ft diameter)		
Flat driveway with moderate vertical alignment change – offset or lip between driveway and street level.		
Driveway with entrance element (e.g., gate)		

Procedure **Test 8: Residential Garage**

This test assesses the false alarm potential when backing into and out of a residential garage (2-stall unit) with associated elements and characteristics to include: variations in the width of the opening, presence of a lip or joint at the entrance threshold, presence of a metal drainage grate near the entrance, presence of metal garage door tracks. A single test approach for implementing these residential garage tests is specified which consists of locating existing real-world garage environments to adequately capture the elements of interest. Maneuvers to be represented include backing into as well as out of the garage. Assess the false alarm potential of the system by following the procedures outlined below.

Residential Garage Environments

1. Locate actual residential garages that conform to the elements and environments detailed below. Parallel forms of the test element or environment should be located to allow exposure to multiple examples of the same basic type of element or environment. Three (3) examples or cases should be identified and tested for each element/environment.
2. Each test should be performed by exposing the vehicle to a single test element or environment.

(Backing Into Garage, Narrow and Wide)

3. When backing into the garage, position the vehicle at least 15 feet in advance (upstream) of entrance, if feasible. Allow sufficient room for the vehicle to reach the designated backing speed. The vehicle's starting position should orient the vehicle so it is directly facing the intended line of travel (straight relative to the opening). The bay should be clear of obstructions to allow the vehicle to be parked.
4. Place the vehicle into "reverse" gear and back the vehicle into the garage at speeds consistent with these maneuvers, below 5 mph (8 km/h). Continue to back until the vehicle is ¾ of the way into the garage (the driver compartment is in the bay).
5. Capture and record whether the system responded during the maneuver and the nature of the response (i.e., the specific countermeasure activated). Ensure that any activations are not due to the rear garage wall (or obstacles), but can be attributed to the entrance feature (doorway or threshold).
6. Repeat the test under each condition (wide and narrow opening) using each of the parallel test forms. Each element or environment should have 3 examples for testing. There should be a total of 6 backing trials (three examples of backing into a narrow garage, and three examples of backing into a wide garage).

(Backing Into Garage, Transition or Lip)

3. When backing into the garage, position the vehicle at least 15 feet in advance (upstream) of entrance, if feasible. Allow sufficient room for the vehicle to reach the designated backing speed. The vehicle's starting position should orient the vehicle so it is directly facing the intended line of travel (straight relative to the opening). The bay should be clear of obstructions to allow the vehicle to be parked.
4. Place the vehicle into "reverse" gear and back the vehicle into the garage at speeds consistent with these maneuvers, below 5 mph (8 km/h). Continue to back until the vehicle is ¾ of the way into the garage (the driver compartment is in the bay).
7. Capture and record whether the system responded during the maneuver and the nature of the response (i.e., the specific countermeasure activated). Ensure that any activations are not due to obstacles, but can be attributed to the entrance feature (transition or lip).
5. Repeat the test using each of the parallel test forms. Each element or environment should have 3 examples for testing. There should be a total of 3 backing trials (three examples of backing into a garage with a transition or lip).

(Backing Into Garage, Metal Drainage Grate)

3. When backing into the garage, position the vehicle at least 15 feet in advance (upstream) of entrance, if feasible. Allow sufficient room for the vehicle to reach the designated backing speed. The vehicle's starting position should orient the vehicle so it is directly facing the intended line of travel (straight relative to the opening). The bay should be clear of obstructions to allow the vehicle to be parked.
4. Place the vehicle into "reverse" gear and back the vehicle into the garage at speeds consistent with these maneuvers, below 5 mph (8 km/h). Continue to back until the vehicle is ¾ of the way into the garage (the driver compartment is in the bay).
5. Capture and record whether the system responded during the maneuver and the nature of the response (i.e., the specific countermeasure activated).
6. Repeat the test using each of the parallel test forms. Each element or environment should have 3 examples for testing. There should be a total of 3 backing trials (three examples of backing into a garage with a metal drainage grate).

(Backing Out Of Garage, Metal Rails)

3. Position the vehicle so that the rear bumper is facing out at least 3 feet from the garage door. The garage door should be completely retracted. There should be no obstructions in the vehicle's path.
4. Place the vehicle into "reverse" gear and back the vehicle out of the garage at speeds consistent with these maneuvers, below 5 mph (8.0 km/h). Continue to back until the vehicle is completely out of the garage (the driver compartment is in the bay).
5. Capture and record whether the system responded during the maneuver and the nature of the response (i.e., the specific countermeasure activated).

6. Repeat the test using each of the parallel test forms. Each element or environment should have 3 examples for testing. There should be a total of 3 backing trials (three examples of backing out of a narrow garage with metal garage door tracks).

<u>Test Elements /Environments</u>

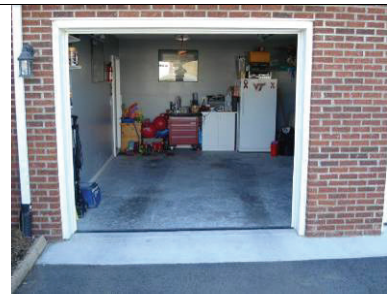
There are a total of 5 test objects/features identified under the residential garage:

- Backing into a garage bay of varying widths representing a small and large garage door opening.
  - Narrow entrance (8 ft wide bay entrance)
  - Wide entrance (10 ft wide bay entrance)
- Backing into a garage with a transition (lip or joint) present between driveway and garage entrance. Maneuvers to be performed using a wide garage door opening 10 ft or greater.
- Backing into a garage with a metal drainage grate present at entrance to garage. Maneuvers to be performed using a wide garage door opening 10 ft or greater.
- Backing out of a garage bay with metal garage door tracks. Maneuver to be performed when backing out of narrow door bay (8 ft in width), with a bay sufficiently deep to expose the rear bumper to the door tracks (bay should be a minimum of 25 ft deep).

Notes:

- There are a total of 5 testing conditions for the residential garage test; each represents exposure to a single test condition.
  - Multiple examples (or parallel forms) of each test condition should be located and used. Testing should be performed with three examples or cases.
- Repeat each testing condition a total of three times to allow for multiple exposures to the same unique test condition (e.g., back out of the same narrow bay garage opening 3 times).
- Backing speeds should be consistent with the typical backing speeds associated with entering and exiting garages, under 5 mph (8 km/h).

Examples

Residential Garage		**Example**
Two-bay garage (each bay is separate) with varying entrance widths. Maneuvers to be performed when backing into bay from the driveway.		
- Narrow entrance (8 ft wide bay entrance)		
- Wide entrance (10 ft wide bay entrance)		
Transition (lip or joint) present between driveway and garage entrance. Maneuvers to be performed when backing into bay from the driveway.		
Metal drainage grate present at entrance to garage. Maneuvers to be performed when backing into bay from the driveway.		
Narrow bay with metal garage door tracks. Maneuvers to be performed when backing out of bay.		

Procedure **Test 9: Commercial Parking Lot**

This test assesses the false alarm potential when backing within a commercial parking lot environment (e.g., shopping center, mall, etc.) with elements (test objects) common to these types of situations including: narrow parking aisles with parked vehicles, pavement markings, signs, parking barriers, metal shopping carts, cart racks, lamp posts, speed humps. The specified approach for implementing these tests consists of locating an existing real-world parking lot which adequately captures the elements of interest. It may be necessary to use multiple test sites in order to capture all of the elements of interest. Several trials are to be performed; each involves backing the vehicle in the specified environment and recording system responses during the maneuver. Assess the false alarm potential of the system by following the procedures outlined below.

Parking Maneuvers (Perpendicular and Angled Parking)

1. Start by positioning the vehicle so it is aligned and ready to back straight into the space (This can be accomplished by first parking the vehicle in the space, then pulling straight forward until the rear bumper of the vehicle is outside of the space and positioned in the parking aisle). Be sure the vehicle is centered in the lane.
2. Each test should be performed by exposing the vehicle to a single test object (element or roadside element); avoid presenting multiple objects/elements during a single test run.
3. Place the vehicle into "reverse" gear and execute the specified parking maneuver. Continue to back the vehicle until it is completely in the parking space (in cases where a curb or wheel stop is present, the vehicle's rear tires should come to rest on the curb or concrete stop). Backing speeds should be consistent with typical parking speeds, under 5 mph (8 km/h).
4. Capture and record whether the system responded to the test object and the nature of the response (i.e., the specific countermeasure activated).
5. Repeat the test for a total of 3 trials; each trial should be performed using one of the available parallel test forms or test cases.

Backing Maneuvers (Speed Hump and Painted Road Markings)

1. Start by positioning the vehicle at least 25 feet in advance (upstream) of any test objects. Be sure the vehicle is centered in the lane.
2. Each test should be performed by exposing the vehicle to a single test object (or roadside element); avoid presenting multiple objects/elements during a single test run.
3. Place the vehicle into "reverse" gear and back the vehicle over the test object/element. Continue to back the vehicle until it is completely past the test element (speed hump or painted road markings). Backing speeds should be consistent with typical short distance backing speeds, under 5 mph (8 km/h).

4. Capture and record whether the system responded to the test object and the nature of the response (i.e., the specific countermeasure activated).
5. Repeat the test for a total of 3 trials; each trial should be performed using one of the available parallel test forms or test cases.

<u>Test Objects/Elements</u>

- Perpendicular Parking to Concrete Wheel Stop
- Perpendicular Parking to Sign Post
- Perpendicular Parking with Vehicles in Adjacent Bays
- Parking with Metal Cart Return in Adjacent Bay
    - Perpendicular parking
    - Angled parking
- Backing over Speed Hump/Bump
- Backing over Painted/Reflective Road Markings

Notes:

- There are a total of 6 testing conditions for the commercial parking lot test; each represents exposure to a single test condition.
    - Multiple examples (or parallel forms) of each test condition should be located and used. Testing should be performed with three examples or cases.
- Repeat each testing condition a total of three times to allow for multiple exposures to the same unique test condition (e.g., back to the same concrete wheel stop 3 times).
- Backing speeds should be consistent with the typical backing speeds associated with parking (under 5 mph; 8 km/h).

Examples

Commercial Parking Lot Element or Environment		Example
Perpendicular Parking to Concrete Wheel Stop		
Perpendicular Parking to Sign Post		
Perpendicular Parking With Vehicles in Adjacent Bays (no vehicle directly behind)		
Parking with Metal Cart Return in Adjacent Bay		
- Perpendicular Parking		

- Angled Parking		
Backing Over Speed Hump		
Backing Over Painted /Reflective Road Markings		

Procedure **Test 10: Public City Street**

This test assesses the false alarm potential when parking and backing in public street environments in the presence of common roadway elements (test objects) found in these settings to include: parking meters, curbs, guardrails, fire-hydrant, potholes, railroad tracks, manhole cover, road debris (crushed aluminum can, etc). The approach calls for locating existing real-world street settings which adequately capture the elements of interest. Test maneuvers require a trained driver to park as well as back in the presence of these elements and to record system responses under these situations.

Parking Maneuvers

1. Position the vehicle in the parking aisle, or street, in preparation to back into the open space (there should be no other vehicles parked in the adjacent spaces).
2. Place the vehicle into "reverse" gear and execute the specified parking maneuver. Continue to back the vehicle until it is completely in the parking space (in cases where a curb or wheel stop is present, the vehicle's rear tires should come to rest against the curb or concrete stop). Backing speeds should be consistent with typical parking speeds, under 4 mph (6.4 km/h).
3. Capture and record whether the system responded to the element or environment and the nature of the response (i.e., the specific countermeasure activated).
4. Repeat the test for a total of 2-3 trials; each trial should be performed using one of the available parallel test forms or test cases (refer to table below showing examples).

Short Backing Maneuvers

1. Start by positioning the vehicle at least 25 feet in advance (upstream) of any test objects. Be sure the vehicle is centered in the lane.
2. Each test should be performed by exposing the vehicle to a single test object (or roadside element); avoid presenting multiple objects/elements during a single test run.
3. Place the vehicle into "reverse" gear and back the vehicle over the test object/element. Continue to back the vehicle until it is completely past the test element. Backing speeds should be consistent with typical short distance backing speeds, approximately 4 mph (6.4 km/h).
4. Capture and record whether the system responded to the test object and the nature of the response (i.e., the specific countermeasure activated).
5. Repeat the test for a total of 2-3 trials; each trial should be performed using one of the available parallel test forms or test cases.

Test Objects/Elements

There are 12 unique test objects/features to be captured under this test:

(Parking)

- Parking to a curbed space
- Parking in presence of a parking meter
- Parking in presence of a fire hydrant
- Parking in presence of a guardrail
- Parking in presence of a fence

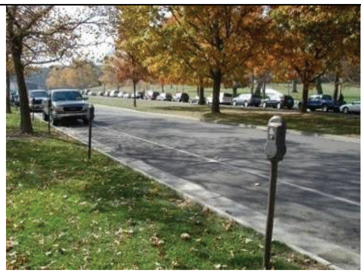
(Short Backing)

- Backing over man hole cover
- Backing over potholes
- Backing over road debris (soda can)
- Backing over railroad tracks
- Backing down alleyway
- Backing over joints
- Backing in presence of overhead sign

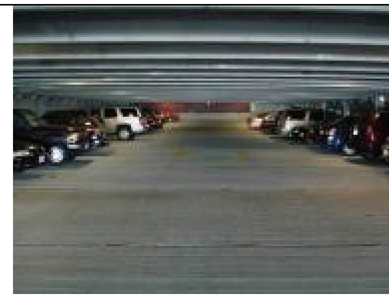
Notes:

- There are a total of 12 testing conditions for the public street test; each represents exposure to a single test element.
    - Multiple examples (or parallel forms) of each test condition should be located and used. Testing should be performed with two to three examples or cases for each object/feature.
- Repeat each testing condition a total of three times to allow for multiple exposures to the same unique test condition (e.g., back to the same manhole cover 3 times).
- Backing speeds should be consistent with the typical backing speeds associated with parking (under 5 mph; 8 km/h), and short backing maneuvers (8 mph; 12.9 km/h). If feasible (sensible), back to a given object feature under the two speed conditions.

Examples

Public Street Environments		Example
Parking Maneuvers		
Baking into a **curbed** parking space (three cases to include: parallel, perpendicular, and angled spaces)		
Backing to a parking space with a **parking meter** (three cases to include: parallel, perpendicular, and angled spaces)		
Backing to a parking space with a **fire hydrant** (two cases to include: parallel and perpendicular spaces)		
Backing to a parking space with a **guardrail** (two cases to include: parallel and perpendicular spaces)		

Backing to a parking space with a **fence** (two cases to include: parallel and perpendicular spaces)		
Short Backing Maneuvers		
Backing over a **man hole cover**		
Backing over **potholes**		
Backing over road debris (**soda can**)		
Backing over **railroad tracks**		

Backing down narrow **alleyway**		
Backing over **joints** (parking garage structure)		
Backing in presence of **overhead sign** (parking garage structure)		

<u>Objective Performance Measures</u>

▪ System Response & Alert/Warning/Intervention	▪ False Alarm Rate Expressed as a Ratio of Observed False Alarms to Total Possible.

DRIVER-IN-THE-LOOP, TESTS OF CRASH AVOIDANCE

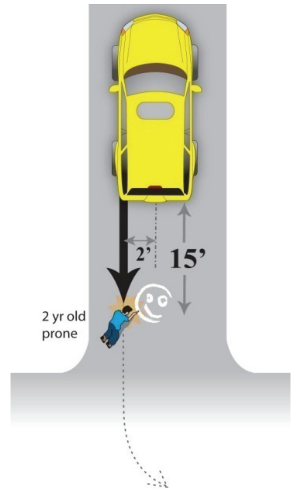
PEDESTRIAN TESTS:

INERTMEDIATE STATIC, NEAR INCURING, AND INTERMEDIATE INCURRING

(TESTS 11, 12, and 13)

Procedure **Test 11: Intermediate, Static Pedestrian (Scenario 3)**

This test assesses the performance of the driver as a means to contribute to the evaluation of the extent to which the presence of the backing countermeasures lead to successful avoidance outcomes under situations where a static (stationary) rear hazard is in relatively close proximity to the vehicle and not directly visible to the driver. This particular test is intended to simulate a common backing crash scenario wherein a driver backs the vehicle from a driveway in the presence of an unknown small child. In this test scenario, the child is prone 4.5 meters (15 feet) behind the vehicle (Scenario 3, Pedestrian #3)[1]. Testing will be performed with a group of 8 drivers (ages 30 to 65 years, balanced by gender, recruited from the general driving public); each driver is assumed to have a basic level of understanding regarding the backing countermeasures, but very limited exposure to or experience with the countermeasures. Unless otherwise noted, testing will be conducted on a straight, level, dry surface under daytime conditions. Test conditions should not bias drivers (e.g., lead to overreliance on system, unduly raise expectancy, etc.), but capture and elicit representative driver behaviors and system performance. Follow the procedures outlined below.



1. Stage the scenario to conform to the following characteristics:
   - ☐ Park the vehicle in a driveway (or comparable situation) requiring the driver to execute a backing maneuver to exit the space and back to a specific location. The setting should allow drivers to back at least 20 feet. It would also be desirable to use a naturalistic setting with other vehicle's and elements in the surrounding environment.
   - ☐ The scenario should be staged to have drivers enter the parked vehicle. It is recommended that drivers approach the vehicle from the front, if feasible.
   - ☐ Place a surrogate test object (resembling characteristics of a prone 2 year old child) 4.5 meters (15 feet) from the rear bumper, and 0.61 m (2 feet) off-centerline toward the driver's side, in the vehicle's backing path; the test object should be placed without knowledge of the driver (note: pop-up target techniques may also be used to accomplish placement of the test object). The test object should not initially be visible to the driver through direct over-the-shoulder glances or via the mirror system.
   - ☐ The study setting should build or allow for a reasonable expectation for pedestrian and vehicular traffic (e.g., active parking lot, presence of occasional pedestrians, etc).

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[1] SCI investigations often were not able to provide detail on the posture or position of the child behind the vehicle (e.g., in driveway backing cases, which were the most common among the SCI cases analyzed). However, the Pedestrian 3 scenario offers a stringent test of system performance since the prone position for a child is very difficult for a system to detect, discriminate, and respond to.

2. Provide an overview of the vehicle features and familiarize drivers with the backing countermeasures (an overview of a subset of these features, such as Park Aid and Rear Vision, may be sufficient). Drivers should be made aware of the backing countermeasures in advance of this test, but should not be forced or compelled to use the features. Limited practice with the features is recommended in order to eliminate or reduce novelty effects which may cause drivers to initially over-rely on the aids. In order to avoid unduly biasing drivers, the familiarization process should not exclusively focus on the backing countermeasures systems, but encompass a broader set or range of in-vehicle devices, features, and functions.
3. Once the familiarization process is complete, ask the driver to back out of the parking space. Drivers should be instructed to back in the direction of the test object; however, do not direct or otherwise instruct the driver to use or rely on the available backing countermeasures. Provide drivers with a specific target location or area to which they are to maneuver the vehicle.
    - □ Limit interactions with the in-vehicle experimenter preceding and during the actual backing maneuver and conflict event. Use an experimenter trained in how to administer the test protocol and in how to handle interactions with participants.
4. Record system responses and driver behaviors in accordance with the metrics outlined in the table below to include driver eye-glance measures and responses to system alerts/warnings and control interventions. Construct a time-line of events surrounding overall outcomes (e.g., hit or avoid test object) in order to develop an understanding of the causal mechanisms underlying these outcomes (e.g., driver avoided object as a result of glancing to the rear video and recognizing the presence of the target, and then braking the vehicle).
    - □ On-board camera systems should enable driver performance and interaction with the countermeasures to be captured and recorded. Desirable camera views include: driver face view, view of the foot controls (brake and accelerator pedals), over the shoulder view (or other wide angle view) allowing the driver's gross body movements to be measured (e.g., over the shoulder glances), view capturing the backing countermeasure responses, external view showing the area behind the vehicle, among others.
    - □ Audio recordings capturing system alerts and drivers commentary are also desirable
5. Debrief the driver immediately following the staged conflict event in order to gauge their understanding of and reliance on the backing countermeasure systems. Specific aspects to be captured include:

    (If Driver Detects or Responds to the Obstacle)
    - □ Why the driver stopped
    - □ A description of the events, including what they saw, were aware of, and did in response to the event
    - □ When the driver first noticed the obstacle
    - □ How the driver came to notice the obstacle
    - □ A description of the nature of the warning or countermeasure and their interpretation of the cues or signals (message being communicated)
    - □ An accounting of the perceived role the countermeasure played in detecting or responding to the obstacle

    (If Driver Fails to Detect or Respond to the Obstacle)

- ☐ An accounting of whether they noticed anything unusual during the backing maneuver
  - ☐ Whether they noticed the in-path obstacle
  - ☐ Whether they noticed the countermeasure system's cues or signals and how they interpreted and responded to these signals and why

Notes:

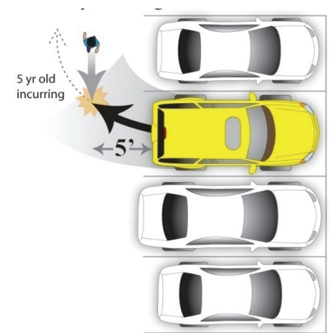
- ☐ Use a ruse (a cover story disguising the true nature and purpose of the study) in order to direct the focus away from the backing countermeasures.
- ☐ Administer the conflict scenario as part of a surprise event trial embedded as part of the first backing episode.
- ☐ The scenario assumes the use of an in-vehicle experimenter who overviews the vehicle's features (including backing countermeasures), and instructs and accompanies the driver, who is trained in the administration of the test protocols.

<u>Objective Performance Measures</u>

▪ Collision Outcome (Percent Avoided/Hit)	If Avoided: ▪ When Detected ▪ Reliance on System	If Hit: ▪ Reliance on System
▪ Search & Detection Performance	▪ Detection (Yes/No) ▪ Method of Detection ▪ Search & Search Time o Glance Locations (Number and Duration)	
▪ Driver Response	▪ Driver Response to Alert/Warning/Intervention	
▪ Other Performance Metrics	▪ Unintended Consequences (countermeasure specific)	

<u>Procedure</u> **Test 12: Near, Incurring Pedestrian (Scenario 5)**

This test assesses the performance of the driver as a means to contribute to the evaluation of the extent to which the presence of the backing countermeasures lead to successful avoidance outcomes under encroachment situations where a moving hazard enters into the path of a backing vehicle. This particular test is intended to simulate a common backing crash scenario wherein a small child darts into the path of a vehicle backing out of a parking space; the child encroaches from the driver's side and is in close proximity (1.5 meters, or 5 feet) to the vehicle (Scenario 5, Pedestrian #5). Testing will be performed with a group of 8 drivers (ages 30 to 65 years, balanced by gender, recruited from the general driving public); each driver is assumed to have a basic level of understanding regarding the backing countermeasures, but very limited exposure to or experience with the countermeasures. Unless otherwise noted, testing will be conducted on a straight, level, dry surface under daytime conditions. Test conditions should not bias drivers (e.g., lead to overreliance on system, unduly raise expectancy, etc.), but capture and elicit representative driver behaviors and system performance. Follow the procedures outlined below.



1. Stage the scenario to conform to the following characteristics:
    a. Park the vehicle in a perpendicular parking space (or comparable parking situation) requiring the driver to execute a backing maneuver to exit the space, and where the line of sight (to either side) is obstructed by parked vehicles.
    b. The scenario should be staged to have drivers enter the parked vehicle. It is recommended that drivers approach the vehicle from the front, if feasible.
    c. The study setting should build a reasonable expectation for pedestrian and vehicular traffic (e.g., active parking lot, presence of occasional pedestrians, etc).
2. Provide an overview of the vehicle features and familiarize drivers with the backing countermeasures. Drivers should be made aware of the backing countermeasures in advance of this test, but should not be forced or compelled to use the features (i.e., drivers should not be specifically instructed to rely on the aids or countermeasures). Limited practice with the features is recommended in order to eliminate or reduce novelty effects which may cause drivers to initially over-rely on the aids. In order to avoid unduly biasing drivers, the familiarization process should not exclusively focus on the backing countermeasures systems, but encompass a broader set or range of in-vehicle devices, features, and functions.
3. Once the familiarization process is complete, ask the driver to back out of the parking space. Drivers should be instructed to back in the direction of the incurring test object; however, do not direct or otherwise instruct the driver to use or rely on the available backing countermeasures. Drivers should be made aware of the backing countermeasures in advance of this test, but should not be forced or compelled to use the features (i.e., drivers should not be specifically instructed to rely on the aids or countermeasures).

a. As the driver initiates backing (i.e., vehicle is placed into reverse and begins to move), introduce a surrogate test object (resembling characteristics of a standing 5 year old child) into the vehicle's backing path, so that it encroaches into the vehicle's line of travel from the driver's side. The method of introduction should be unobtrusive, and should not attract the driver's attention, but should allow him/her to remain unaware of a potential conflict. The test object should move at a rate of 2 mph (3.2 km/h) to be consistent with pedestrian walking speeds (Mazzae, 2006), and traverse a perpendicular path located approximately 1.5 meters (5 feet) behind the vehicle's initial starting position. The test object should remain at the starting position before it starts to incur, but should not be directly visible to the driver.

4. Record system responses and driver behaviors in accordance with the metrics outlined in the table below to include driver eye-glance measures and responses to system alerts/warnings and control interventions. Construct a time-line of events surrounding overall outcomes (e.g., hit or avoid test object) in order to develop an understanding of the causal mechanisms underlying these outcomes (e.g., driver avoided object as a result of glancing to the rear video and recognizing the presence of the target, and then braking the vehicle).
   - □ On-board camera systems should enable driver performance and interaction with the countermeasures to be captured and recorded. Desirable camera views include: driver face view, view of the foot controls (brake and accelerator pedals), over the shoulder view (or other wide angle view) allowing the driver's gross body movements to be measured (e.g., over the shoulder glances), view capturing the backing countermeasure responses, external view showing the area behind the vehicle, among others.
   - □ Audio recordings capturing system alerts and drivers commentary are also desirable
5. Debrief the driver immediately following the staged conflict event in order to gauge their understanding of and reliance on the backing countermeasure systems. Specific aspects to be captured include:

   (If Driver Detects or Responds to the Obstacle)
   - □ Why the driver stopped
   - □ A description of the events, including what they saw, were aware of, and did in response to the event
   - □ When the driver first noticed the obstacle
   - □ How the driver came to notice the obstacle
   - □ A description of the nature of the warning or countermeasure and their interpretation of the cues or signals (message being communicated)
   - □ An accounting of the perceived role the countermeasure played in detecting or responding to the obstacle

   (If Driver Fails to Detect or Respond to the Obstacle)
   - □ An accounting of whether they noticed anything unusual during the backing maneuver
     - □ Whether they noticed the in-path obstacle
     - □ Whether they noticed the countermeasure system's cues or signals and how they interpreted and responded to these signals and why

Notes:

- ☐ Use a ruse (a cover story disguising the true nature and purpose of the study) in order to direct the focus away from the backing countermeasures.
- ☐ Administer the conflict scenario as part of a surprise event trial embedded as part of the first backing episode.
- ☐ The scenario assumes the use of an in-vehicle experimenter who overviews the vehicle's features (including backing countermeasures), and instructs and accompanies the driver, and one who is trained in the administration of the test protocol.

Objective Performance Measures

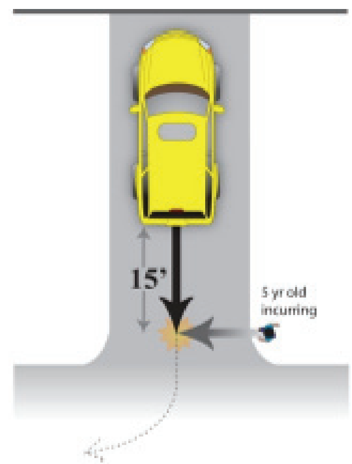
<table>
<tr><td>▪ Collision Outcome (Percent Avoided/Hit)</td><td>If Avoided:

▪ When Detected
▪ Reliance on System</td><td>If Hit:

▪ Reliance on System</td></tr>
<tr><td>▪ Search & Detection Performance</td><td colspan="2">▪ Detection (Yes/No)
▪ Method of Detection
▪ Search & Search Time
o Glance Locations (Number and Duration)</td></tr>
<tr><td>▪ Driver Response</td><td colspan="2">▪ Driver Response to Alert/Warning/Intervention</td></tr>
<tr><td>▪ Other Performance Metrics</td><td colspan="2">▪ Unintended Consequences (countermeasure specific)</td></tr>
</table>

Procedure **Test 13: Intermediate, Incurring Pedestrian (Scenario 4)**

This test assesses the performance of the driver as a means to contribute to the evaluation of the extent to which the presence of the backing countermeasures lead to successful avoidance outcomes under encroachment situations where a moving hazard enters into the path of a backing vehicle. This particular test is intended to simulate a common backing crash scenario wherein a small child darts into the path of a vehicle backing out of a driveway; the child encroaches from the passenger's side at an intermediate distance (4.5 meters, or 15 feet) to the vehicle (Scenario 4, Pedestrian #4). Testing will be performed with a group of 8 drivers (ages 30 to 65 years, balanced by gender, recruited from the general driving public); each driver is assumed to have a basic level of understanding regarding the backing countermeasures, but very limited exposure to or experience with the countermeasures. Unless otherwise noted, testing will be conducted on a straight, level, dry surface under daytime conditions. Test conditions should not bias drivers (e.g., lead to overreliance on system, unduly raise expectancy, etc.), but capture and elicit representative driver behaviors and system performance. Follow the procedures outlined below.



1. Stage the scenario to conform to the following characteristics:
    a. Park the vehicle in a driveway (or comparable situation) requiring the driver to execute a backing maneuver (traversing at least a 20 ft path). It would also be desirable to use a naturalistic setting with other vehicle's and elements in the surrounding environment.
    b. The scenario should be staged to have drivers enter the parked vehicle. It is recommended that drivers approach the vehicle from the front, if feasible.
    c. The study setting should build or allow for a reasonable expectation for pedestrian and vehicular traffic.
2. Provide an overview of the vehicle features and familiarize drivers with the backing countermeasures. Drivers should be made aware of the backing countermeasures in advance of this test, but should not be forced or compelled to use the features (i.e., drivers should not be specifically instructed to rely on the aids or countermeasures). Limited practice with the features is recommended in order to eliminate or reduce novelty effects which may cause drivers to initially over-rely on the aids. In order to avoid unduly biasing drivers, the familiarization process should not exclusively focus on the backing countermeasures systems, but encompass a broader set or range of in-vehicle devices, features, and functions.
3. Once the familiarization process is complete, ask the driver to back out of the driveway. Drivers should be instructed to back in the direction opposite to that from which the test object is incurring; however, do not direct or otherwise instruct the driver to use or rely on the available backing countermeasures. Drivers should be made aware of the backing countermeasures in advance of this test, but should not be forced or compelled to use the features (i.e., drivers should not be specifically instructed to rely on the aids or countermeasures).

a. As the driver initiates backing (i.e., vehicle is placed into reverse and begins to move), introduce a surrogate test object without attracting driver awareness (resembling characteristics of a standing 5 year old child) into the vehicle's backing path, so that it encroaches into the vehicle's line of travel from the passenger side. The test object should move along a straight path at a rate of 2 mph (3.2 km/h) to be consistent with pedestrian walking speeds (Mazzae, 2006), and traverse a perpendicular path located approximately 4.5 meters (15 feet) behind the vehicle's initial starting position.

4. Record system responses and driver behaviors in accordance with the metrics outlined in the table below to include driver eye-glance measures and responses to system alerts/warnings and control interventions. Construct a time-line of events surrounding overall outcomes (e.g., hit or avoid test object) in order to develop an understanding of the causal mechanisms underlying these outcomes (e.g., driver avoided object as a result of glancing to the rear video and recognizing the presence of the target, and then braking the vehicle).
   - □ On-board camera systems should enable driver performance and interaction with the countermeasures to be captured and recorded. Desirable camera views include: driver face view, view of the foot controls (brake and accelerator pedals), over the shoulder view (or other wide angle view) allowing the driver's gross body movements to be measured (e.g., over the shoulder glances), view capturing the backing countermeasure responses, external view showing the area behind the vehicle, among others.
   - □ Audio recordings capturing system alerts and drivers commentary are also desirable
5. Debrief the driver immediately following the staged conflict event in order to gauge their understanding of and reliance on the backing countermeasure systems. Specific aspects to be captured include:

   (If Driver Detects or Responds to the Obstacle)
   - □ Why the driver stopped
   - □ A description of the events, including what they saw were aware of, and did in response to the event
   - □ When the driver first noticed the obstacle
   - □ How the driver came to notice the obstacle
   - □ A description of the nature of the warning or countermeasure and their interpretation of the cues or signals (message being communicated)
   - □ An accounting of the perceived role the countermeasure played in detecting or responding to the obstacle

   (If Driver Fails to Detect or Respond to the Obstacle)
   - □ An accounting of whether they noticed anything unusual during the backing maneuver
     - □ Whether they noticed the in-path obstacle
     - □ Whether they noticed the countermeasure system's cues or signals and how they interpreted and responded to these signals and why

Notes:

- ☐ Use a ruse (a cover story disguising the true nature and purpose of the study) in order to direct the focus away from the backing countermeasures.
- ☐ Administer the conflict scenario as part of a surprise event trial embedded as part of the first backing episode.
- ☐ The scenario assumes the use of an in-vehicle experimenter who overviews the vehicle's features (including backing countermeasures), and instructs and accompanies the driver, and one who is trained in the administration of the test protocols.

<u>Objective Performance Measures</u>

<table>
<tr><td>▪ Collision Outcome (Percent Avoided/Hit)</td><td>If Avoided:

▪ When Detected
▪ Reliance on System</td><td>If Hit:

▪ Reliance on System</td></tr>
<tr><td>▪ Search & Detection Performance</td><td colspan="2">▪ Detection (Yes/No)
▪ Method of Detection
▪ Search & Search Time
    ○ Glance Locations (Number and Duration)</td></tr>
<tr><td>▪ Driver Response</td><td colspan="2">▪ Driver Response to Alert/Warning/Intervention</td></tr>
<tr><td>▪ Other Performance Metrics</td><td colspan="2">▪ Unintended Consequences (countermeasure specific)</td></tr>
</table>

DRIVER-IN-THE-LOOP, TEST OF CRASH AVOIDANCE

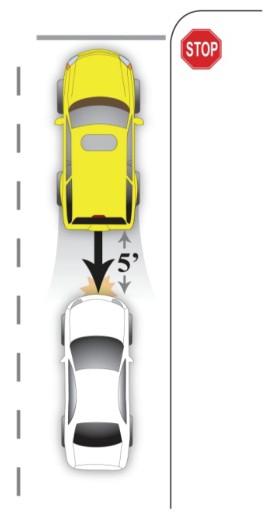
VEHICLE, FIXED OBJECT TESTS:

NEAR STATIC VEHICLE, AND INTERMEDIATE STATIC POLE

(TESTS 14 and 15)

Procedure **Test 14: Near Static Vehicle (Scenario 7)**

This test assesses the performance of the driver as a means to contribute to the evaluation of the extent to which the presence of the backing countermeasures lead to successful avoidance outcomes under situations where a static (stationary) rear hazard (a vehicle) is located in close proximity to the vehicle. This particular test is intended to simulate a common backing crash scenario wherein a driver backs the vehicle in the presence of an unexpected vehicle which is stationary directly 1.5 meters (5 feet) behind the vehicle (Scenario 7, Vehicle 1). Testing will be performed with a group of 8 drivers (ages 30 to 65 years, balanced by gender, recruited from the general driving public); each driver is assumed to have a basic level of understanding regarding the backing countermeasures, but very limited exposure to or experience with the countermeasures. Unless otherwise noted, testing will be conducted on a straight, level, dry surface under daytime conditions. Test conditions should not bias drivers (e.g., lead to overreliance on system, unduly raise expectancy, etc.), but capture and elicit representative driver behaviors and system performance. Follow the procedures outlined below.



1. Stage the scenario to conform to the following characteristics:
   a. The site should allow drivers to execute a low speed backing maneuver, allowing drivers to back at least 20 ft. A ruse will likely be necessary in order to occasion the necessary backing maneuver.
   b. The study setting should build or allow for a reasonable expectation for vehicular and/or pedestrian traffic (e.g., active parking lot, roadway, etc).
2. Provide an overview of the vehicle features and familiarize drivers with the backing countermeasures. Drivers should be made aware of the backing countermeasures in advance of this test, but should not be forced or compelled to use the features (i.e., drivers should not be specifically instructed to rely on the aids or countermeasures). Limited practice with the features is recommended in order to eliminate or reduce novelty effects which may cause drivers to initially over-rely on the aids. In order to avoid unduly biasing drivers, the familiarization process should not exclusively focus on the backing countermeasures systems, but encompass a broader set or range of in-vehicle devices, features, and functions.
3. Once the familiarization process is complete, ask the driver to back the vehicle (or provide a ruse to occasion a backing maneuver); do not direct or otherwise instruct the driver to use or rely on the available backing countermeasures. Drivers should be made aware of the backing countermeasures in advance of this test, but should not be forced or compelled to use the features (i.e., drivers should not be specifically instructed to rely on the aids or countermeasures).
   a. In advance of the actual backing maneuver, place a surrogate test object (ISO pole consisting of a 1 meter tall, 75mm diameter PVC pole) directly behind the vehicle approximately 1.5

meters (5 feet) from the centerline of rear bumper in the vehicle's backing path; the test object should be placed inconspicuously and without knowledge of the driver (note: pop-up target techniques may also be used to accomplish placement of the test object). The ISO pole is used to represent a vehicle (based on the notion that if a system could respond to a small vehicle, such as a bicycle which could have a very narrow profile, it could also respond to a larger vehicle in a similar position). The test object will likely be visible to the driver through direct over-the-shoulder glances or via the rear view mirror system.

4. Record system responses and driver behaviors in accordance with the metrics outlined in the table below to include driver eye-glance measures and responses to system alerts/warnings and control interventions. Construct a time-line of events surrounding overall outcomes (e.g., hit or avoid test object) in order to develop an understanding of the causal mechanisms underlying these outcomes (e.g., driver avoided object as a result of glancing to the rear video and recognizing the presence of the target, and then braking the vehicle).
    - □ On-board camera systems should enable driver performance and interaction with the countermeasures to be captured and recorded. Desirable camera views include: driver face view, view of the foot controls (brake and accelerator pedals), over the shoulder view (or other wide angle view) allowing the driver's gross body movements to be measured (e.g., over the shoulder glances), view capturing the backing countermeasure responses, external view showing the area behind the vehicle, among others.
    - □ Audio recordings capturing system alerts and drivers commentary are also desirable
5. Debrief the driver immediately following the staged conflict event in order to gauge their understanding of and reliance on the backing countermeasure systems. Specific aspects to be captured include:

    (If Driver Detects or Responds to the Obstacle)
    - □ Why the driver stopped
    - □ A description of the events, including what they saw, were aware of, and did in response to the event
    - □ When the driver first noticed the obstacle
    - □ How the driver came to notice the obstacle
    - □ A description of the nature of the warning or countermeasure and their interpretation of the cues or signals (message being communicated)
    - □ An accounting of the perceived role the countermeasure played in detecting or responding to the obstacle

    (If Driver Fails to Detect or Respond to the Obstacle)
    - □ An accounting of whether they noticed anything unusual during the backing maneuver
        - □ Whether they noticed the in-path obstacle
        - □ Whether they noticed the countermeasure system's cues or signals and how they interpreted and responded to these signals and why

Notes:

- □ This scenario is functionally similar to Test 11 (Pedestrian Scenario 3) in the sense that the obstacle is stationary and present before the vehicle maneuver is initiated. Differences include the nature of the threat, its distance from the vehicle, and its visibility.
- □ A pole, rather than a vehicle, is used to simulate a lapse in driver attention. In backing crashes with fixed objects, such as this one, there is believed to be an attentional lapse that contributes to the conflict – and since the object is visible to the driver, this can be difficult to set up in a test scenario. The use of a *small* object as a test object helps facilitate the possibility that the driver will be unaware of its presence during the test (perhaps emulating the moment of lapsed attention in a real conflict).
- □ Use a ruse (a cover story disguising the true nature and purpose of the study) in order to direct the focus away from the backing countermeasures.
- □ Administer the conflict scenario as part of a surprise event trial embedded as part of the first backing episode.
- □ The scenario assumes the use of an in-vehicle experimenter who overviews the vehicle's features (including backing countermeasures), and instructs and accompanies the driver.

<u>Objective Performance Measures</u>

▪ Collision Outcome (Percent Avoided/Hit)	If Avoided: ▪ When Detected ▪ Reliance on System	If Hit: ▪ Reliance on System
▪ Search & Detection Performance	▪ Detection (Yes/No) ▪ Method of Detection ▪ Search & Search Time o Glance Locations (Number and Duration)	
▪ Driver Response	▪ Driver Response to Alert/Warning/Intervention	
▪ Other Performance Metrics	▪ Unintended Consequences (countermeasure specific)	

Procedure **Test 15: Intermediate Static Pole (Scenario 10)**

This test assesses the performance of the driver as a means to contribute to the evaluation of the extent to which the presence of the backing countermeasures lead to successful avoidance outcomes under situations where the vehicles strikes a fixed object within its backing path. This particular test is intended to simulate a common backing crash scenario wherein the driver strikes a pole, mailbox, or other fixed object in the path of a vehicle backing out of a driveway or garage; the pole is located 4.5 meters (or 15 feet) from the vehicle (Scenario 10, Fixed Object). Testing will be performed with a group of 8 drivers (ages 30 to 65 years, balanced by gender, recruited from the general driving public); each driver is assumed to have a basic level of understanding regarding the backing countermeasures, but very limited exposure to or experience with the countermeasures. Unless otherwise noted, testing will be conducted on a straight, level, dry surface under daytime conditions. Test conditions should not bias drivers (e.g., lead to overreliance on system, unduly raise expectancy, etc.), but capture and elicit representative driver behaviors and system performance. Follow the procedures outlined below.

1. Stage the scenario to conform to the following characteristics:
   a. The site should allow drivers to execute a low speed backing maneuver over a range of at least 4.5 meters (15 ft), and require drivers to follow a specific path (requiring a turning maneuver) during its execution in the presence of roadside obstacles.
   b. The study setting should build or allow for a reasonable expectation for vehicular and/or pedestrian traffic (e.g., active parking lot, roadway, etc), and the presence of roadside obstacles. Place multiple poles in the areas surrounding the vehicle (mailbox, light posts, basketball pole, etc). This is meant to provide a visually demanding environment requiring drivers to search before backing.
   c. Since the presence of the roadside obstacles should be clearly visible to drivers, the scenario should simulate a conflict situation resulting from errors in judging the distance to the rear object, or in accurately mapping the location of these objects relative to the vehicle (and/or a moment of inattention). This can be accomplished using pop-up or surprise targets.
2. Provide an overview of the vehicle features and familiarize drivers with the backing countermeasures. Drivers should be made aware of the backing countermeasures in advance of this test, but should not be forced or compelled to use the features (i.e., drivers should not be specifically instructed to rely on the aids or countermeasures). Limited practice with the features is recommended in order to eliminate or reduce novelty effects which may cause drivers to initially over-rely on the aids. In order to avoid unduly biasing drivers, the familiarization process should not exclusively focus on the backing countermeasures systems, but encompass a broader set or range of in-vehicle devices, features, and functions.
3. Once the familiarization process is completed, ask the driver to back the vehicle (or provide a ruse to occasion a backing maneuver); do not direct or otherwise instruct the driver to use or rely on the available backing countermeasures. Drivers should be made aware of the backing

countermeasures in advance of this test, but should not be forced or compelled to use the features (i.e., drivers should not be specifically instructed to rely on the aids or countermeasures).

a. Introduce the surrogate test object at some point before the driver turns into its path while backing out of the driveway. The test object (ISO pole consisting of a 1 meter tall, 75mm diameter PVC pole) should be located 4.5 meters (15 ft) from the vehicle's original starting position and placed on the passenger side. Pop-up target techniques may be used to accomplish placement of the test object.

4. Record system responses and driver behaviors in accordance with the metrics outlined in the table below to include driver eye-glance measures and responses to system alerts/warnings and control interventions. Construct a time-line of events surrounding overall outcomes (e.g., hit or avoid test object) in order to develop an understanding of the causal mechanisms underlying these outcomes (e.g., driver avoided object as a result of glancing to the rear video and recognizing the presence of the target, and then braking the vehicle).
   - ☐ On-board camera systems should enable driver performance and interaction with the countermeasures to be captured and recorded. Desirable camera views include: driver face view, view of the foot controls (brake and accelerator pedals), over the shoulder view (or other wide angle view) allowing the driver's gross body movements to be measured (e.g., over the shoulder glances), view capturing the backing countermeasure responses, external view showing the area behind the vehicle, among others.
   - ☐ Audio recordings capturing system alerts and drivers commentary are also desirable
5. Debrief the driver immediately following the staged conflict event in order to gauge their understanding of and reliance on the backing countermeasure systems. Specific aspects to be captured include:

   (If Driver Detects or Responds to the Obstacle)
   - ☐ Why the driver stopped
   - ☐ A description of the events, including what they saw, were aware of, and did in response to the event
   - ☐ When the driver first noticed the obstacle
   - ☐ How the driver came to notice the obstacle
   - ☐ A description of the nature of the warning or countermeasure and their interpretation of the cues or signals (message being communicated)
   - ☐ An accounting of the perceived role the countermeasure played in detecting or responding to the obstacle

   (If Driver Fails to Detect or Respond to the Obstacle)
   - ☐ An accounting of whether they noticed anything unusual during the backing maneuver
     - ☐ Whether they noticed the in-path obstacle
     - ☐ Whether they noticed the countermeasure system's cues or signals and how they interpreted and responded to these signals and why

Notes:

- ☐ Use the pop-up technique (or similar means of having a test object suddenly appear) to simulate a lapse in driver attention.
- ☐ Use a ruse (a cover story disguising the true nature and purpose of the study) in order to direct the focus away from the backing countermeasures.
- ☐ Administer the conflict scenario as part of a surprise event trial embedded as part of the first backing episode.
- ☐ The scenario assumes the use of an in-vehicle experimenter who overviews the vehicle's features (including backing countermeasures), and instructs and accompanies the driver, and one trained in the administration of the test protocol.

<u>Objective Performance Measures</u>

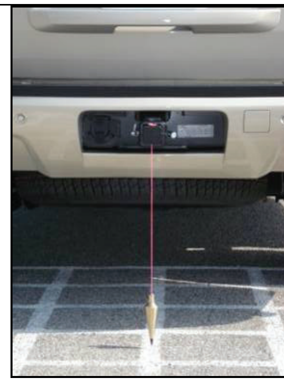
▪ Collision Outcome (Percent Avoided/Hit)	If Avoided: ▪ When Detected ▪ Reliance on System	If Hit: ▪ Reliance on System
▪ Search & Detection Performance	▪ Detection (Yes/No) ▪ Method of Detection ▪ Search & Search Time ○ Glance Locations (Number and Duration)	
▪ Driver Response	▪ Driver Response to Alert/Warning/Intervention	
▪ Other Performance Metrics	▪ Unintended Consequences (countermeasure specific)	

Vehicle Alignement Protocol

This protocol details the procedure for aligning the vehicle so that it is square with the test grid prior to data collection. This is accomplished through the use of two plum bobs, one hanging at the center point of the front and rear of the vehicle (this may also be accomplished using a laser pointer device in place of the plum bobs).

Align the vehicle within the grid following the steps outlined below:

1. Using an observer as an outside spotter, position the vehicle at the approximate starting point (row)
    a. Vehicle should be centered over the center line of the grid
        i. Center line is middle line within grid (same distance from each side)
    b. Position the rear of the vehicle along the desired row
        i. Plum bob will also be used to align rear of vehicle with starting point of test
2. Attach plum bobs to front and rear of vehicle (both should hang within ¼ inch of ground surface)
    a. Attach plum bob to hanging line from hitch-mounted bracket
    b. Attach plum bob to hanging line from fabricated bracket attached to front license plate
3. Verify that plum bobs at front and rear come to rest centered over the grid center line. In other words, the point of each plum bob should come to rest directly over the center point of the grid center line (refer to the pictures below).
    a. If necessary, re-position vehicle until both plum bobs are centered over center line (wait until plum bobs come to rest before verifying position)
4. Confirm that rear bumper is at desired starting point for testing procedures. Rear mounted plum bob should be centered within the line parallel with the vehicle’s bumper that represents the starting point for the test procedure.
    a. Verify that the vehicle is still aligned with grid according to step #3 following alignment with test starting point.
5. The vehicle is square to the test grid when both the front and rear plum bobs are equidistant from the grid’s centerline (refer to pictures below).

Alignment of Vehicle Rear	
	

Alignment of Vehicle Front	
	

Test Objects

Test Objects used in Grid tests and Camera Field of View evaluations are depicted in the figure below (from Left to right: Gen II 5 year old, Gen II 2 year old, Cardboard Cylinder, Gen II sitting child, PVC Pole, Gen 1 Prone 5 year old), and specifications for all test objects are detailed in the table below (additional details can also be found in Appendix D).

For tests requiring objects to incur into the vehicle's path (dynamic test objects), mechanisms were developed and constructed to achieve this function; one mechanism to support the Grid Tests, and another for use in Driver-in-the-Loop tests. Both allowed object movement speeds to be varied, as specified in the objective test procedures, without altering the radar cross section of the test objects themselves.

	Height (floor to highest point)	**Width or Diameter** (shoulder to shoulder for mannequins, diameter for poles)
Generation II Mannequins		
5 year old girl (model FC6FM)	45 inches	12 inches
2 year old boy (Model Tyler Toddler)	33 inches	9.5 inches
Seated Child (model MN-038)	19.5 inches	10 inches
Generation 1 Mannequin		
5 year old	44 inches	11 inches
2 year old	33 inches	10 inches
Pole Objects		
Cardboard Cylinder	40 inches	12 inches
PVC pole	40 inches	3 inches

Notes:

- Generation I Mannequin, used for Driver-in-the-Loop and grid tests, were procured from the "Mannequin Store" (www.mannequinstore.com).
- Generation II mannequins, used exclusively for Grid tests, were acquired from "Mannequinland" (www.mannequinland.com).

APPENDIX B:

VARIABLE CODING AND DATA DICTIONARY FOR GRID AND DRIVER-IN-THE-LOOP TESTS

Advanced Crash Avoidance Technologies Program (ACAT)
Backing crash Countermeasures Project

GRID TEST VARIABLE CODING DATA DICTIONARY

Variable Name	Variable Description	Units
Valid_Trial	Indicates whether the given trial meets all requirements for a correctly-executed trial (use combination of below based on test requirements). Incurring Obstacle Tests: Test object appears to move smoothly through the field of view without excessive swaying (more than 1 square in each direction. Dynamic Vehicle Tests: The vehicle backs while remaining centered on grid. Full Lock Tests: The vehicle backs while remaining centered on path of circle. Static Obstacle Tests: The test object stays upright and does not blow over during trial. Incurring Obstacle Plus Dynamic Vehicle Tests: In addition to above separate requirements, the test object should be within the width of the rear tires when the vehicle strikes the object or comes to a stop through avoidance.	0 = no; 1 = yes;
Detection	All tests: For a valid detection there must be an auditory tone accompanied with a warning symbol (both must be present). If the tone occurs but the symbol is not directly over the obstacle it should still be counted as a detection	0 = no detection; 1 = detection;
Outcome	Dynamic Vehicle Tests: Indicates any contact between vehicle and test object as noted on experimenter notesheet and confirmed through video analysis.	0 = avoid; 1 = strike;
Sync_object_visible	Incurring Obstacle Tests: Point in time where any part of the test object is visible in the rear view camera image as seen by driver	Sync Value (10Hz)
Vehicle_location_Obj_Vis	Indicates vehicle location when object is first visible. Dynamic Vehicle Tests: If more than half the grid cell is visible then that cell number should be marked. If not,	Numerical indicator of Row (1,2….,89) OR

	the next grid cell should be recorded. [Resolution of approximately 12 inches] <u>Full Lock Tests:</u> Record closest painted marking along circle path. [Resolution of approximately 3 inches]	Numeric indicator of circle position (i.e., 25.25, 25.5.25.75…)
Warning_sync Brake_Pulse_Sync Auto_Brake_Sync	<u>All tests:</u> Point in time when LED's/Brake Pulse/Automatic Braking are first issued (when applicable)	Sync Value (10Hz)
LED_status	<u>Static Vehicle Tests:</u> Indicates level of Park Assist (5 is N/A) warning issued upon initial detection <u>Dynamic Vehicle Tests:</u> Indicates level of Park Assist warning or Backing Warning issued upon initial detection	1 = 1st LED; 2 = 1st 2 LED's; 3 = All 3 LED's; 4 = All 3 LED's flashing; 5 = 3rd LED only (backing warning)
Brake_Pulse_Status	<u>Dynamic Vehicle Tests:</u> Indicates if brake pulse was present during trial as noted on experimenter notesheet and confirmed through video analysis.	0 = no; 1 = yes;
Auto_Brake_Status	<u>Dynamic Vehicle Tests:</u> Indicates if Automatic Braking was present during trial as noted on experimenter notesheet and confirmed through video analysis.	0 = no; 1 = yes;
Warning_location BP_Vehicle_Location AB_Vehicle_Location	Indicates vehicle location on grid or circle when LED's/Brake Pulse/Automatic Braking are first issued. <u>Dynamic Vehicle Tests:</u> If more than half the grid cell is visible then that cell number should be marked. If not, the next grid cell should be recorded. [Resolution of approximately 12 inches] <u>Full Lock Tests:</u> Record closest painted marking along circle path. [Resolution of 3 inches]	Numerical indicator of Row (1,2….,89) OR Numeric indicator of circle position (i.e., 25.25, 25.5.25.75…)
Object_column_detection BP_Object_Location AB_Object_Location	Indicates location of incurring object when LED's/Brake Pulse/Automatic Braking are first issued. <u>Incurring Obstacle Tests:</u> If object is more than half way over a line in between cells mark as next cell. If it is not more than halfway over the line mark it is current cell. [Resolution of approximately 12 inches]	Alphanumeric Indicator of Column (A,B,C….,AA)

DRIVER-IN-THE-LOOP VARIABLE CODING DATA DICTIONARY

Variable Name	Variable Description	Units
Event_Begin	Beginning of event coincides with 3 seconds prior to driver shift into reverse	Sync Value (10Hz)
Event_End	End of event defined as one of the following (whichever applicable): 1) Point of Detection 2) Experimenter Intervention (interferes with or prevents any subsequent detection) 3) Driver pulls forward and does not detect obstacle 4) Driver gets out of vehicle to check behind	Sync Value (10Hz)
Event_Duration	Difference remaining after subtracting Event_Begin from Event_End and dividing by 10 to convert to seconds.	Seconds
Detection_Point	Point where participant is judged to detect obstacle. Detection is defined by any verbal comment or obvious visual or behavioral response to presence of obstacle (i.e., double take, braking response, etc)	. = no detection Sync Value (10Hz) for detection cases
Detection Method	Method of obstacle detection by participant. Countermeasure or means	0 =direct look or mirrors; 1 = Rear Vision display;

	via which detection was achieved.	
Outcome	Avoidance outcome. Any contact with obstacle is considered a strike.	0 = Avoid; 1 = Strike;
Highest Countermeasure Received	Indicates the highest countermeasure received during the event. Countermeasures are defined within a continuum representing the most intrusive or urgent level of intervention received by drivers (information, alert, warning, or active control assist). Rear Vision represents the lowest form of intrusion, Park Aid is next, followed by the Cautionary and Imminent Backing warning, with Automatic Braking offering the highest level of intrusion.	0 = Rear Vision Only; 1 = Park Assist 1st LED; 2 = Park Assist Final Stage; 3 = Cautionary Backing Warning; 4 = Imminent Backing Warning; 5 = Automatic Braking
Driver_Behavioral_Response (Search)	Quantifies the driver's response (or lack or a response) to system outputs (e.g., alerts, warnings, control intervention). Uses video of the driver's face to code search behavior.	0= no observable search behavior in response to countermeasure (no change in the normal course of backing) 1= search mirrors, or made direct looks 2= searched Rear Vision display 3= searched both mirrors and RV display
Driver_Behavioral_Response (Control Action)	Quantifies the driver's response (or lack or a response) to system outputs (e.g., alerts, warnings, control intervention). Uses video of the vehicle's controls (brake and	0= no observable behavior in response to countermeasure (no change in the normal course of backing) 1= stopped & remained stopped 2= stopped initially, then resumed

	accelerator pedals) and forward or rear view cameras.	3= never started backing 4= stopped, then put into drive and pulled forward
Countermeasure Activation States		
Park Assist (Park Aid) Operates at speeds less than 5mph	1st Stage. Single amber LED is illuminated accompanied by single auditory beep.	
	2nd Stage. Two amber LED's are illuminated.	
	3rd Stage. All LED's are illuminated (Two amber and one Red) – steady burn (no flashing).	
	Final Stage. All LED's flash accompanied by series of 5 audile beeps.	
Backing Warning Operates at speeds above 5mph, provides a cautionary and imminent warning.	Cautionary Backing Warning - single red flashing LED (right-most LED) and a single audible beep.	
	Imminent Backing Warning - single red flashing LED (right-most LED) and 5 rapid audible beeps with brake pulse (brief brake pedal application then release).	

Automatic Braking Active at any backing speed below 20mph	(Under 4mph) While braking: single red flashing LED (right-most LED), and 5 rapid beeps with full brake pedal application (vehicle braking to a stop). When stopped (and AB Holding brake), all LED Flash with steady beeping. When driver depresses brake, appropriate Park Aid state presented. (Over 4mph) While braking, single red flashing LED (right-most LED) with full brake pedal application. Other states same as above.	

APPENDIX C:

PARTICIPANT SURPRISE EVENT DEBRIEF

Advanced Crash Avoidance Technologies Program (ACAT)
Backing crash Countermeasures Project

SURPRISE EVENT DEBRIEF

Driver Notices/Detects Obstacle:

1) Why did you stop?

2) When did you first notice the obstacle? (before started to back, while backing, after hit, other)

3) Can you tell me what the obstacle is?

4) How did you come to notice the obstacle? (direct look, mirrors, rear camera display, heard impact, etc)

5) What role do you feel the aid played in your detecting the obstacle? (would have hit without, little or no help)

Driver FAILS to Notice/Detect Obstacle:

1) Did we hit something? Please Stop.

2) Did you notice that there was an obstacle behind us?

3) Are you OK? Would you like to get out of the car and look at the obstacle?

- I am very sorry but we deliberately staged this event with the *[object type]* behind the car. We placed the obstacle behind the car so that it would be very difficult to detect without the use of the aids.
- The reason I didn't tell you that this would happen ahead of time is that we wanted to get your natural reaction. An important part of the study is to examine whether these aids would not only be helpful in parking tasks, but whether they could also help drivers detect unexpected rear obstacles.
- This type of situation can help us to understand the need for more proactive types of aids that would alert drivers to the presence of an in-path obstacle, such as a backing warning system.
- I hope you will understand why I deliberately misled you. This type of surprise will not happen again.

Please initial one of the following:

_______I give my voluntary consent for the data collected to be used in the analysis for this research project.

_______I do not give my consent for the data collected to be used in the analysis for this research project.

APPENDIX D:

ANALYSIS OF SCI CASES USING DREAM METHODOLOGY

ADVANCED CRASH AVOIDANCE TECHNOLOGIES PROGRAM (ACAT)

BACKING CRASH COUNTERMEASURES PROJECT

1 ANALYSIS OF SCI CASES USING DREAM METHODOLOGY

1.1 Analysis of SCI Cases Using the DREAM Methodology

1.1.1 Introduction to the CREAM/DREAM Methodology

An adaptation of two related methodologies, one derived from the other, DREAM and CREAM, were used to understand and organize contributing factors and causes for the 35 pedestrian backover cases from SCI that are the subject of this report. The methodology called DREAM, an acronym for Driving Reliability and Error Analysis Methodology, was developed in Sweden and has been used on the FICA project (Factors Influencing the Causation of Accidents and Incidents). It was originally developed by Ljung (2002), and has most recently been updated as Version 3.0 by Warner, Aust, Sandin, Johansson, and Bjorklund (2008) (which is now available in English). It was developed to enable systematic classification and storage of accident causation information from in-depth investigations of driving conflicts and crashes. It provides a structured way of sorting the causes and contributing factors behind the crashes into a set of formally defined categories (Warner et al., 2008). This method was derived from an earlier method, called CREAM (for Cognitive Reliability and Error Analysis Methodology), developed by Hollnagel (1998).

In the research reported here, the analysis necessarily relied heavily on the original CREAM method, with the authors of this research making adaptations suitable to driving based on their understanding from verbal reports of what had been done in DREAM (as well as from the published work of Sandin and Ljung, 2007). An English translation of DREAM (Version 2.1) was not available to the GM-VTTI team – and so the work reported here was done without the advantage of DREAM 3.0 (subsequently made available at the end of October 2008). While the exact definitions of DREAM 2.1 and their updates in 3.0 may not have been precisely followed, at a general level (at the level of highest coding categories), the CREAM/DREAM method was followed as closely as possible, given what was available to the GM-VTTI team in the way of written material. It is for this reason that the method used here is identified as an adaptation of the CREAM/DREAM methodology.

In the CREAM/DREAM method, crashes are conceptualized as resulting from an unsuccessful interplay between the **driver**, the **vehicle-and-traffic-environment**, and the **organization** responsible for shaping the conditions under which the driving occurs. Its classification scheme is built upon this conceptualization, and comprised of observable effects immediately prior to the crash in the form of human actions and system events which it calls "Phenotypes". Contributing factors which may have brought about these observable effects are separately identified and are called "Genotypes". The methodology provides a method for linking genotypes (contributing causes) to phenotypes (observable effects immediately prior to crash) as well as for linking phenotype to phenotype. The notion is that a crash type is uniquely identifiable through its phenotype, using a metaphor from natural biological systems. In addition, application of this technique by Sandin and Ljung (2007) has demonstrated that different crash types often necessitate different countermeasure approaches (since they arise through a different network of contributing causes and effects).

Thus, the CREAM/DREAM analysis was applied to pedestrian backover crashes from SCI, to discover if it would yield new insights about contributing causes, offer insights with which to confirm or refine objective tests (particularly relative to where in the crash sequence countermeasures of different types can provide support or assistance).

1.1.2 Specific Methods Applied in This Research

In the work reported here, the research followed the following procedure:

- A matrix of SCI cases x "genotypes" ("contributing causes") was constructed using Microsoft Excel. Within the matrix, along the left side, the individual SCI cases were grouped into scenarios (based on the classification reported earlier in this report).
- Within each scenario, and using the team's adapted CREAM/DREAM analysis, individual SCI cases were coded and entered into the matrix.
- Within each scenario, an aggregation across the individual cases was conducted to obtain a "scenario-level" model for the scenario-level type of backover crash. To do this, frequencies of contributing causes were tabulated across cases within each scenario
- The backing crash countermeasure to be examined in this ACAT project was "applied" analytically in the context of the scenario-level model, to better understand its role in prevention or mitigation (when the countermeasure is available and used).
- Key attributes for selecting and developing objective tests were identified (in order to facilitate development of objective tests, and the protocols through which they would be administered to evaluate countermeasures.)

1.1.3 Results of Adapted CREAM/DREAM Analysis

1.1.3.1.1.1 <u>High-Level Results</u>

From the frequency count for each genotype, it was determined that the contributing factors and causes under the "human/driver" category of genotypes had the most impact in contributing to a backover crash.

The most common human factor was *insufficient knowledge/education regarding line of sight and blind spots* followed by *incomplete visual scan* and *faulty diagnosis.* It was unknown if the drivers were fully aware of their true blind zones. Therefore, it was hypothesized that those drivers may have had insufficient knowledge or the education necessary regarding the vehicles' line-of-sight limitations. This became relevant because the behavior of most drivers was subject to strong cognitive expectations and biases that the backing path was clear at the time they initiated backing. (This related to their beliefs about where children had been left, the tendency to believe that the state of the world would remain unchanged while they were entering the vehicle (i.e., the child in their care would stay where he/she had last been left or been seen), and/or the tendency to believe that if other adults were present in the vicinity, they would be able to and would intervene in the event of risks). Additionally, many drivers reported not completing a full visual scan of their surroundings for the entire backing sequences. Some reported only checking mirrors, only looking in one direction, or not continuing to check the backing path as they backed. In the most extreme case, one person stated he/she did not look at any point during the backing sequence. (Note that scanning patterns are influenced in part by expectations about whether the backing path is clear, and are subject to confirmation biases during scan; the notion being that if a driver expects nothing to be seen in the backing path, the visual scan will be cursory and incomplete, sampling only a few points, with the likely conclusion that nothing will be seen from the scan, thus confirming the original notion that the backing path is clear.) The most common environmental factor was *hidden information in environment*, followed by *children/pedestrian occupied area*. Most pedestrians were not seen prior to the backing crash and were hidden from the driver's field of view, a circumstance affirming the driver's expectations that the path was clear. In most of the cases where pedestrians frequented the backing area, the setting was either in a parking lot, play area, or on a sidewalk. Finally, the most common technology factor was the position of the headrests. For these cases, at least one of the headrests was typically reported as being in the maximum upright position; potentially further obstructing the driver's field of view. The most commonly reported factors across all genotypes are reported in Figure D- 1 below.

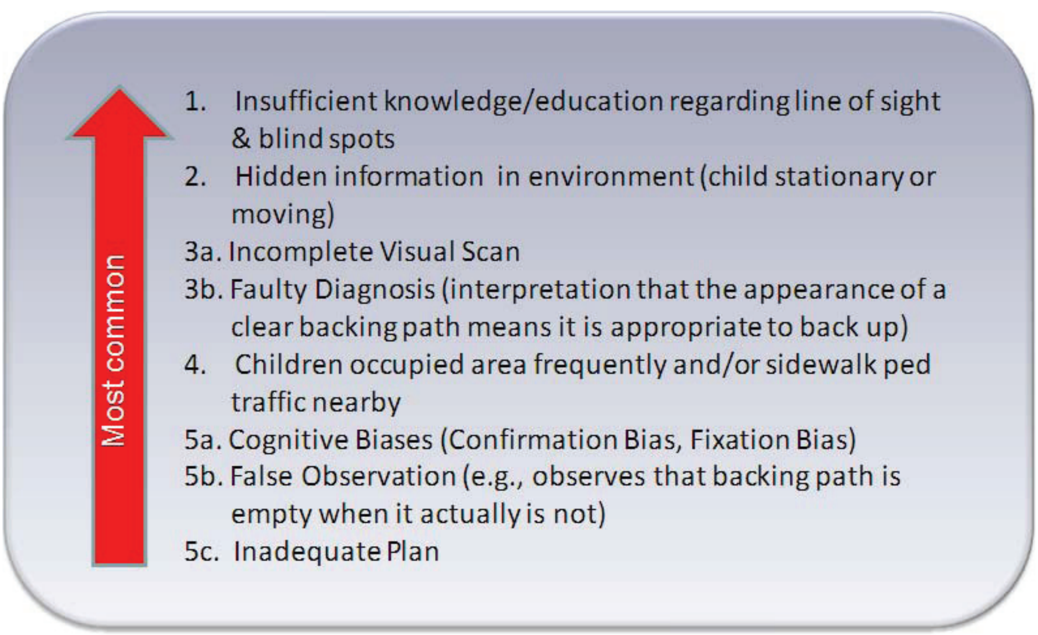


Figure D- 1. Top Five Most Common Factors

1.1.3.1.1.2 Scenario-Level Results

As mentioned above, each of the 35 SCI cases studied here were individually coded into the CREAM/DREAM matrix and then aggregated into a scenario-level model that could be depicted in a graphical way (somewhat like Sandin and Ljung, 2007). To illustrate what was done, and the insights that were revealed, the driveway scenarios (Pedestrian Scenarios #3 and #4) are used as an example. Once the coding of all individual cases within each scenario was completed, it became apparent from the tabulation of genotypes that the similarities across these two pedestrian scenarios were quite high for this small sample. Therefore, a single scenario-level model was developed to represent them, and is graphically illustrated in Figure D- 2.

The model in Figure D- 2 is intended to be “read” from left to right – with the genotypes starting at the left, and leading towards (or contributing to) observable effects identified by the phenotype boxes at the far right of the diagram. These two phenotypes are “Action of Wrong Type” (meaning that backing is initiated instead of the action of stopping-and-clearing-path) and “Action at Wrong Time” (meaning that braking is omitted and backing continues too long [for speed X distance]). These actions, in turn, are hypothesized to lead to the crash (and an instance of the scene diagram for one such crash appears in the upper right corner of the diagram to connote this). The factors and causes which are proposed to give rise to these phenotypes begin with (working from the bottom left and moving up the left side of the diagram) cognitive biases and errors by drivers, erroneous expectations by drivers (regarding the presence and locations of obstacles in the backing path in which they often believe that the backing path is clear and that any children remain where they were last left or last seen), and missing knowledge or an inadequate mental model of vehicle blind zones. These factors are hypothesized to lead the driver to perform an incomplete visual scan, and perhaps to allocate too little attention to areas of possible change in the backing path (e.g., areas where children could incur). These factors are suggested to be concurrently coupled in time with an unexpected change in the state of the world (beyond what the driver was last aware of prior to entering the vehicle) where a pedestrian enters or is present in the backing path without the driver’s knowledge *and* is hidden from the driver’s view; for example, either by the vehicle’s structure (e.g., beltline or pillars, or the position of interior or exterior elements such as headrests, stored cargo, or externally mounted bikes, tires, or other paraphernalia) or by elements of the environment such as closely parked cars, or by bushes, building structures, and the like. Together, these two sets of genotypes lead to another set of genotypes: a missed observation of the information that is hidden from view (the pedestrian in path), a false observation (that the backing path appears to be empty and free from obstacles), a faulty diagnosis (that the backing path is clear and ready for backing to be initiated or continue), and a false reaction/decision (namely, to initiate or continue backing). These genotypes, then, lead to the phenotypes described above, “Action of Wrong Type” (meaning that backing is initiated *instead of* the action of stopping-and-clearing-path) and “Action at Wrong Time” (meaning that braking is omitted and backing continues too long [for speed X distance]) – actions which, in turn, lead to the backover crash.

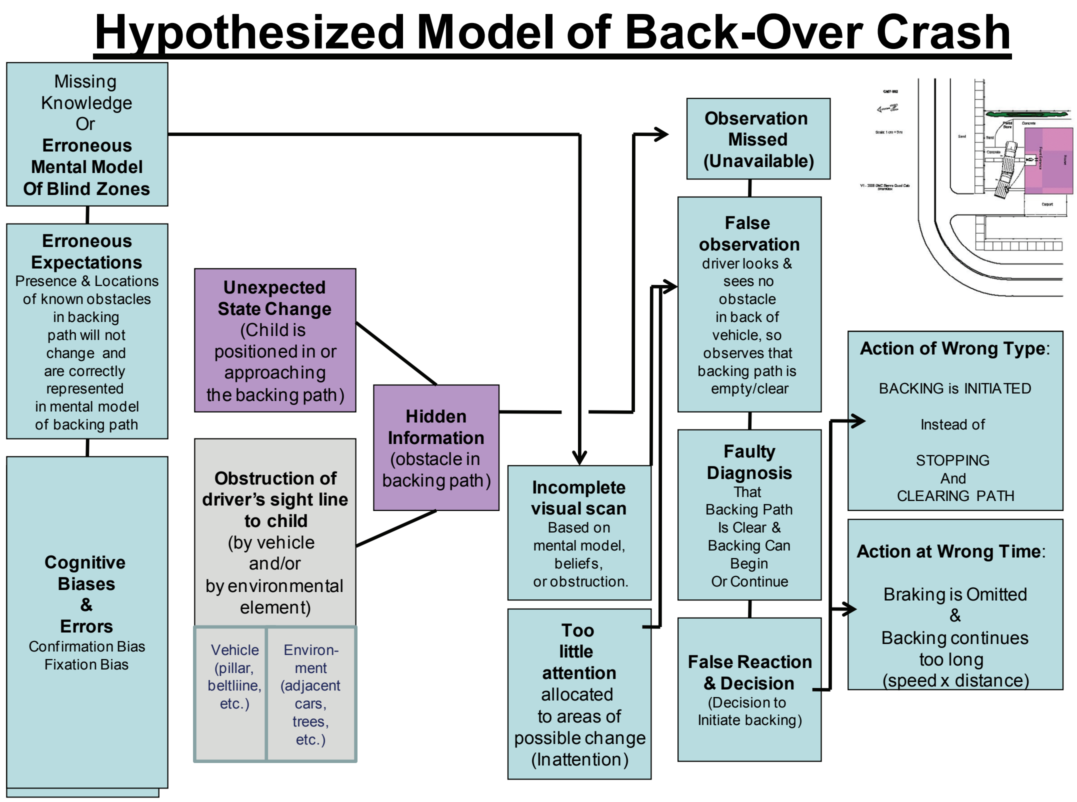


Figure D- 2. A Graphical Depiction of the Scenario-level Model from the Adapted CREAM/DREAM Analysis of Backing-out-of-driveway Backover Scenarios (Pedestrian Scenarios #3 and #4, Combined.

This scenario-level model suggests key points at which a backing crash countermeasure system could intervene, if it were to be effective in preventing or mitigating backover crashes of this type. Figure D- 3, below, illustrates these points with yellow boxes. These points in yellow boxes are those within the crash sequence where countermeasure assistance could potentially be of assistance. The prototype countermeasure system configured for evaluation in this ACAT project provides functions at each point identified by these yellow boxes (except the customer information element). Furthermore, these yellow boxes identify key items to be tested by a set of Objective Tests that are intended to produce data evaluating the effectiveness of a countermeasure in preventing and/or mitigating these types of crashes. Note that the item circled in red – obstructions of the backing path caused by environmental elements outside of the vehicle (bushes, buildings, adjacent vehicles) is the one genotype element that cannot be addressed by a vehicle-based countermeasure system.

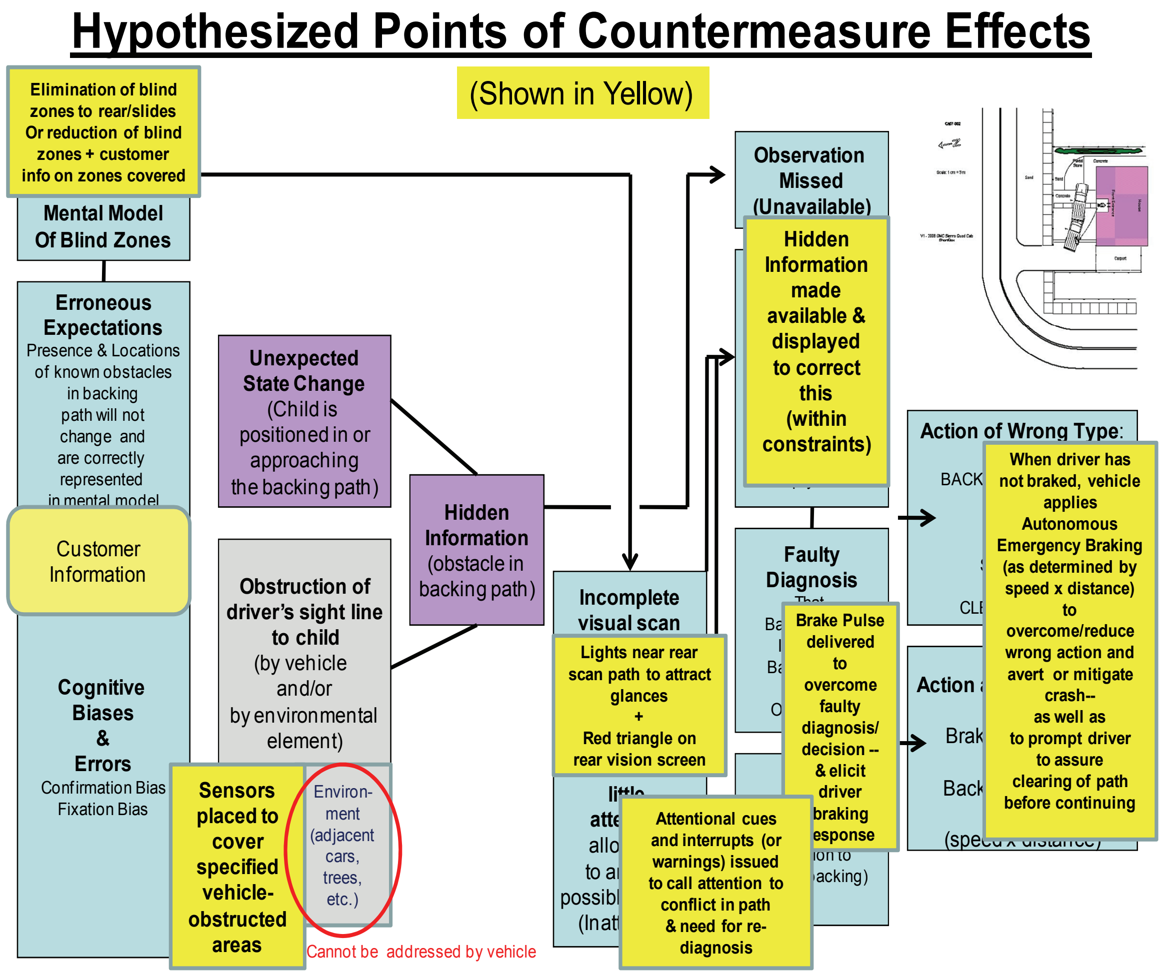


Figure D- 3. Illustration of how the CREAM/DREAM Model can be used to identify where backing crash countermeasure functions may be required (and where those functions may be effective in preventing or mitigating a backover of the type modeled here – those occurring during "backing-out-of-driveway" scenarios).

The integrated countermeasure set studied in this project acts on all of the identified error modes and key vehicle-related underlying causes in this model, *except* that of environmental sources of obscuration. Thus, the adapted CREAM/DREAM analysis added confirmation to the countermeasure system configured for evaluation in the project, as well as for the Objective Tests which include assessments of the field-of-response covered by the countermeasure system, its ability to perform on curved paths, and with both stationary and incurring obstacles across a variety of speeds and distances – as well as driver-in-the-loop scenarios to evaluate driver response to the system. Some of the issues that emerge from the CREAM/DREAM modeling done here, relative to the effectiveness of countermeasure systems, are these:

- Effectiveness of systems will depend somewhat on the proportion of sight-line obstructions of backing path that are due to the vehicle versus caused by environmental elements (or both). This small set of cases provides insufficient data on this issue.
- Effectiveness of systems may be modulated by the spatial distribution of actually occurring obstacles in backing paths, relative to the coverage zones of countermeasure systems. Here, too, the small sample of SCI cases does not yet provide sufficient data to evaluate the natural frequencies with which objects that could cause false alarms actually occur in backing paths (e.g., hoses, driveway cracks, etc.). This is important, since inappropriate false alarm rates may lead to unintended driver behaviors (e.g., ignoring warnings or turning off systems).
- Effectiveness of the system will depend on how well sensors (and accompanying processors) cover the vehicle-obstructed areas for obstacles of interest. (This suggests that a test of a system's Coverage Zone be included in the Objective Tests, which it has been.)
- Effectiveness of the system will depend on how driver and vehicle respond together as a system (system performance). (This suggests inclusion of Driver-in-the-loop Tests of full system function, which have been included in the Objective Test set.)
- Effectiveness of the system will depend upon how false alarm rate affects driver responses within the system (especially use of /turning off of system). (This suggests inclusion of a False Alarm Rate test in the Objective Tests, which has been addressed in the test set – as well as the need for broader real-world experience and treatment in the SIM.)
- Effectiveness of the system may depend upon any unintended consequences not yet anticipated.

To summarize, then, the CREAM/DREAM modeling effort suggested that objective tests should cover effectiveness issues that are related to **vehicle and driver.** These include:

- How well sensors/processors cover the vehicle-obstructed areas for obstacles of interest (Test of Coverage Zone for System Responses – Static and Dynamic –for Straight and Curved Paths)
- How driver and vehicle respond together as a system (system performance)(Driver-in-loop Tests of full system function)
- How false alarm rate affects driver responses within the system (False Alarm Rate Test)

Remaining issues (those beyond the ones related to vehicle and driver) can only be addressed in another way (e.g., from detailed crash context analysis). These include:

- Proportion of sight-line obstructions that are due in part or in whole to environmental elements (rather than to the vehicle)
- Spatial distribution of actually occurring obstacles in the real world, relative to coverage zones
- Especially in zones which are to be 'ignored' by vehicle sensors due to the high frequency presence of false-alarm triggers in those areas (this relates to the balance between false alarms and correct detection rate)
- Unintended consequences

Some additional insights which emerged from the CREAM/DREAM Modeling were related to environmental conditions. The scenario models suggest that those environmental conditions that are important to include in the objective tests are only those that may interact with (or modify) the effectiveness of the countermeasure. Specifically, those insights include:

- That the *environment* mainly exerts its effect by:
    - obstructing the driver's line of sight – OR
    - by altering/changing the vehicle sensors' coverage or function
- Therefore, the environmental attributes which must be selected for inclusion in a test will be specific to a backing system:
    - to the number,
    - types,
    - fields-of-view, and
    - object detection algorithms that it employs

1.1.4 Key Observations from the Adapted CREAM/DREAM Analysis

To summarize insights from this analysis, application of an adapted CREAM/DREAM method to the 35 SCI cases examined here was helpful in (1) gaining insights into the contributing factors and causes of backover crashes, (2) adding confirmation to which objective tests should be included in the test battery (described in Chapter 7), and (3) clarifying when environmental conditions are important for inclusion.

APPENDIX E:

HRL REPORT: CHILD MANNEQUIN DEVELOPMENT FOR REAR OBJECT SENSING

Advanced Crash Avoidance Technologies Program (ACAT)
Backing crash Countermeasures Project

2 Child Mannequin Development for Rear Object Sensing Systems:

3 Final Report

Submitted by:

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Executive Summary

Child mannequins have been developed as test objects for rear object sensing systems. The mannequins realistically represent actual children in terms of their physical dimensions, visible attributes, and 24 GHz ultra-wideband (UWB) radar cross sections.

Static measurements of two-year-old and five-year-old children in standing, seated, and supine postures were conducted at the HRL Laboratories outdoor short range radar testing facility. Commercially available two-year-old (size 2T) and five-year-old (size 5) child mannequins were identified and found to exhibit 24 GHz UWB radar returns that were comparable to, or slightly lower than, the measured children. The mannequins were then modified with various metallic objects to match their radar returns to that of the children.

HRL Laboratories has delivered a set of nine child mannequins to Virginia Tech Transportation Institute for rear object detection systems testing. The set includes multiple two-year-old and five-year old mannequins in each of the standing, seated, and supine postures.

This report documents the short range radar measurements performed at HRL Laboratories. It includes the challenges faced during the development process, as well as any known limitations of the mannequins. This report offers insight on how to effectively utilize child mannequins as test objects when evaluating the performance of automotive rear object detection systems.

1. Introduction

The objective of this project was to search for, acquire, test, and modify commercial off-the-shelf (COTS) mannequins that are reasonable representations of child pedestrians in terms of physical appearance and 24 GHz radar cross section. The mannequins are to emulate children in the evaluation of rear object detection (ROD) systems associated with automotive backing crash countermeasure systems.

In the future, ROD systems may consist of multiple sensing modalities, including vision and infrared cameras, radar, and LIDAR systems. An ideal child mannequin model would behave as a real child does under each of these sensor systems simultaneously. However, the current ROD prototype system includes only a vision camera and a 24 GHz ultra-wideband (UWB) short range radar sensor.

Considering the capabilities of the prototype ROD system and the need for ROD system performance evaluation, the scope of this project was limited to developing children mannequins whose visual characteristics and static radar returns matched that of typical two-year-old and five-year-old children. Characterization of these and other children mannequins by alternate sensing modalities (i.e. infrared, LIDAR) should be considered as a follow-on effort. The project outline is shown in Figure 1.

This report is organized as follows: In Section 2, the outdoor measurement setup used to characterize the 24 GHz radar return of children and child mannequins is described. In Section 3, the various static measurements performed on the two-year-old and five-year-old children at HRL's facility is discussed. Also explained is an approach to defining upper and lower signal-to-noise (SNR) ratio bounds on the measurement data. In Section 4, details of the COTS child mannequins that were identified as having a reasonable match to the radar returns of the measured two-year-old and five-year-old children are presented. The modification methods used to increase the radar return of the mannequins for certain postures are described, and the fitting results for all test cases are presented. In Section 5, two corner reflectors are characterized to establish a set of fixed and repeatable reference targets. In Section 6, limitations in using these mannequin models as test objects when validating the performance of ROD systems are highlighted. In Section 7, future measurement campaigns that could compliment this current mannequin development effort are proposed. Findings are concluded in Section 8.

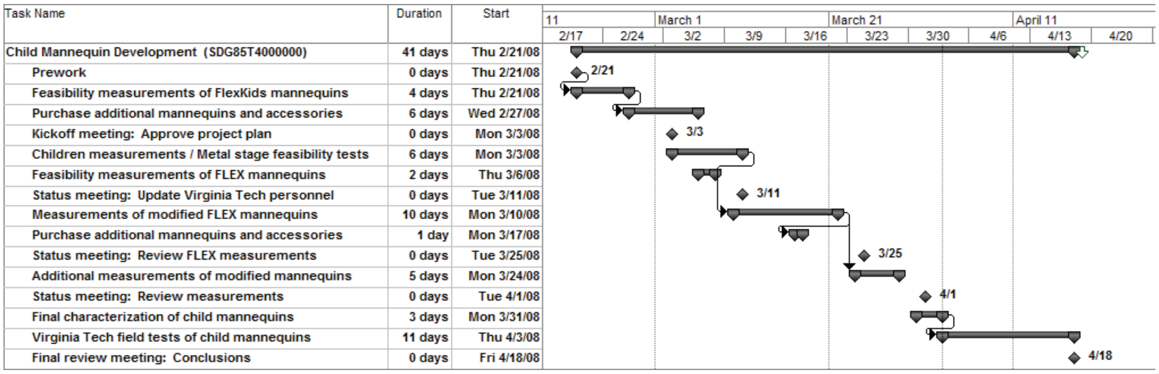

Figure 1: Gantt chart for the child mannequin development effort

2. Measurement Setup

A commercially available 24 GHz ultra-wideband (UWB) short range radar sensor was utilized for all radar measurements. Figure 2 is a schematic of the measurement grid used throughout the project. The grid was defined with duct tape on the pavement of an empty outdoor parking lot on HRL's campus. The distance from the ground to the bottom of the sensor was 18 in. The sensor was mounted such that the bottom surface was parallel to the ground, with an elevation tilt angle error of approximately 1.5 degrees and an azimuth tilt angle error of approximately 2 degrees. The surface of the pavement varied up to approximately 2 degrees over the entire measurement grid.

A series of reference measurements were performed with small and medium sized corner reflectors on several occasions, usually before or after conducting experiments with children or mannequins. These reference measurement results confirmed that data sets from different days and different measurement campaigns were repeatable and could be directly compared to each another.

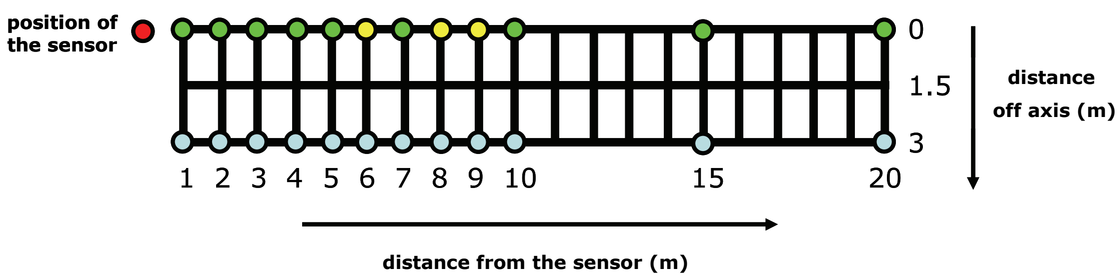

Figure 2 - Measurement grid for children and mannequin radar characterizations. Two-year-old and five-year-old children were measured at (or near) the green positions on-axis to the sensor. Child mannequin models were optimized to have comparable radar returns to the measured children at each of the green and yellow positions. Preliminary off-axis measurements on a limited subset of mannequins were also performed at each of the blue positions.

3. Measurements of Five-Year-Old and Two-Year-Old Children

The pictures of the two five-year-old children and two two-year-old children measured are depicted in Figure 3. From left to right, they are referred to as the following: 5C - 1, 5C - 2, 2C – 1, and 2C – 2. Table 1 lists the age and relevant physical parameters for each of the four children.

The children were asked to remain stationary for approximately 10 seconds at a time, in each of the following postures: standing, seated, and supine. Figure 4 shows examples of child 5C - 2 in each of these postures.

A data capture software program was used to log the performance of the radar sensor over an approximately 10 second time period, resulting in data sets of about 200 to 250 samples. In particular, the SNR values of the assigned tracks of the radar sensor were recorded over the measurement window and averaged. These mean SNR values, along with standard deviation (SD) and total number of samples in which the target was actually detected, were recorded and plotted. The five-year-old children were measured on-axis to the sensor, at each of the following separation distances: 1, 2, 3, 4, 5, 7, 10, and 15 meters. The measured radar mean SNR strength vs. distance from sensor for the five-year-old children in each of the standing, seated, and supine postures is shown in Figure 5. Child 5C – 1 is shown in blue, while child 5C – 2 is shown in yellow.

Figure 3 - Measured children, from left to right: five-year-old #1 (5C - 1), five-year-old #2 (5C - 2), two-year-old #1 (2C - 1), and two-year-old #2 (2C - 2).

Table 1 - Age and physical dimensions of measured five-year-olds and two-year-old children.

Child Number	5C - 1	5C - 2	2C - 1	2C - 2
Age	5 yr. & 6 mo.	5 yr. & 1 mo.	2 yr. & 6 mo.	1 yr. & 10 mo.
Standing Height	44 in	46 in	35 in	34 in
Seated Height	21 in	22.5 in	19.5 in	20 in
Shoulder Width	10 in	11 in	8 in	9 in

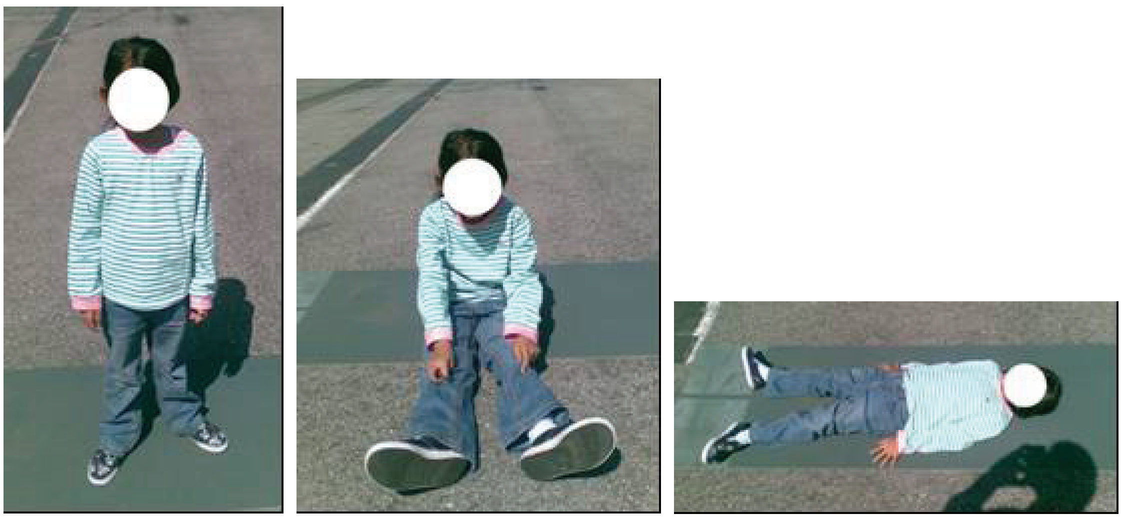

Figure 4 - Children were measured in three postures: standing, seated, and supine.

At any distance from the sensor, the upper bound (UBnd) is defined as the largest SNR value plus one standard deviation of either child 5C – 1 or child 5C – 2. Similarly, the lower bound (LBnd) is defined as the smallest SNR value minus one standard deviation of either child. These upper and lower bounds mark the range of SNR values the short range radar sensor will typically return for a typical five-year-old. In Section 4, the measured SNR values of the modified child mannequins are plotted and shown to fall within these same upper and lower bounds at all distances of interest.

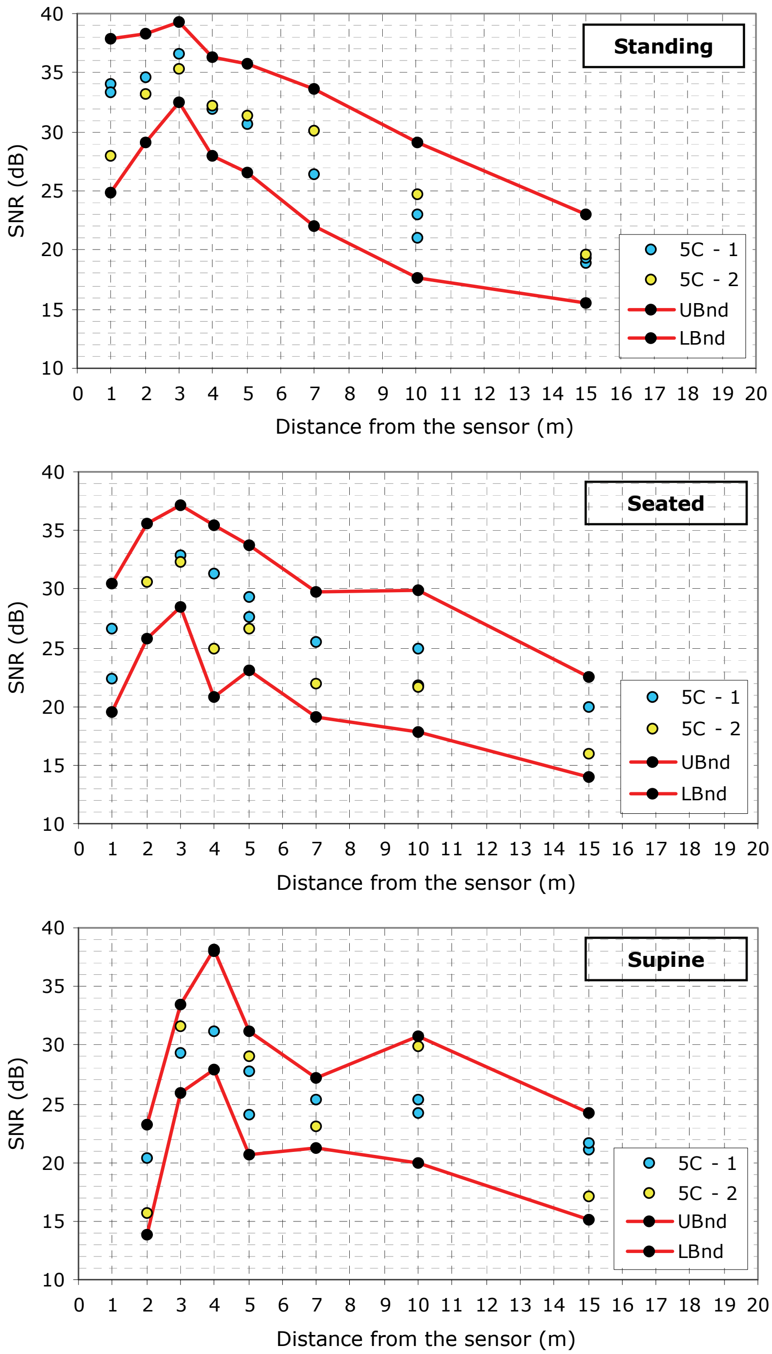

Figure 5 - Measured 24 GHz UWB radar SNR strength vs. distance from sensor for five-year-old children in standing, seated, and supine postures

The two-year-old children were also measured on-axis to the sensor, at various separation distances between 1 and 15 meters. The measured radar mean SNR strength vs. distance from sensor for the two-year-old children in each of the standing and seated postures is shown in Figure 6. Child 2C – 1 is shown in blue, while child 2C – 2 is shown in yellow. Reliable data for two-year-old children in a supine posture could not be captured. The upper and lower bounds of Figure 6 are defined analogously to those of Figure 5.

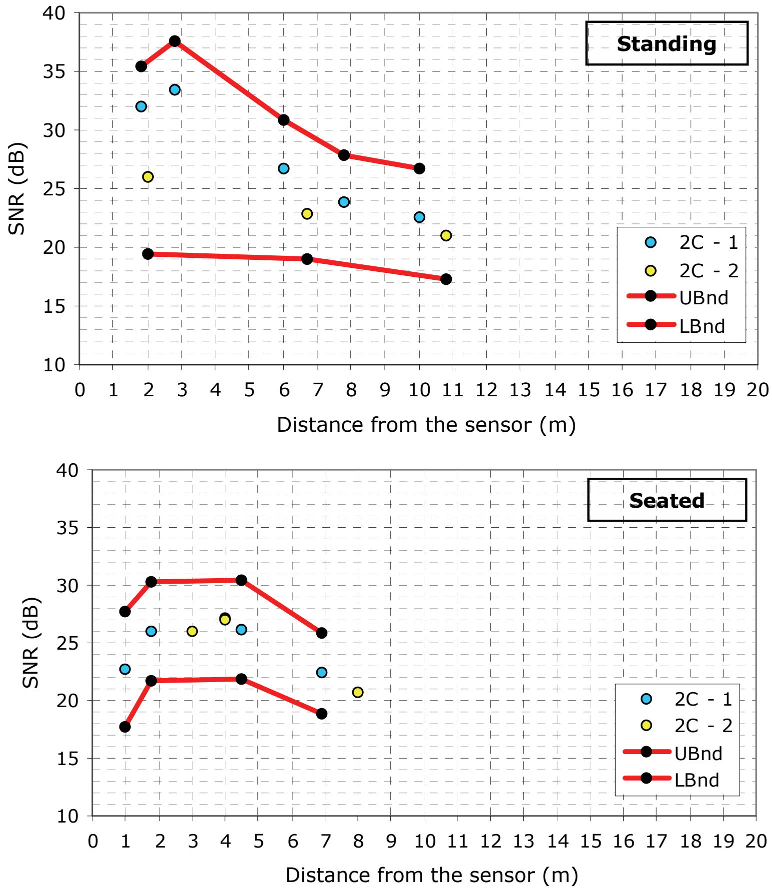

Figure 6 - Measured 24 GHz UWB radar SNR strength vs. distance from sensor for two-year-old children in standing and seated postures

4. Measurements of Child Mannequins

Flexible child mannequins were procured from the Mannequin Store (located at website: www.mannequinstore.com). Physical dimensions of the five-year-old mannequins (FLEX-5) and two-year-old mannequins (FLEX-2T) are listed in Table 2. These mannequins consist of a flexible metal wire frame covered with a dense layer of foam in the shape of a child body. A thin layer of flesh colored cloth material covers the entire outer surface of the mannequin. The head is fixed into the base of the neck with a metal screw. The two arms have metal joints that slide into metal shoulder sockets of the torso.

Table 2 - Physical dimensions of five- (FLEX-5) and two-year-old (FLEX-2T) child mannequins

Mannequin Type	FLEX-5	FLEX-2T
Standing Height	44 in	33 in
Seated Height	22.5 in	22 in
Shoulder Width	11 in	10 in

The flexible FLEX-5 and FLEX-2T mannequins were manipulated into standing, seated, and supine postures, and placed at the following distances in front of the 24 GHz radar sensor: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, and 20 meters. If necessary, the mannequins were outfitted with sections of copper tape, aluminum foil, or both, so that the SNR value recorded by the radar sensor was within the measured upper and lower bounds of the measured children presented in Section 3. Photographs of the optimized FLEX-5 and FLEX-2T mannequins for the standing, seated, and supine postures are shown in Figures 7 through 11.

For the standing posture, the FLEX-5 and FLEX-2T mannequins did not require any modifications in order to match the SNR radar signal to fall within the bounds of the measured children. Note that a metal stand was used for mounting the standing mannequins upright. By itself, this stand registered as a target to the radar sensor. However, placing a segment of radar absorbing material on the pavement directly in front of the metal plate caused the plate to remain undetected by the sensor. Therefore, all standing mannequin measurements were performed with a section of absorber in front of the metal stand.

For the seated position, both the FLEX-5 and FLEX-2T mannequins required modifications with either copper tape, aluminum foil, or both, as shown in Figure 8 and Figure 11, respectively. Note that Figure 8 and Figure 11 include two photographs of the same modified seated mannequin, both with and without masking tape covering the copper tape segments. It was experimentally verified that one thin layer of masking tape over copper tape strips caused a negligible effect on the SNR value reported by the radar sensor, yet aided in the adhesion of the copper tape segments to the material surface of the mannequins. In addition, the tape matched the flesh color of the mannequins and resulted in a more accurate visible representation of a typical child. Therefore, the seated mannequins were delivered with masking tape on top of any copper tape segments.

For the supine posture, the FLEX-5 mannequins required significant additions of copper tape (FLEX-5-supine-A) or aluminum foil (FLEX-5-supine-B) to match the SNR values of the measured five-year-old children, as seen in Figure 9. Note that the FLEX-2T standing mannequins can also be used in a supine posture. However, no reliable measurement data was available for two-year-old children for validating the SNR values of these mannequins in the supine posture, so the accuracy of these mannequins as a valid model of a two-year-old child lying down is unknown.

For each mannequin posture and distance combination, the data capture software program logged the performance of the radar sensor over an approximately 10 second time period, resulting in data sets of about 200 to 250 samples. The SNR values of the assigned tracks of the radar sensor were recorded over the measurement window and averaged. These mean SNR values, along with the standard deviation (SD) and the total number of samples in which the target was detected, were recorded and plotted along the upper and lower bounds of the measured five-year-old and two-year-old children.

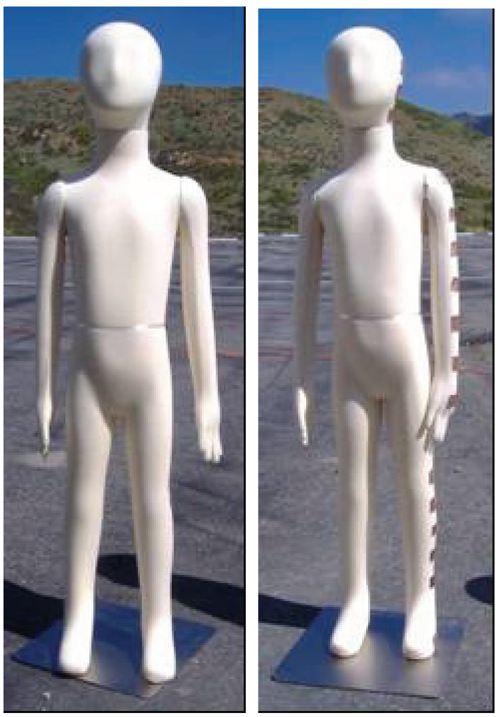

Figure 7 - Standing five-year-old child mannequins: FLEX-5-standing-A (left) and FLEX-5-standing-B. Note that the FLEX-5-standing-B also serves the role of a five-year-old in supine posture (i.e. FLEX-5-supine-A).

Figure 8 - Seated five-year-old child mannequins, from left to right: FLEX-5-seated-A, FLEX-5-seated-A with masking tape, FLEX-5-seated-B, and FLEX-5-seated-B with masking tape)

Figure 9 - Five-year-old child mannequins modified for the supine posture, from left to right: FLEX-5-supine-A (shown standing upright) and FLEX-5-supine-B. FLEX-5-supine-A also serves the role of a five-year-old in the standing posture (i.e. FLEX-5-standing-B).

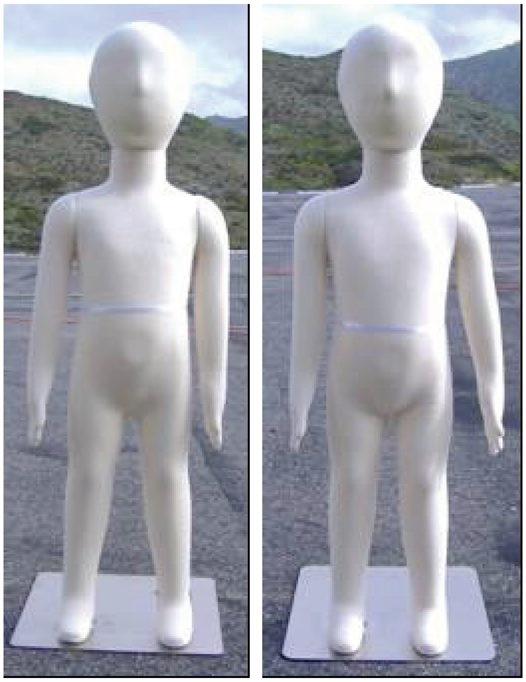

Figure 10 - Standing two-year-old child mannequins: FLEX-2T-standing-A (left) and FLEX-2T-standing-B.

Figure 11 - Seated two-year-old child mannequins, from left to right: FLEX-2T-seated-A, FLEX-2T-seated-A with masking tape, and FLEX-2T-seated-B. FLEX-2T-seated-B with masking tape is not shown

The measured radar mean SNR value vs. distance from sensor for the two five-year-old child mannequins in each of the standing, seated, and supine postures is shown in Figure 12. For any given posture, mannequin version A is shown in blue, while mannequin version B is shown in yellow. The black bars indicate the standard deviation of the SNR at any given sensor to mannequin separation distance.

For all postures, matching has been achieved with the FLEX-5 mannequins from about 3 to 15 meters. At separation distances less than 3 meters, the following FLEX-5 mannequins return SNR values near the lower boundary of the measured five-year-old children: FLEX-5-standing-B, FLEX-5-seated-A, FLEX-5-supine-A, and FLEX-5-supine-B. Therefore, these mannequins may be good candidates for consideration as approximate worst-case representations of five-year-old children at close distances, i.e. if the mannequin is detected, then a five-year-old child would be as well.

The measured mean SNR value vs. distance from sensor for the two two-year-old child mannequins in each of the standing, seated, and supine postures is shown in Figure 13. As in Figure 12, for any given posture mannequin version A is shown in blue, while mannequin version B is shown in yellow. The black bars indicate the standard deviation of the SNR at any given sensor to mannequin separation distance.

Between the lower and upper bounds within which two-year-children were measured, the SNR values of the FLEX-2T mannequins are a strong match to children for the standing posture. A reasonable match has been achieved for the seated posture as well.

As mentioned earlier, no reliable measurement data could be acquired for two-year-old children in the supine posture, so no upper and lower bounds could be defined. Nevertheless, the FLEX-2T standing mannequins were measured in a supine posture and plotted in Figure 13. Note that this is simply the raw measured data, and that no fitting procedure has been carried out to validate that this FLEX-2T mannequin is an accurate representation of a two-year-old in the supine position.

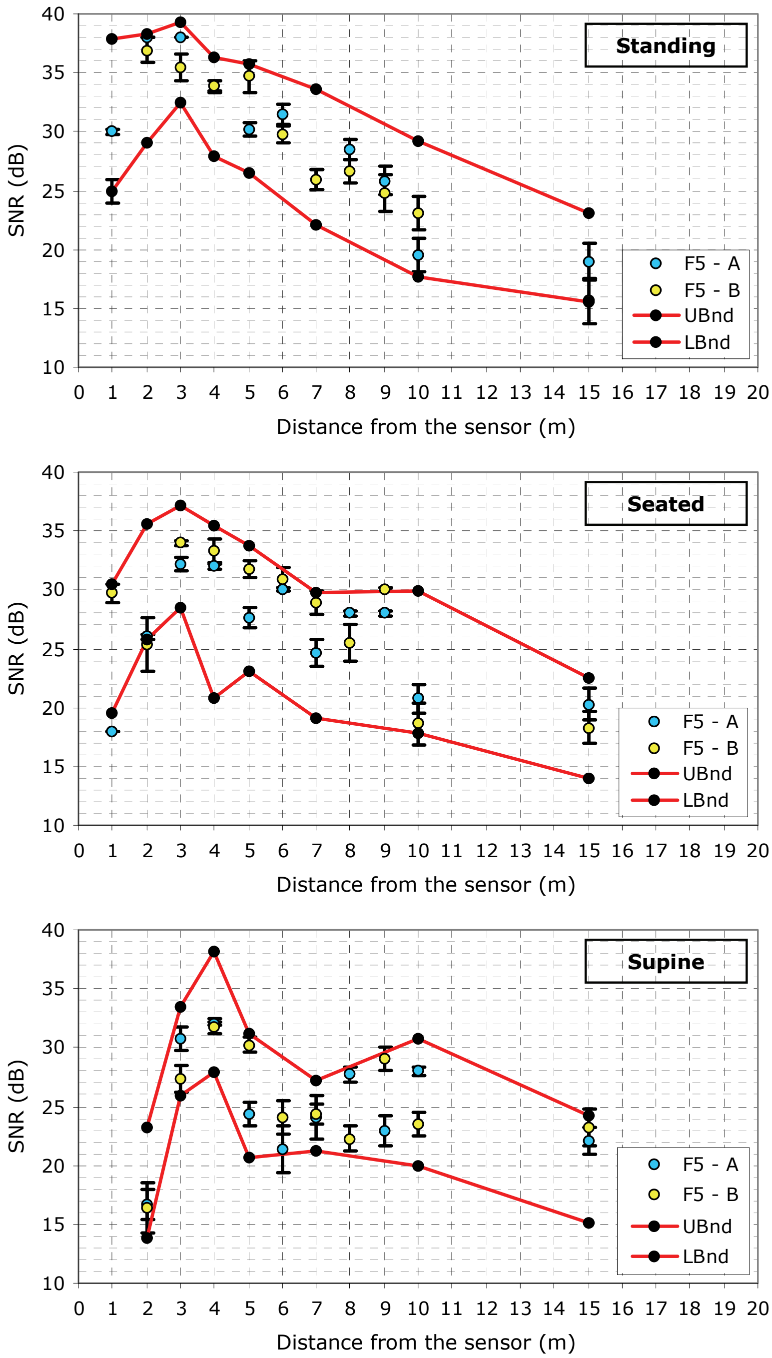

Figure 12 - Measured 24 GHz UWB radar SNR strength vs. distance from sensor for modified FLEX-5 mannequins in standing, seated, and supine postures

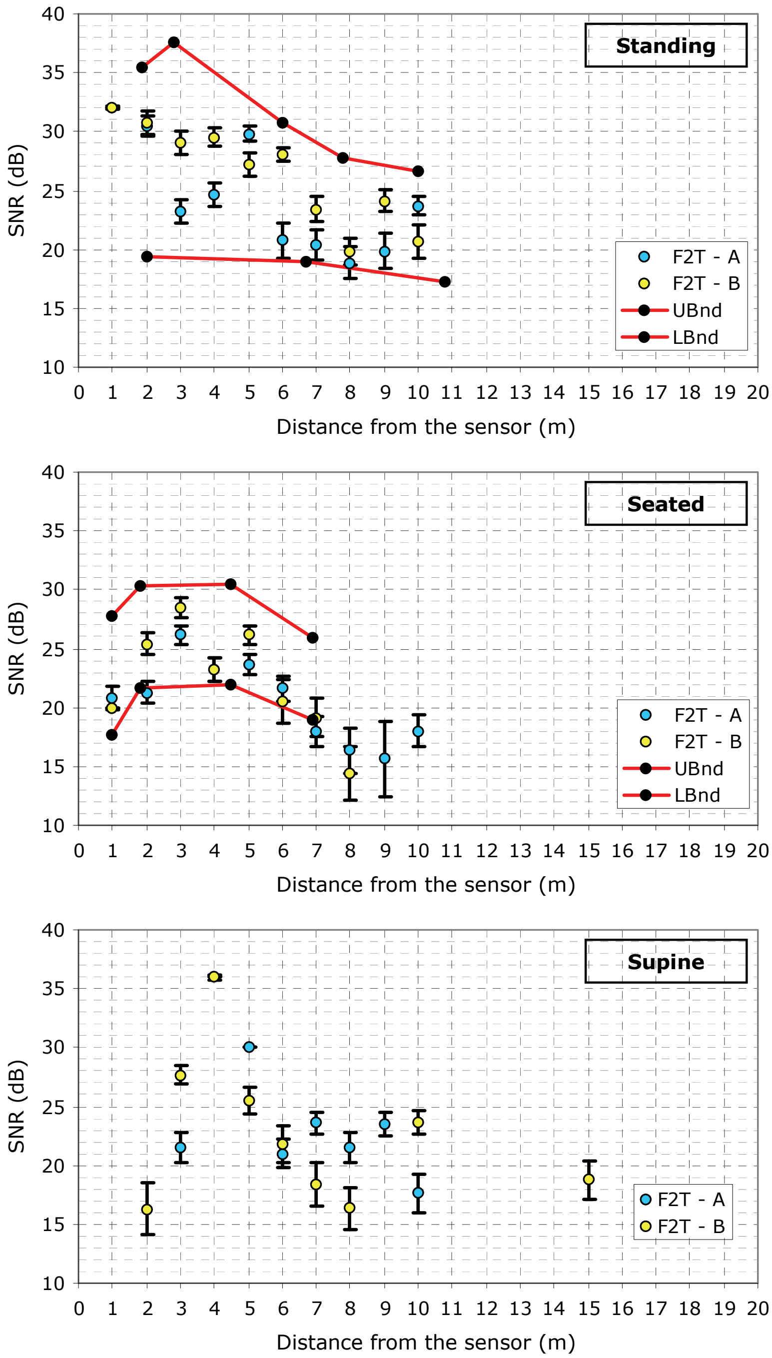

Figure 13 - Measured 24 GHz UWB radar SNR strength vs. distance from sensor for modified FLEX-2T mannequins in standing, seated, and supine postures.

5. Measurements of Corner Reflectors

Two corner reflectors of known dimensions and radar cross section (RCS) at 24 GHz were characterized in the same manner described in Section 4. A photograph of the small corner reflector (A, on the left) and the medium corner reflector (B, on the right), along with their respective physical dimensions and RCS values, is shown in Figure 14. The corner reflectors were placed with one flat side parallel to the pavement at the following distances in front of the radar 24 GHz radar sensor: 1, 2, 3, 4, 5, 7, 10, 15, and 20 meters.

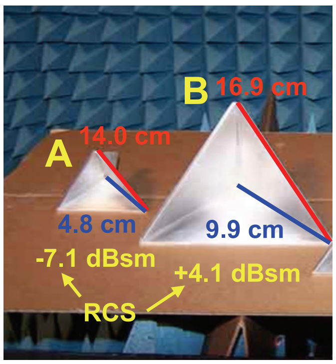

Figure 14 - Small and Medium corner reflectors

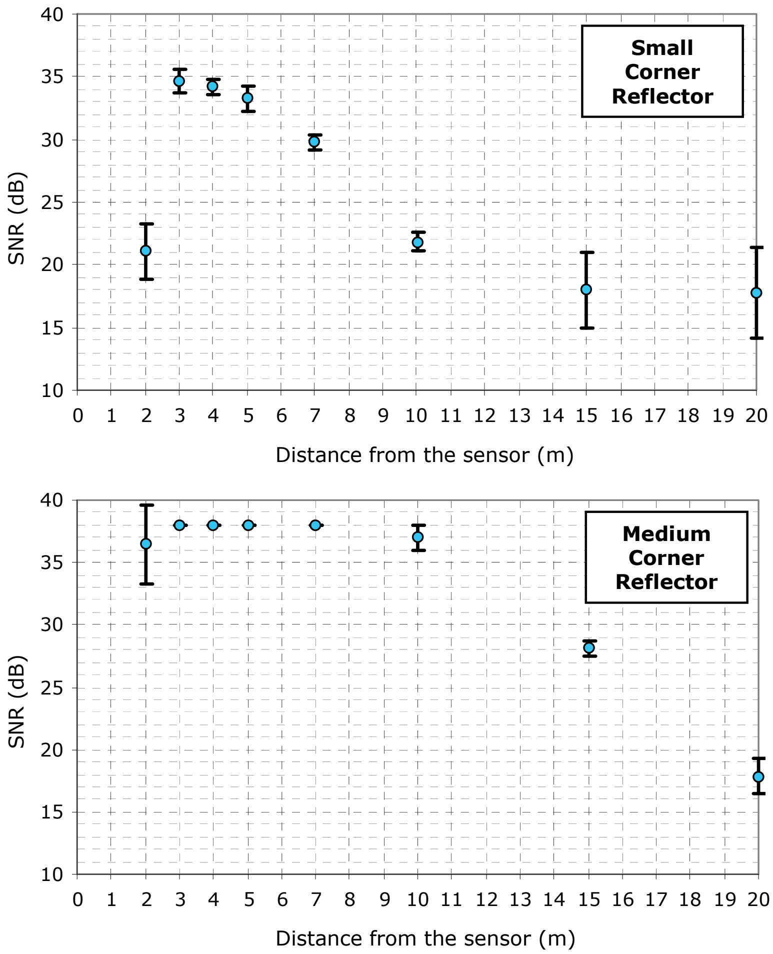

Figure 15 - Measured 24 GHz UWB radar SNR strength vs. distance from sensor for small and medium sized corner reflectors.

The measured radar mean SNR value vs. distance from sensor for the small and medium corner reflectors is shown in Figure 15. At distances greater than 2 meters, the small corner reflector serves as a reasonable representation for five-year-old children in both standing and seated postures. At distances less than 5 meters and greater than 7 meters, the small corner reflector also serves as a reasonable representation of a five-year-old child in a supine posture. In addition, at distances greater than 3 meters, the small corner reflector has a similar radar return to that of standing two-year-old children. The radar SNR value of the medium corner reflector was larger than that of both five-year-old and two-year-old children at nearly all distances, with the exception of five-year-olds standing at distances less than 4 meters.

6. Limitations

The following are several known limitations with the children and child mannequin measurements performed.

6.1. Limited number of measurements on children

Only the measurements of two five-year-olds and two two-year-olds were used to define the upper and lower bounds of the standard children of these age groups. Of course, there exists a wide range of sizes of children of any age, so this must be considered. A larger sample of children measurements would give more confidence in the validity of the child mannequins developed in this effort.

In most cases, the children measured were periodically fidgeting and moving temporarily out of position. This likely contributed to the large standard deviation values as measured by the radar sensor. It was especially difficult to work with the two-year-old children and get them to remain stationary for any reasonable length of time.

6.2. All measurements were static

Only static measurements of the children and mannequins were performed during this measurement effort. The radar sensor is known to utilize Doppler information and apply other movement tracking techniques to improve performance in dynamic situations. Therefore, dynamic measurements would add confidence and reliability to the static results acquired during this measurement effort.

6.3. All measurements were on-axis

All of the measurements were conducted on-axis to the radar sensor. In the standing and seated cases, all tests were performed with the mannequins positioned face forward. The supine posture cases were performed with the mannequin positioned on its back and with its feet pointed perpendicular to the direction of the sensor. Off-axis measurements at various angles and distances would add confidence and reliability to the on-axis results acquired during this measurement effort.

6.4. Choice of flexible mannequins

Initially, flexible child mannequin models were chosen with the intention that in all postures, a single mannequin would return a similar radar SNR value to that of a child. After conducting initial feasibility measurements, it was clear that the FLEX style mannequin could not easily be modified to achieve a match at all distances and over such a large set of positions. Therefore, the decision was made to design individual mannequins for each of standing, seated, and supine postures.

The flexible nature of the mannequin came at the price of a metal wire frame and other metallic components near the neck and shoulder joints. Preliminary 360 degree rotation measurements of a standing FLEX-5 child mannequin 5 meters in front of the sensor resulted in about 11 dB of variation in SNR values as the angle of orientation of the mannequins with respect to the radar sensor was varied. In contrast, the variation over orientation angle of child 5C – 2 was only about 5 dB. A fixed framed, non-flexible mannequin with no metallic components may report a more uniform SNR value as a function of orientation angle. In addition, careful attention must be paid to not alter the positions of the mannequins developed during this effort since any major modifications to the positions of the arms, legs, head, or torso might affect the accuracy of the model.

7. Proposed Next Steps

The following are some areas of interest for future measurement efforts.

7.1. Additional radar measurements of children

Conducting radar measurements on a larger number of child test subjects in standing, seated, and supine postures would add confidence and reliability to the results acquired during this measurement effort. Additional tests could be conducted, such as a full 360 degree characterization of children in standing, seated, and supine postures. Children in alternate postures could also be characterized. Sets of dynamic tests could also be conducted with the following scenarios: moving children in front of a stationary radar sensor, stationary children in front of a moving radar sensor, and moving children in front of a moving sensor.

7.2. Additional radar measurements

A more comprehensive set of radar measurements could be conducted on the child mannequins developed during this effort. Analogous to that proposed in Section 7.1 for children, full 360 degree characterizations of the child mannequins in standing, seated, and supine postures could be conducted, as well as in additional postures of particular interest to rear object sensing systems. Dynamic measurements would add confidence and reliability to the static results acquired during this measurement effort.

In addition, the radar sensor was found to exhibit short distance performance inconsistencies during this measurement effort. A study of how the sensor processes nonlinear behavior at short distances could be utilized to attempt to identify ways to resolve these inconsistencies.

Lastly, many other targets of interest could be studied and characterized in a similar manner to the child mannequins in this measurement campaign.

7.3. Validation of mannequins with other radar sensors

The child mannequins developed in this effort have only been identified as accurate representations of two-year-old and five-year-old children as seen by a single commercially available 24 GHz UWB radar sensor. Other versions of short range radar sensors exist that utilize alternative waveforms and post-processing detection and clustering algorithms. Validating the performance of our child mannequins with other 24 GHz radar sensors (UWB vs. non-UWB) and alternate 77 GHz radar sensors would add confidence and reliability to the results acquired during this measurement effort.

7.4. Utilize generic indoor radar system testbed

HRL is in the process of establishing an indoor, waveform independent, radar system test bed. The goal of this testbed is to evaluate the performance of any arbitrary radar system architecture in various test scenarios. It could be used to establish a database of effective radar return signal characteristics based on experimentally measured data for different targets (i.e. pedestrians, fixed and mobile roadway objects, etc.) and different transmit waveform characteristics (pulse width, pulse shape, center frequency, Barker code, UWB pulse vs. pulse stepped frequency waveforms, etc.) This test bed may also compliment algorithm testing efforts to establish a relationship between radar return signal characteristics and the target detection and false detection probabilities of specific radar systems.

The testbed utilizes a Vector Network Analyzer (VNA), transmitting and receiving wideband horn antennas, a 360 degree rotating target platform located in the far-field, and translation stage(s). VNA S21 data at discrete continuous-wave (CW) frequencies can be integrated over the spectral components of any arbitrary UWB radar system to construct the corresponding UWB radar return profiles.

This generic radar system testbed could be utilized to characterize sensor independent radar cross sections of children, child mannequins, and an arbitrary number of other targets. This could provide insight into the fundamental nature of any given radar sensor and help isolate sensor hardware performance limits from post-processing decision making algorithms.

7.5. Validation of mannequins with non-radar sensing modalities

As mentioned in Section 1, future ROD systems may consist of multiple sensing modalities, including vision and infrared cameras, radar, and LIDAR systems. Ideal child mannequin models should behave as real children under each of these sensing systems simultaneously. Further characterization could be carried out on the child mannequins with LIDAR and infrared imaging systems.

7.6. Develop alternate sets of mannequins

As mentioned in Section 6.4, flexible child mannequin models were chosen with the intention that in all postures, a single mannequin would return a similar radar SNR value to that of a child. However, the FLEX style mannequin could not easily be modified to achieve a match at all distances and over such a large set of positions. Therefore, the decision was made to design individual mannequins for each of standing, seated, and supine postures.

There are some drawbacks with the FLEX style mannequins, including the presence of metallic wires and shoulder joints, along with the difficulty of maintaining the exact posture of a mannequin for extended periods of time. These contributed to measurable variations in the SNR value of the radar sensor between multiple data sets.

Fixed framed, non-flexible mannequins with no metallic components may produce more repeatable results and more uniform SNR values as a function of orientation angle of the mannequins with respect to the radar sensor. Further testing would be required to investigate various stationary mannequins in standing, seated, and supine postures. Multiple suppliers of non-flexible mannequins have already been identified.

Alternative mannequins could be developed that are filled partially or completely with water or some other liquid substance that closely resembles the dielectric constants of human skin, tissue, and fat. For example, specific absorption rate (SAR) tests for monitoring the affects of cell phone radiation on humans utilize specific anthropomorphic mannequin (SAM) phantom models. A SAM phantom that represents a human head typically consists of a shell made from low permittivity and low loss microwave material that is filled with a liquid, such as a glycol mixture, whose dielectric properties match that of human brain tissue. A similar approach could be used to construct full-sized child SAM phantom models for short range radar testing. These SAM phantoms may behave more like real children as observed using alternate non-radar sensing modalities.

8. Conclusion

Five-year-old and two-year-old child mannequins were developed to emulate children for rear object sensing systems utilizing vision cameras and 24 GHz UWB radar sensors. The results of static measurements of two-year-old and five-year-old mannequin models in standing, seated, and supine postures were presented and shown to correlate well with measured data of five-year-old and two-year-old children. Limitations of the child mannequins and the short range radar sensor were identified, and potential follow on efforts have been proposed.

4 Child Mannequin Development for Rear Object Sensing: Phase 2
5 Final Report

Submitted by:

LABORATORIES

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Executive Summary

A new set of child mannequins have been developed as test objects for 24GHz ultra-wideband (UWB) radar-based rear object sensing systems improving on those developed for the earlier Phase 1 effort. The second generation mannequins realistically represent 2 and 5 year old children in specific postures in terms of their physical dimensions, visible attributes, and 24 GHz UWB radar cross sections.

Static measurements of two-year-old and five-year-old child mannequins in standing and seated positions were conducted at the HRL Laboratories' indoor radar chamber testing facility with a commercially available 24 GHz UWB short range radar sensor. Commercially available child mannequins with fewer metallic components than the first generation mannequins were identified and found to exhibit radar returns that were comparable to measured children of appropriate size and age. The child mannequins were analyzed in terms of their radar return as a function of distance, orientation, and lateral offset with respect to boresight.

HRL Laboratories has delivered a set of three child mannequins to Virginia Tech Transportation Institute for further rear object detection systems testing. The set includes a two-year-old and five-year-old mannequin in the standing posture and one additional mannequin to satisfy both the seated two-year-old and seated five-year-old postures. An additional set has been delivered to General Motors.

This report documents the set of Phase II 24GHz UWB radar child mannequin measurements performed at HRL Laboratories. In addition, the report describes work related to the development of a hybrid ultrasonic and 24 GHz UWB radar testing standard.

1. Introduction

The objective of this project was to search for, acquire, test, and modify commercial off-the-shelf (COTS) mannequins that are reasonable representations of child pedestrians in terms of physical appearance and 24 GHz UWB radar cross section. It was required to improve on some of the issues associated with the prior delivered FLEX-style child mannequins, as documented in “Child Mannequin Development for Rear Object Sensing Systems: Final Report.” The mannequins are to emulate the 24GHz radar sensor return of children in the evaluation of rear object detection (ROD) systems associated with automotive backing crash countermeasure systems.

In the future, ROD systems may consist of multiple sensing modalities, including vision and/or infrared cameras, radar, and LIDAR systems. An ideal child mannequin model would behave as a real child does under each of these sensor systems simultaneously. However, the current ROD prototype system includes only a vision camera and a commercially available 24 GHz ultra-wideband (UWB) short range radar sensor.

Considering the capabilities of the prototype ROD system and the need for ROD system performance evaluation, the scope of this project was limited to developing a robust set of child mannequins whose visual characteristics and static radar returns matched that of typical two-year-old and five-year-old children. This work is a follow-on effort to improve the on delivered set of child mannequins in the Phase 1 effort and evaluate their lateral-to-boresight performance. The project outline is shown in Figure 1.

This report is organized as follows: In Section 2, the indoor and outdoor measurement setups used to characterize the 24 GHz radar return of the child mannequins are described, as well as supplemental test objects for ROD. In Section 3, the various static measurements performed on the two-year-old and five-year-old child mannequins at the HRL facility are discussed. Details of the COTS child mannequins that were identified as having a reasonable match to the radar returns of the measured two-year-old and five-year-old children are presented. In Section 4, the development process and evaluation of a hybrid ultrasonic and 24 GHz radar testing standard is described. In Section 5, future measurement campaigns that could compliment this current mannequin development effort are proposed. Section 6concludes the findings.

Task Name	Duration	Start
Child Mannequin Development - Phase 2 (SDG85T4100000)	74 days	Fri 8/1/08
Purchase stationary plastic mannequins	26 days	Fri 8/1/08
24 GHz short range radar (SRR) test plan	9 days	Mon 8/18/08
Purchase accessories, coatings, liquids, etc.	18 days	Tue 8/12/08
Feasibility measurements of mannequins with M/A-COM sensor	35 days	Fri 9/5/08
Status meeting: Review M/A-COM sensor feasibility measurements	0 days	Thu 10/9/08
Status meeting: Decision to purchase final mannequin deliverables	0 days	Thu 10/16/08
Purchase additional stationary plastic mannequins	7 days	Thu 10/16/08
Status meeting: Decision to ship mannequins to Virginia Tech	0 days	Thu 10/23/08
Final characterization of mannequins with M/A-COM sensor	5 days	Fri 10/24/08
Status meeting: Review characterization of mannequins	0 days	Fri 10/31/08
Ship mannequins to Virginia Tech	5 days	Fri 10/31/08
Mannequins arrive at Virginia Tech	0 days	Fri 11/7/08
Characterization of hybrid reflectors	8 days	Mon 11/3/08
Final review meeting: Conclusions	0 days	Thu 11/13/08

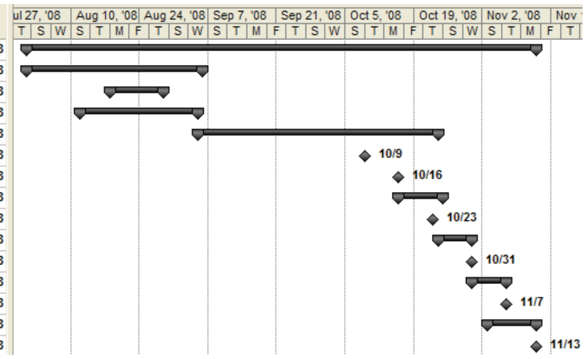


Figure 1. Gantt chart for the Phase 2 child mannequin development effort.

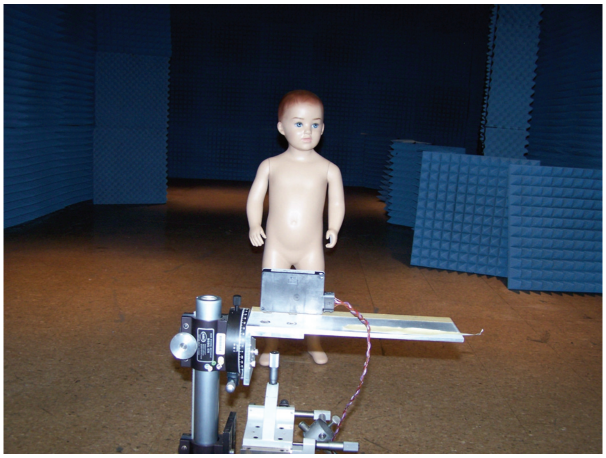
2. Measurement Setup

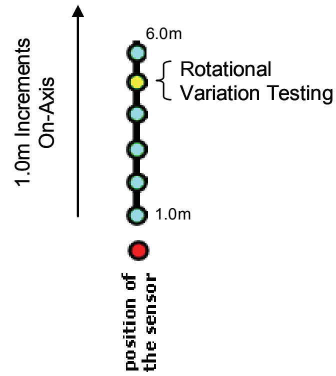
A commercially available 24 GHz ultra-wideband (UWB) short range radar (SSR) sensor was utilized for all radar measurements. The results shown in this report are a combination of indoor and outdoor measurements. All the measurements obtained in the following described indoor and outdoor setups were static.

2.1 Indoor Radar Testbed Setup

HRL's Radar Chamber Testing Facility is 14 ft wide x 22 ft deep X 8 ft high with radar absorber material covering all 4 walls and ceiling (22-29 GHz band), as shown in Figure 2(a). There is a controlled radar sensor mounting capability exhibiting high precision control over sensor height, rotation, and tilt. Other capabilities not used in this project include a 3 meter programmable linear translation stage for high speed dynamic tests as well as a mechanism for mounting fascia samples directly in front of the radar sensor. The indoor radar chamber testing facility was specifically designed for the testing of automotive radar. It provides a high degree of isolation and improves testing efficiency.

The child mannequins were first characterized through the use of the indoor radar testbed. Figure 2(b) represents a schematic of the measurement grid used for the radar chamber testing facility throughout the project. As can be seen, the testing in this indoor setup was restricted to the on-axis evaluation of the child mannequins. The grid was defined with masking tape on the floor. The distance from the ground to the bottom of the sensor was 18 inches, as was used in HRL Laboratories' earlier work regarding child mannequins. The sensor was mounted such that the bottom surface was parallel to the ground within approximately 2 degrees.





(b)

Figure 2. HRL's indoor radar test chamber facility (a) and grid (b).

A series of reference measurements were performed with a small-sized corner reflector. This was done to confirm that the earlier Phase I outdoor measurements of children and the Phase II indoor measurements of child mannequins could be directly compared. For more information regarding the Phase I 24 GHz radar measurements of children, refer to "Child Mannequin Development for Rear Object Sensing: Phase 1 Final Report". Slightly different ground slopes were present in the outdoor and indoor measurement grids. By measuring the return of a small-sized corner reflector at various elevation tilt angles within the indoor radar testbed, a comparison can be made to similar calibration measurements conducted in Phase I. The results of these corner reflector Signal to Noise Ratio (SNR) measurements appear to very closely agree when the indoor sensor tilt angle is approximately 1.5 degrees upward, as seen in Figure 3.

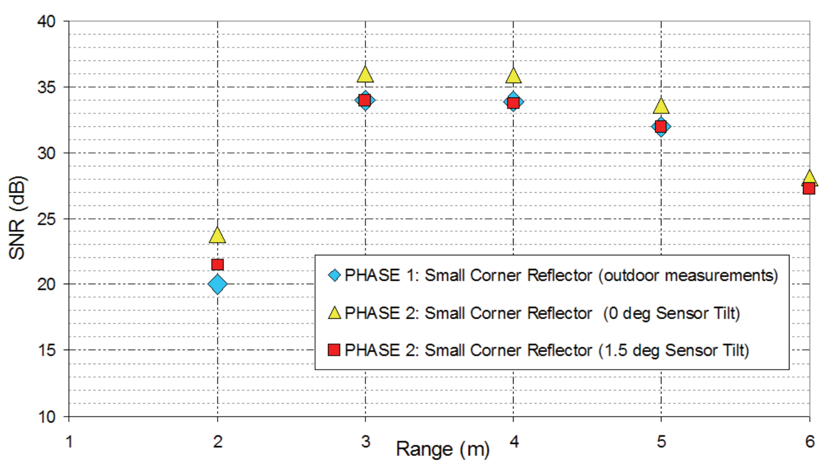
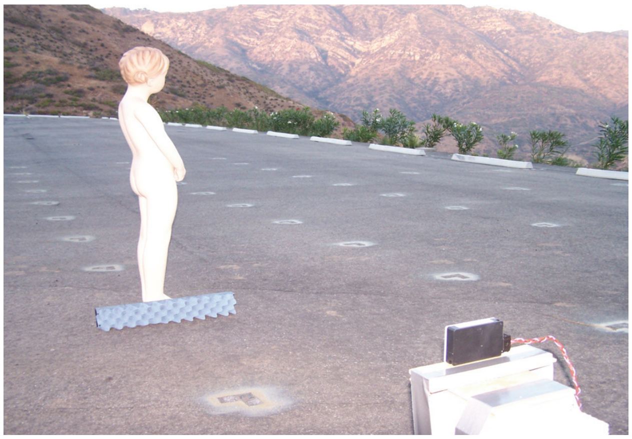


Figure 3. Reference measurements of a small sized corner reflector to determine the



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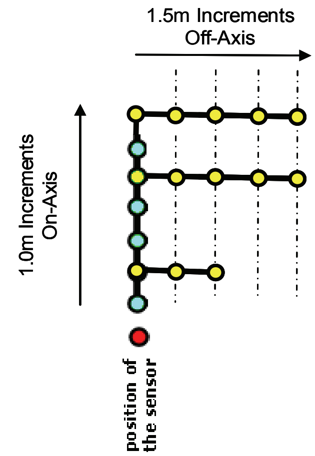


(b)

Figure 4. HRL's outdoor radar test setup (a) and grid (b).

2.2 Outdoor Setup

While very useful, the indoor radar chamber testing facility is relatively limited in space. Lateral-to-boresight testing is relevant for rear object detection systems; however, the off-axis radar measurements require a much larger space than offered in the indoor setup. Therefore, an outdoor setup was utilized that consisted of an empty parking lot at HRL Laboratories. Again, the distance from the ground to the bottom of the radar sensor was 18 in. The sensor was mounted such that the bottom surface was parallel to the ground. The schematic of the measurement grid used in the outdoor setup can be seen in Figure 4.

Like the indoor radar facility, a series of reference measurements were performed with small sized corner reflectors on several occasions, usually before or after conducting experiments with children or mannequins. No adjustment to the elevation tilt angle of the radar sensor was necessary. These reference measurement results confirmed that data sets from different days and different measurement campaigns were repeatable and could be directly compared to each another.

3. Measurements of Child Mannequins

In the earlier phase of this project, two five-year-old children and two two-year-old children were measured with the same radar sensor. The children were asked to remain stationary for approximately 10 seconds at a time, in each of the following postures: standing, seated, and supine at various distances from the radar sensor. After compiling the results, upper and lower bounds were determined that mark the range of SNR values the radar sensor will typically return for a typical five or two-year-old.

In Phase 2, specific measurement issues associated with the delivered FLEX-style child mannequins were improved upon those documented in the "Child Mannequin Development for Rear Object Sensing Systems: Phase 1 Final Report.". One issue identified during the Phase 1 effort was that the presence of metallic wires in the limbs, along with metal shoulder and neck joints, caused the radar return values of the FLEX-type mannequins to vary as a function of orientation angle with respect to the radar sensor. In Phase 2, 10 mannequins with limited metallic components representing two and five year old children in standing and seated positions were identified, acquired, and tested . The majority of these mannequins consisted of a hard fiber glass shell type, as opposed to the type tested in Phase 1, which consisted of a flexible metal wire frame covered with a dense layer of foam.

The mannequins were initially characterized by their forward facing return measurements as a function of distance, as well as their return at a fixed distance as a function of aspect angle (rotational variation). According to those testing criteria, three child mannequins were selected, shown in Figure 5, that appeared to be good radar representations of two-year-old and five-year-old children. The physical dimensions can be found in Table 1. The mannequin depicted in Figure 5(a) was chosen to represent a standing five-year-old, and the mannequin in Figure 5(b) was chosen to represent a standing two-year-old child. The mannequin in Figure 5(c) was a good representation of both cases: the seated two-year-old and five-year-old children. This can be easily explained since the physical dimensions of a seated five-year-old and a seated two-year-old child are comparable.

(a) (b) (c)

Figure 5. Standing five-year-old mannequin (a), standing two-year-old mannequin (b), and seated mannequin representing both five- and two-year-old children (c).

For the supine position, no reliable measurement data was available for two-year-old children in order to validate the radar sensor's SNR strengths of these mannequins. (In addition, only very limited five-year-old child data in the supine posture is available.) Therefore, the accuracy of these mannequins as a valid model of a child lying down is unknown. As a result of this lack of comprehensive data for children in the supine position, measurement efforts were concentrated on the standing and seated positions.

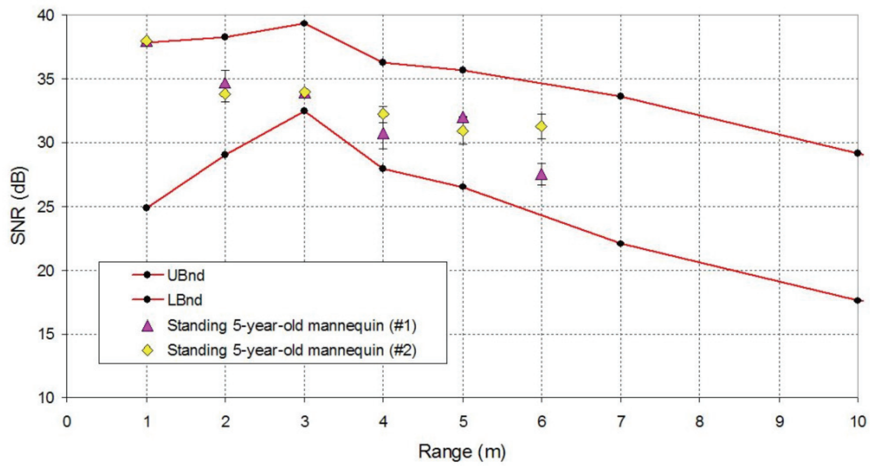
Table 1. Physical dimensions of the child mannequins.

Child Mannequin	Standing 5 year old	Standing 2 year old	Seated 2 & 5 year old
Overall height	45”	33”	19 ½ “
Shoulder-to-shoulder width	12”	9 ½ “	10”
Elbow-to-elbow width	15”	11”	13”
Front-to-back width	6 ¼”	6 ¼ “	6”

Throughout the course of testing, a data capture software program was used to log the performance of the radar sensor over an approximately 10 second time period, resulting in data sets of about 200 to 250 samples. In particular, the SNR values of the assigned tracks of the radar sensor were recorded over the measurement window and averaged. These mean SNR values, along with standard deviation (SD) and total number of samples in which the target was actually detected, were recorded and plotted.

3.1 Forward Facing Return Measurements

Forward facing return measurements were taken using the indoor radar testbed facility setup. Each of the three mannequins described above were oriented facing the UWB 24 GHz radar sensor and placed at the following distances in front of the sensor: 2, 3, 4, 5, 6, and 20 meters. Figures 6 and 7 portray a series of plots of the measured 24 GHz UWB radar SNR strength vs. distance from radar sensor for the mannequins in standing and seated postures with the appropriate upper and lower bounds. Since the seated mannequin is able to represent both the five-year-old and two-year-old seated cases, the test data is identical in both plots of Figure 7. As a result, the child mannequins do not require any modifications to alter or improve their forward facing return measurements. The SNR strengths recorded by the radar sensor are within the measured upper and lower bounds of the measured children determined in Phase 1. The black bars indicate the standard deviation of the SNR at any given separation distance between the sensor and mannequin. Overall, the standard deviation of the radar SNR strengths of the child mannequins is much smaller than the actual children. This was expected since the hard fiberglass child mannequins are a highly controlled test object, especially when compared to a child.



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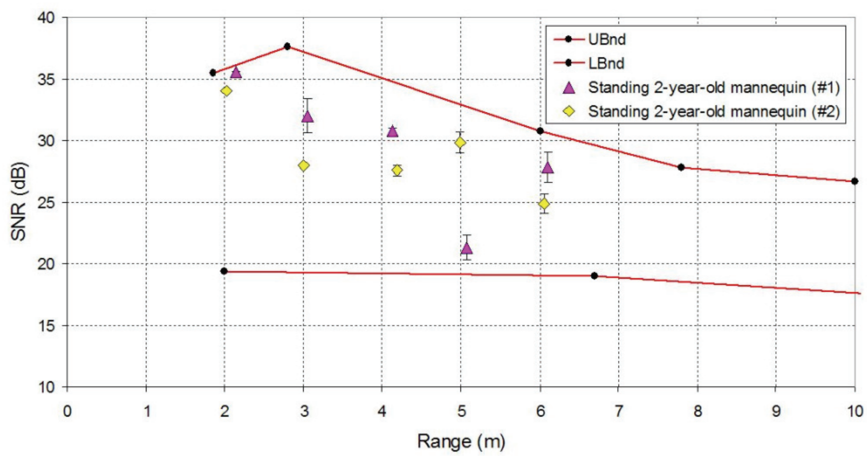
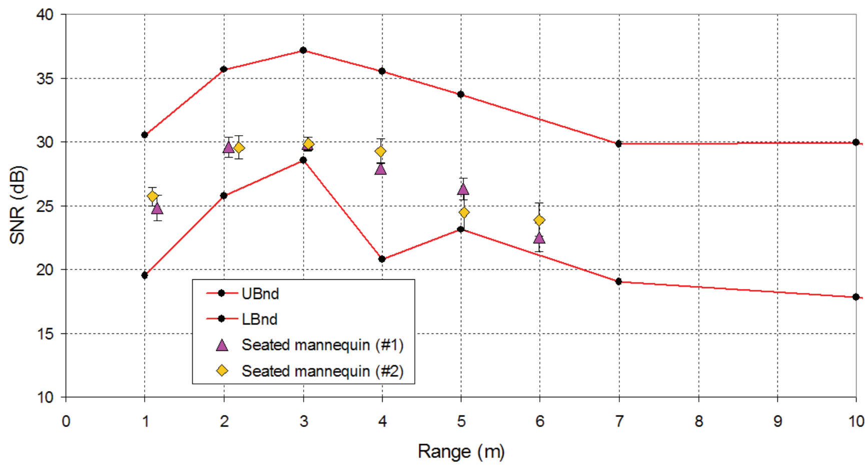


(b)

Figure 6. Measured 24 GHz UWB radar SNR strength of the standing five-year-old child mannequin (a), standing two-year-old child mannequin (b).



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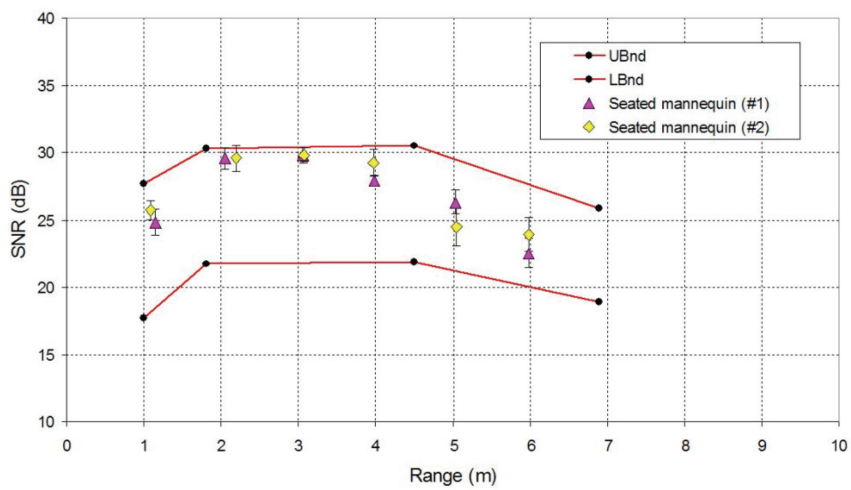


(b)

Figure 7. Measured 24 GHz UWB radar SNR of the seated child mannequin with bounds of a five-year-old seated child (a) and with bounds of a two-year-old seated child (b).

3.2 Rotational Variation Return Measurements

Like the forward facing measurements, rotational variation tests were also taken using the indoor radar testing chamber facility setup. Each of the three mannequins were individually placed 5 meters from the radar sensor on-axis. The SNR value was recorded by the radar sensor as the child mannequin was rotated in increments of 45 degrees. The rotational variation for each mannequin is defined as the maximum change in SNR strength as perceived by the radar sensor during the testing. Overall, the rotational variation for each mannequin falls within acceptable limits, as compared to the Phase 1 child measurement data depicted in Figure 8. For example, the change in SNR strength as a function of rotation angle, averaged over all of the five-year-old standing children measured in Phase 1, was 8.2 dB. In comparison, the 8.33 dB average SNR rotation variation for the standing five-year-old mannequin, as depicted in Table 2, is well within one standard deviation (approximately 4 dB) of the actual child measurement results.

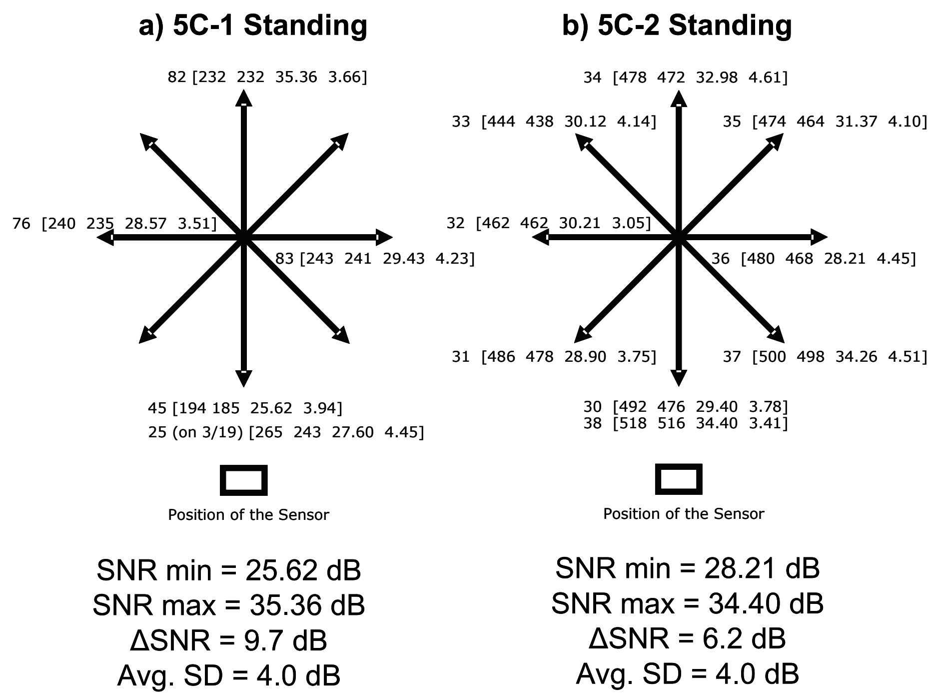


Figure 8. Rotation measurement data of five-year-old child 5C-1 standing (a) and five-year-old child 5C-2 standing (b).

Table 2. Average rotational variation of the child mannequins.

Child Mannequin	Avg. Rotational Variation
Standing 5-year-old mannequin	8.33 dB
Standing 2-year-old mannequin	8.92 dB
Seated mannequin	6.05 dB

3.3 Lateral-to-Boresight Measurements

The lateral-to-boresight measurements were the only test series performed using the outdoor setup described in Section 2.2. The measurements were obtained with the standing five-year-old and two-year-old mannequins at on-axis distances of 2, 5, and 7 meters. The child mannequins were oriented with their right-hand side facing the sensor and measured in 1.5 meter increments off-axis. Figure 9 displays the results of the lateral-to-boresight testing as a function of bearing angle as recorded by the radar sensor. No tracks were identified for the child mannequins with bearing angle readings greater than 35 degrees. This is consistent will the limited number of off-axis children measurements that were performed in the earlier study. Another relevant observation was the fact that the standing two-year-old child mannequin varied less in SNR strength than the five-year-old child mannequin as the measurements were offset from boresight. The radar cross sections of the child mannequins are dependent on aspect angle. Therefore, at each test point on the grid the radar cross section will vary considerably. In general, the depicted behavior is very similar to measurements seen with children in the previous radar work.

For example, measurement data was previously captured for a five-year-old child standing in front of the radar sensor 5 meters out 3 meters off-axis. The sensor recorded an SNR reading for the child of 25.62 dB, with a standard deviation of 3.94 dB. Figure 9(b) shows that the five-year-old mannequin located in the same position results in an SNR reading of 22.5 dB, with a standard deviation of 1.0 dB. Since these results are within one standard deviation of the child measurement data, it can be concluded that the five-year-old mannequin is a reasonable representation for five-year-old children both on-axis and off-axis. Limited measurement data for a five-year-old child walking slowly approximately 7 meters in front of the sensor and 3 meters off-axis also resulted in an SNR reading that is within approximately 2 dB of the 18.4 dB SNR reading for the five-year-old mannequin when located in the same position, as seen in Figure 9(c).

3.4 Clothing Measurements

HRL performed a brief study on the influence clothes had upon the return measurements of the child mannequins. For the testing, a white cotton T-shirt was placed on the standing two-year-old and five-year-old child mannequins, as depicted in Figure 10, at a fixed distance of 5 meters from the radar sensor. The measured difference in return was only just measurable on the child mannequins. An average change in SNR, ΔSNR_{avg}, was determined to -0.5 dB. It is expected that such an effect would be negligible compared to the standard deviation of actual children. For this reason, most related research work can reasonably assume that clothes have a negligible effect on the radar return of humans.

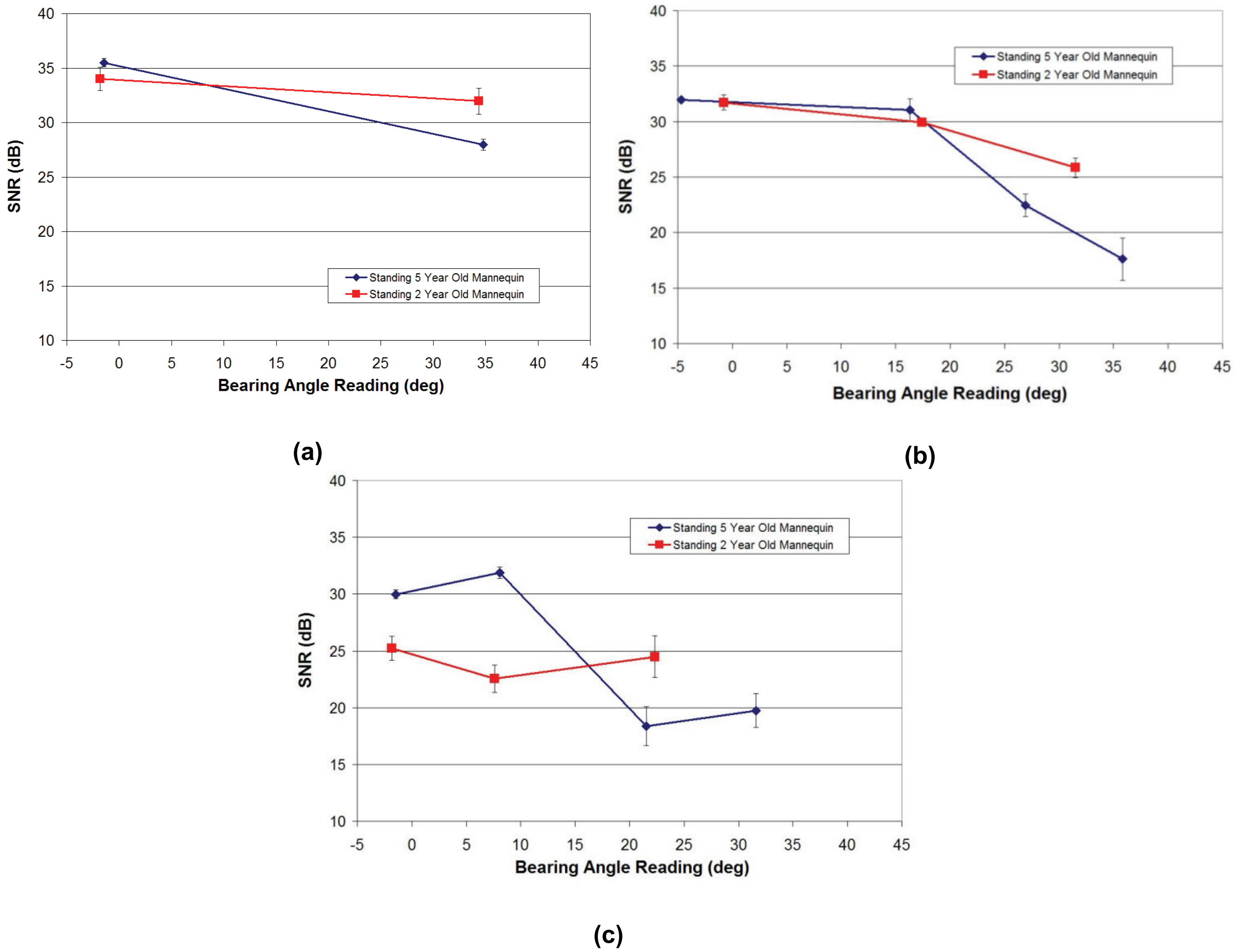


Figure 9. Measured 24 GHz UWB radar SNR strength as a function of bearing angle at an on-axis distance of 2 m (a), 5 m (b), and 7 m (c).

Figure 10. Standing five-year-old mannequin with a white cotton T-shirt.

4. Hybrid Reflector

This work initiated as a follow-on effort for HRL to support the potential design and testing of a hybrid ultrasonic and radar reflector. In evaluating parking guidance systems, a 3” PVC pole has become the accepted standard for ultrasonic radar, whereas a 1” metal pipe has become the accepted standard for 24 GHz UWB radar. In order to increase testing capability and improve efficiency, a single hybrid reflector is desired. Ideally, it would replace the current test standards for both ultrasonic sensors and 24 GHz radar sensors.

In the development process, HRL Laboratories was responsible for evaluating the hybrid reflector in terms of its 24 GHz radar performance. For the testing, a series of measurements was made with the radar sensor at different distances from the sensor. The targets, depicted in Figure 11, were cut to 1 meter in length and oriented in such a way that their axis was perpendicular to the floor of the indoor radar testing chamber. During the testing, the sensor height remained at 18” off the floor; however, the cylindrical targets stood directly off the floor. Measurements were taken of the targets at three distances of 5 ft, 15 ft, and 21.5 ft (maximum length of radar testing facility). Only on-axis measurements were necessary since radar cross section of a cylindrical geometry is independent of aspect angle.

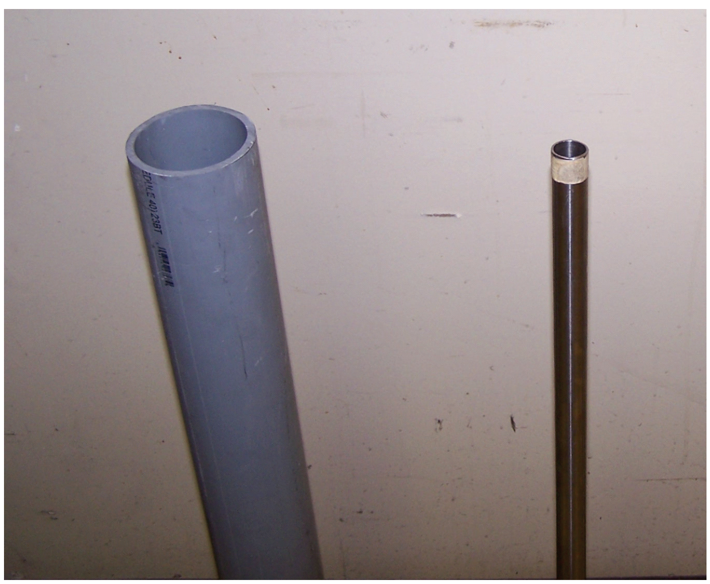
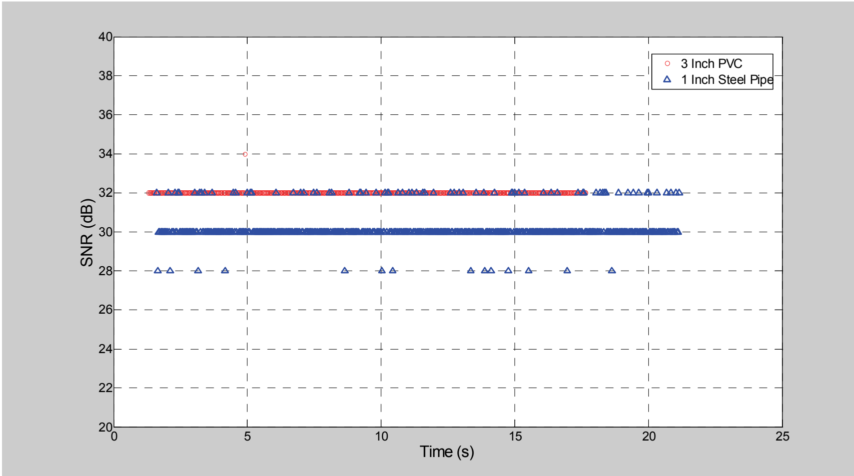


Figure 11. Ultrasonic radar testing standard, 3” diameter PVC pipe (left) 24 GHz UWB radar testing standard, 1” diameter steel (pipe).



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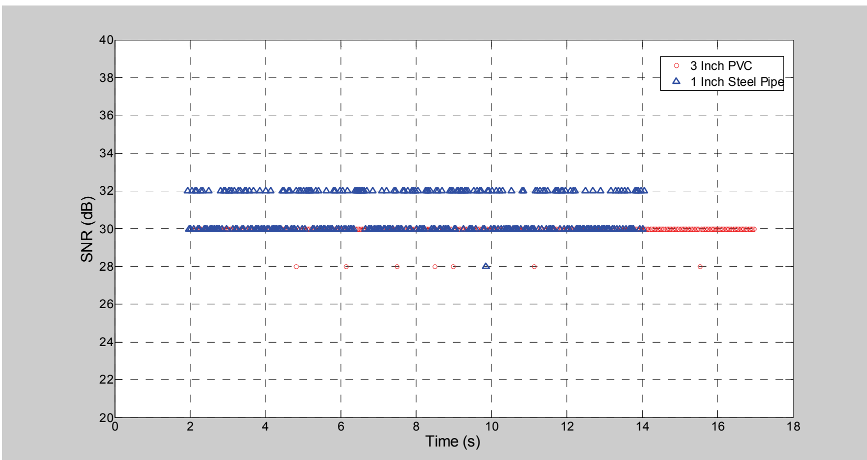

(b)

Figure 12. Measured 24 GHz UWB radar SNR strength of the 3” PVC pipe & 1” steel pipe at a distance of 15 ft (a) and a distance of 21.5 ft (b).

At a distance of 5 ft, the returns from both targets saturated the radar sensor at SNR strength of 38 dB. Figure 12 shows the post-processed SNR strengths from the radar sensor at distances of 15 ft and 21.5 ft. The blue trace represents the SNR strength of the 1” steel pipe, and the red trace represents the 3” PVC pipe. They are in close agreement. An average SNR strength of 30.3 dB was determined for the 1” steel pipe and 32.0 dB for the 3” PVC pipe at a distance of 15 ft, whereas at the longer distance of 21.5 ft, an average return SNR strength of 30.8 dB was obtained for the 1” steel pipe and 30.0 dB for the 3” PVC pipe. By comparing the recorded SNR strength from the radar sensor, the 3” PVC pipe was shown to have a similar radar cross section to that of the 1” steel pipe.

The current ultrasonic sensor standard, 3” PVC pipe, can effectively emulate the 24 GHz radar return of a 1” metal pipe. As a result, the PVC by itself satisfies the 24 GHz radar criteria for a hybrid target. It is not necessary to add any conductive cylindrical inserts to the 3” PVC pipe in order to modify its Radar Cross Section (RCS) to be equivalent to the 1” steel pipe. Fortunately, this simpler geometry also avoids any destructive (or constructive) interference issues that might have been extremely sensitive to the position of metal insert within the PVC.

5. Proposed Next Steps

The following are some areas of potential interest for future measurement efforts.

5.1. Additional radar measurements of children

Conducting radar measurements on a larger number of child test subjects in standing, seated, supine, and alternate postures would add confidence and reliability to the results acquired during this measurement effort. Sets of dynamic tests could also be conducted with the following scenarios: moving children in front of a stationary radar sensor, stationary children in front of a moving radar sensor, and moving children in front of a moving sensor.

5.2. Validation of mannequins with other commercial radar sensors

The child mannequins developed in this effort have only been identified as accurate representations of two-year-old and five-year-old children as seen by a 24 GHz UWB radar sensor. Other versions of short range radar sensors exist that utilize alternative waveforms and post-processing detection and clustering algorithms. Validating the performance of our child mannequins with other 24 GHz radar sensors (UWB vs. non-UWB) and alternate 77 GHz radar sensors would add confidence and reliability to the results acquired during this measurement effort.

5.3. Utilize generic indoor radar system testbed capabilities

HRL Laboratories has established an indoor, waveform independent, radar system testbed facility. The purpose of this testbed is to evaluate the performance of any arbitrary radar system architecture in various test scenarios. It can be used to establish a database of effective radar return signal characteristics based on experimentally measured data for different targets (i.e. pedestrians, fixed and mobile roadway objects, etc.) and different transmit waveform characteristics (pulse width, pulse shape, center frequency, Barker code, UWB pulse vs. pulse stepped frequency waveforms, etc.) This testbed may also compliment algorithm testing efforts to establish a relationship between radar return signal characteristics and the target detection and false detection probabilities of specific radar systems.

This generic radar system testbed can be utilized to characterize sensor independent radar cross sections of children, child mannequins, and an arbitrary number of other targets. This could provide insight into the fundamental nature of any given radar sensor and help isolate sensor hardware performance limits from post-processing decision making algorithms.

5.4. Validation of mannequins with non-radar sensing modalities

As mentioned in Section 1, future ROD systems could consist of multiple sensing modalities, including vision and infrared cameras, radar, and LIDAR systems. Ideal child mannequin models should behave as real children under each of these sensing systems simultaneously. Therefore, further characterization could be carried out on the child mannequins with LIDAR and infrared imaging systems.

5.5. Develop alternate sets of mannequins

Alternative mannequins could be developed that are filled partially or completely with water or some other liquid substance that closely resembles the dielectric constants of human skin, tissue, and fat. For example, specific absorption rate (SAR) tests for monitoring the affects of cell phone radiation on humans utilize specific anthropomorphic mannequin (SAM) phantom models. A SAM phantom that represents a human head typically consists of a shell made from low permittivity and low loss microwave material that is filled with a liquid, such as a glycol mixture, whose dielectric properties match that of human brain tissue. A similar approach could be used to construct full-sized child SAM phantom models for short range radar testing. These SAM phantoms may behave more like real children as observed using alternate non-radar sensing modalities.

6. Conclusion

Second generation five-year-old and two-year-old child mannequins have been developed to emulate children for rear object sensing systems utilizing vision cameras and 24 GHz UWB radar sensors. The results of static measurements of fixed framed two-year-old and five-year-old mannequin models in standing and seated postures were presented and shown to correlate well with measured data of five-year-old and two-year-old children. Lastly, potential follow on efforts have been proposed.

APPENDIX F:

RESULTS OF LITERATURE REVIEW OF DRIVER MODEL DATA

Advanced Crash Avoidance Technologies Program (ACAT)
Backing crash Countermeasures Project

1 DRIVER MODEL LITERATURE REVIEW

1.1 Brake Reaction Time Distribution

In order to equip the SIM with appropriate data on Brake Reaction Times, it is necessary to address responses that can occur under two broad types of conditions during backing – (1) those where no vehicle-based system is providing alerts or assistance (in which the driver is not alerted to a potential conflict), and (2) those conditions where some system is actively providing one or more alerts, and/or assistance (in which the driver *is* alerted to a potential conflict). In order to discover data relevant for the SIM on backing Brake Reaction Times under these two conditions, several studies were identified and examined.

These studies were reviewed with respect to key variables that may significantly affect brake reaction times during backing, such as the variables of alerted versus non-alerted state, backing maneuver type, variability between drivers (e.g., due to age and gender), as well as with respect to other factors that may determine how the SIM would need to represent backing brake reaction times. Factors that are important to the estimation and representation of backing brake reaction times in the SIM are discussed briefly to explain their role, to identify key parameters for the SIM, and to specify sources of data used to establish distributions and values for the SIM. Eight factors that were found to be important in these studies were:

- Alerted versus Non-alerted State of Driver
- Driver Foot Position at the time braking is initiated (on brake pedal, on accelerator pedal, or located elsewhere)
- Type of Surprise Event
- Age of the driver (younger, middle-aged, older; especially in combination with Alerted State)
- Backing Task or Maneuver being completed when a backing conflict occurs
- Vehicle Type
- Backing Warning Type
- Backing Warning Timing

In the sections below, relevant studies are reviewed with particular attention to what they reveal about these key factors, as well as certain other factors which were shown not to be of significant concern in affecting brake reaction times.

1.1.1 Alerted versus Non-Alerted Brake Reaction Times

Whether a driver is completely surprised by an event at the time of braking or has been alerted to the need to brake has a significant effect on brake reaction times. Alerted brake reaction times are faster, as shown by several of the studies surveyed.

1.1.1.1 Paine & Henderson (2001)

Figure F- 1 below shows a distribution for *alert* driver reaction times made in response to a back-up alarm system (taken from Paine & Henderson, 2001). The figure is consistent with previous work by

Eberhard et al. (1994). The distribution is uniquely shaped, and has the appearance of a Weibull (including some positive skew). Its mode lies near 0.50, and the median (illustrated by the vertical bar) lies at about 0.62 seconds.

In contrast to alerted brake reaction times, surprise reaction times tend to be around 0.3 seconds greater than the alerted reaction times depicted below (Paine and Fisher, 1996 as cited in Paine & Henderson, 2001). This implies that the distribution as a whole may shift upward by 0.3 seconds for non-alerted, surprise conditions. Were this the case, it would suggest that the central tendency of the distribution for _non-alerted reaction times_ might lie roughly in the range from 0.80 – 0.92 seconds.

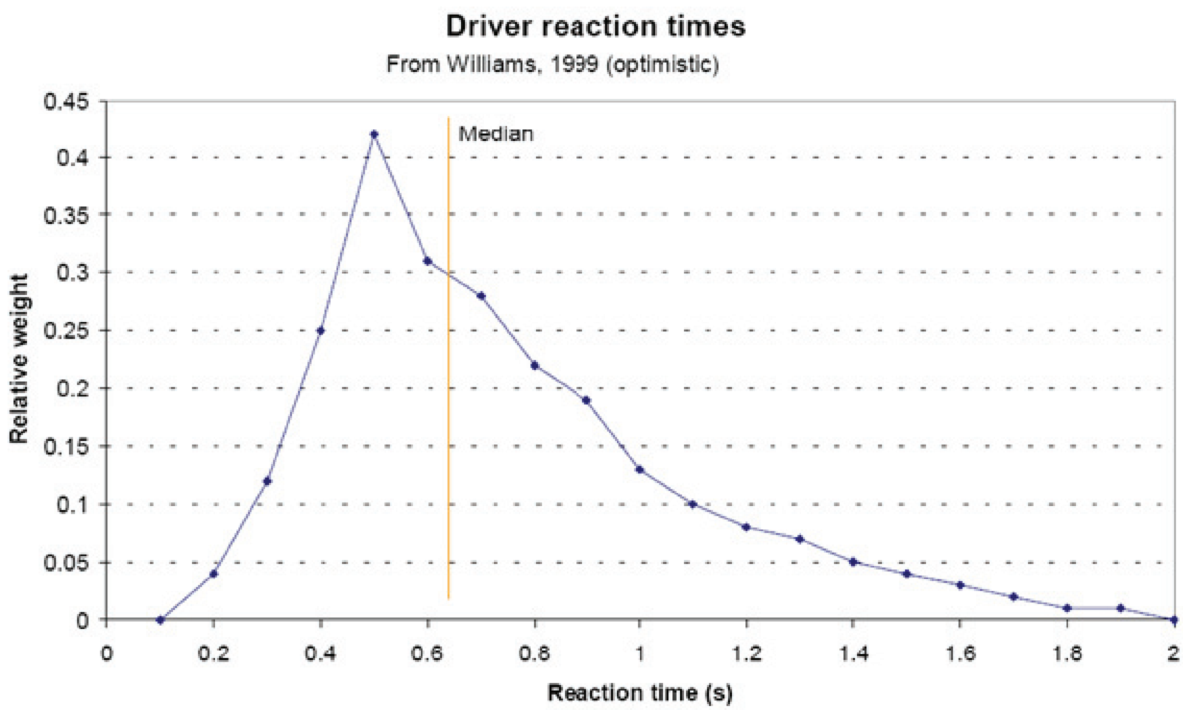

Figure F- 1. Distribution of alerted brake reaction times as a result of an alarm presence during a backing task – from Williams (1999) as cited in Paine and Henderson (2001).

1.1.1.2 Mazzae & Garrott (2006)

A Monte Carlo simulation was conducted by Mazzae and Garrott (2006) to determine maximum stopping distances while backing that could be expected based on several variables. One of these variables was driver reaction time in response to an alert. A mean value of 1.17 seconds and a standard deviation of 0.31 seconds was used to represent _non-alerted_ drivers (Mazzae, Baldwin, Barickman, & Forkenbrock, 2003) rather than a mean time of 0.54 seconds for _alerted_ drivers (Harpster, Huey, & Lerner, 1996).

1.1.1.3 Llaneras, McLaughlin, et al.

A proprietary study evaluated 88 drivers between the ages of 21 and 70 in driver reaction to an automatic braking response in an imminent crash situation. Two of the driving scenarios were backing tasks: short range backing and long range backing; the third was a forward scenario. One of these scenarios involved an event that occurred as a complete surprise, when participants were unaware both that a backing system was on the vehicle and that they would encounter an event. The "Barrel Launch" trial occurred while backing along a line of stationary barrels. One of those barrels was launched into the path of the vehicle. Subsequent trials were treated as alerted trials, since participants knew that the vehicle was equipped with a special system and that they may encounter events. The automatic braking (AB) system was able to apply the brakes faster than even attentive drivers, at a mean of 0.36 s. In contrast, the brake reaction times for drivers, even attentive ones, were longer – with the means falling at 0.82 s with the AB system versus 1.33 s without the AB system (all of these times are for the surprise event only). Reaction times of the drivers to apply the brakes were significantly shorter for those that experienced the early autonomous braking system, by 0.51 seconds. The onset of this early automatic braking system served as an effective braking cue to elicit driver braking. On average, drivers with the automatic braking system responded on the brake 0.84 s faster than drivers without the system in backing maneuvers. Figure F- 2 shows the cumulative distributions for the Brake Reaction Times across these conditions, and Table F- 1 shows percentile values for reaction time by scenario for the surprise event. For each of the three backing scenarios, brake reaction times are separately listed for the automatic braking system (AB System Brake RT), conditions in which drivers alone did the braking (Driver Brake RT), and driver latency to brake after an automatic braking system response (Driver Latency to Respond Following AB).

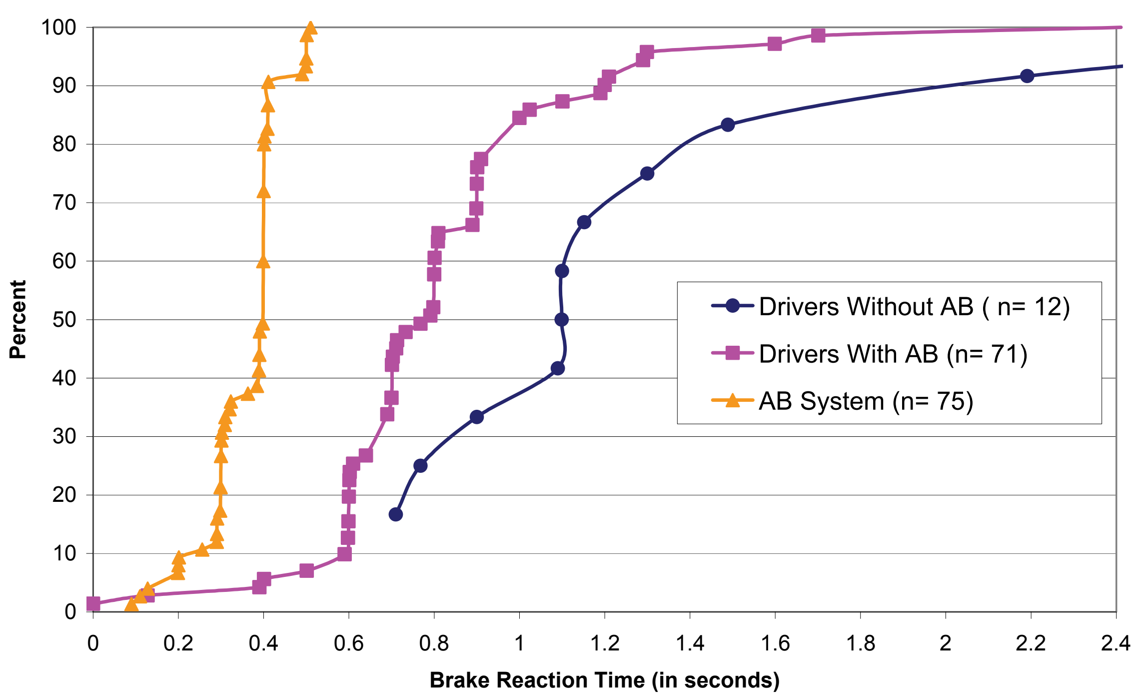

Figure F- 2. Brake Reaction Times for three conditions: Drivers without automatic braking, drivers with automatic braking, and for the automatic braking system itself. Times are for the surprise event only. Taken from Llaneras, McLaughlin, et al. (proprietary).

Table F- 1. Various braking reaction times to the surprise event from Llaneras, McLaughlin, et al. (proprietary). "AB" represents "Automatic Braking" in the table below. "Driver Brake RT" refers to "Driver Alone." Taken from Llaneras, McLaughlin, et al. (proprietary).

Task	**Percentile Values**				
	10th	**25th**	**50th**	**75th**	**90th**
Long Backing					
AB System Brake RT	0.30	0.39	0.40	0.41	0.50
Driver Brake RT	0.51	0.69	0.80	0.91	1.59
Driver Latency to Respond Following AB	0.10	0.20	0.40	0.50	0.89
Driveway Backing					
AB System Brake RT	0.19	0.27	0.35	0.40	0.40
Driver Brake RT	0.61	0.70	1.00	1.21	1.49
Driver Latency to Respond Following AB	0.20	0.34	0.56	0.80	1.29
Overall					
AB System Brake RT (sec)	0.26	0.30	0.39	0.40	0.41
Driver Brake RT (sec)	0.59	0.69	0.80	1.00	1.29
Driver Latency to Respond Following AB (sec)	0.19	0.29	0.41	0.60	0.85

1.1.2 Driver Foot Position at Initiation of Braking

The position of the driver's foot at the time of an alert was found to be an important predictor for brake reaction time (Harpster, Huey, & Lerner, 1996; Paine & Henderson, 2001). Reaction times were up to a second faster when the foot was on the brake pedal at the onset of the alert compared to when it was on the gas pedal and had to be moved to the brake. If the foot was already on the brake pedal, reaction times averaged 0.3 seconds, whereas mean reaction times were 0.66 seconds for those whose foot was on the accelerator (collapsed across all conditions). Two studies, in particular, provide relevant data on this effect. Note that these two studies used drivers who were aware they would receive an alert, and in that sense were not surprised by that alert. Studies including surprise events (discussed in the previous section) typically find a large influence of surprise in the length of time to react to the event. Therefore, use of the reaction times observed in these studies should occur in conjunction with adjustments or corrections based on this "surprise" effect.

1.1.2.1 Lerner, Harpster, Huey, and Steinberg (1997)

Reaction time to alerts given during backing tasks was investigated. Twelve drivers in two age groups, older (70 +) and younger (20-40), who were divided equally by gender, drove their own vehicle in a range of backing maneuvers. Three backing tasks were used: backing to a wall, parallel parking between two cars, and extended curved backing. Alarms were triggered at three locations (early, late and none). Table F- 2 below shows mean speed and brake reaction time as a function of foot location (at onset of alert). Standard deviations of the mean are in a separate column. Values found were similar to those in previous studies (N. D. Lerner, Ratte, & Huey, 1990) which suggested a brake reaction time in the range from 0.50 to 0.75 seconds as a response to an unpredictable acoustic signal, with the most typical values around 0.30 seconds for those drivers whose feet were on the brake at the onset of the signal.

Table F- 2. Participant brake reaction times by driver foot position on pedal prior to alert. Taken from Lerner, Harpster, Huey, and Steinberg (1997).

	Mean Speed (km/h)	Mean Brake Reaction Time (s)	SD of brake reaction time (s)	Mean total distance (m)
Overall	4.2	0.54	.	2.2
Driver Foot Position				
Accelerator	5.0	0.66	0.31	2.8
Brake	3.4	0.30	0.09	1.3
Neither	3.1	0.41	.	1.2

1.1.2.2 Harpster, Huey, Lerner and Steinberg (1996)

Brake reaction time as a response to an auditory alert during backing was examined. Participants drove their own vehicles to six different locations where three different backing sequences were performed (extended curved backing, backing to a wall, and parallel parking). Participant age and gender were controlled. Two different age groups, older (mean 71.5 yrs) and younger (mean 30.5 yrs) participated in the study. Three males and three females were included in each group for a total sample size of 12. Twelve trials were completed per participant (3 tasks, 4 alert conditions [early, middle, late, none]). Foot position, reaction time, and stopping time were measured. Table F- 3 below shows *mean reaction time* as well as the *standard deviation (SD)* of reaction time as a function of foot pedal position at alert onset for each age group (older and younger) as well as overall. Age of the participant was not found to have any significant effect on reaction times. As can be seen in Table F- 3, however, older drivers' backing speeds were slightly slower (Harpster, Huey, & Lerner, 1996; Harpster, Huey, Lerner, & Steinberg, 1996). The brake reaction times between ages were similar, showing that brake reaction times tend to be faster when the foot is already positioned on the brake, and slower when the foot must be moved from some other location to the brake (with the slowest reaction times being associated with movement from the gas pedal to the brake pedal). The only condition in which age groups appeared to perform a little differently was the one condition in which the foot was already on the brake pedal. Under that condition, the older drivers' reaction times were slower than for the one younger driver for whom data were available in that condition. However, given that only a single data point was available for younger drivers in the "foot on brake pedal" condition, the observation may not be stable, and the possibility of an interaction could not be tested formally. Therefore, for purposes of the SIM, these studies did not reveal a substantial effect of age on brake reaction time – but did identify that the position of the foot at the time braking is initiated does affect brake reaction times.

Table F- 3. Participant backing speed and brake reaction times as a response to an auditory alarm as a function of foot position (at time of alert) and age group. Taken from Harpster, Huey, Lerner and Steinberg (1996).

Driver Foot Position	N	Speed		Reaction Time (s)	
(pedal location of foot at time of alert)		Mean	SD	Mean	SD
Overall	78	2.6	2.2	0.54	0.31
Gas	43	3.1	2.7	0.66	0.31
Brake	11	2.1	1.2	0.30	0.09
Neither	24	1.9	1.1	0.41	0.21
Older Overall	44	2.1	1.2	0.53	0.32
Gas	19	2.3	1.5	0.72	0.30
Brake	10	1.9	1.0	0.41	0.30
Neither	15	1.8	0.8	0.38	0.23
Younger Overall	34	3.3	2.9	0.56	0.29
Gas	24	3.7	3.2	0.62	0.32
Brake	1	4.3	.	0.10	.
Neither	9	2.0	1.5	0.46	0.14

Table F- 4 provides percentile and standard deviation data for brake reaction times (from the Harpster, Huey, Lerner et al., 1996 study), as a function of foot position for the group overall and for each age group separately.

Table F- 4. The 90th percentile for brake reaction time by foot position and age group. Taken from Harpster, Huey, Lerner and Steinberg (1996).

Participant Reaction Time	N	Reaction Time (s)		
		90%	Mean	SD
Overall	78	0.89	0.54	0.31
Gas	43	1.04	0.66	0.31
Brake	11	0.78	0.30	0.09
Neither	24	0.71	0.41	0.21
Older Overall	44	0.97	0.53	0.32
Gas	19	1.09	0.72	0.30
Brake	10	0.83	0.41	0.30
Neither	15	0.80	0.38	0.23
Younger Overall	34	0.87	0.56	0.29
Gas	24	0.92	0.62	0.32
Brake	1	.	0.10	.
Neither	9	0.70	0.46	0.14

Differences in brake reaction time as a function of foot position arise because foot position relative to the pedals can vary during backing in one of three ways:

1. During different <u>phases</u> of the backing sequence, the driver's foot may be differently positioned:

a. During the preparatory phase – the foot may be on the brake, especially since it is required to be for the shift from Park to Reverse

b. During active backing – the foot will likely be on the gas pedal to accelerate in reverse,

c. During modulations of active backing – the foot may be shifting between the brake and accelerator, or held somewhere between the two, and

d. At end of a backing maneuver, full braking may occur prior to the driver's shifting into forward gear and transitioning into another (e.g., forward) maneuver

2. During <u>alert sequences</u> from a countermeasure, depending on the type of alert that has been issued, the driver's foot movement to the brake may be elicited (e.g., after a brake pulse, the driver's foot may move to the brake, thereby decreasing the brake reaction time), and

3. In connection with and contingent upon other driver behaviors (such as glances). For example, glancing at and noticing a backing conflict on a rear video screen – or glancing over the shoulder and noticing an incurring obstacle in some conditions – may lead automatically to the movement of the foot to the brake pedal (with some probability and haste that are unknown).

Knowledge of these foot behaviors, and the way that they co-vary with other aspects of backing conditions, would allow the SIM to apply reaction times from the appropriate brake reaction time distribution (depending upon the exact phase of backing at which the braking is occurring, whether it is within an alert sequence or not [and, if so, what type], and whether there are any other co-occurring behaviors that might facilitate a faster reaction time). However, data on the frequencies with which these behaviors occur are not publicly available, and make adaptation of this parameter to the SIM possible only as part of future efforts outside the scope of the current project. Furthermore, issuance of an alert does not necessarily imply that the driver will respond. These times are useful when drivers brake, but drivers may choose not to do so (e.g., when they receive an auditory alert but cannot find visual confirmation of the threat while backing).

1.1.3 Gender Effects on Brake Reaction Time

Harpster, Huey, Lerner et al. (1996) found no appreciable effects of gender on brake reaction times, as can be seen in Table F- 5 (showing mean brake reaction times) and Table F- 6 (showing 90th percentile and mean brake reaction times). On the basis of this finding, it would not appear necessary for the SIM to address gender differences with respect to Brake Reaction Time. There are some studies, however, that have revealed a significant gender effect; and it has been difficult to determine why it has emerged in those studies and not others (Llaneras, McLaughlin et al., proprietary; Llaneras, Neurauter, Doerzaph, & Green, proprietary).

Table F- 5. Participant mean reaction time as a response to an auditory alarm, broken down by gender. Taken from Harpster, Huey, Lerner and Steinberg (1996).

Gender	N	Speed		Reaction Time (s)	
		Mean	SD	Mean	SD
Male	45	2.5	2.1	0.54	0.29
Female	33	2.7	2.3	0.56	0.33

Table F- 6. The 90th percentile for brake reaction time by gender. Taken from Harpster, Huey, Lerner and Steinberg (1996).

Gender	N	Reaction Time (s)		
		90%	Mean	SD
Overall	78	0.89	0.54	0.31
Male	45	0.87	0.54	0.29
Female	33	0.98	0.56	0.33

1.1.4 Effects of Backing Task and Timing of Alert

Harpster, Huey, Lerner et al. (1996) found some variation in mean brake reaction times as a function of three backing tasks (parallel parking, backing toward a wall, and backing around an extended curve) – ranging between 0.45 and 0.63 seconds. Somewhat larger variations in brake reaction times were found as a function of the timing of an alert (here the range was from 0.33 to 0.81, and depended upon braking maneuver). Early alerts tended to lengthen reaction times for the parallel parking and extended curve backing maneuvers. In Table F- 7, the means and SDs for brake reaction times (broken down by timing of alert) are shown.

Table F- 7. Participant mean brake reaction times as a response to an auditory alarm, shown as a function of task and timing of alert (early, middle, and late). Taken from Harpster, Huey, Lerner and Steinberg (1996).

Task	N	Reaction Time (s)	
		Mean	SD
Parallel	17	0.53	0.37
Early	7	0.80	0.42
Middle	7	0.33	0.18
Late	3	0.36	0.23
Wall	27	0.45	0.21
Early	8	0.44	0.31
Middle	10	0.50	0.11
Late	9	0.39	0.18
Extended Curve	34	0.63	0.32
Early	12	0.81	0.38
Middle	12	0.49	0.26
Late	10	0.58	0.23

1.1.4.1 Llaneras, McLaughlin et al.

As previously described, this was a proprietary study that evaluated 88 drivers between the ages of 21 and 70 in driver reaction to an automatic braking response in an imminent crash situation. Recall that two of the driving scenarios were backing tasks: short range backing and long range backing; the third was a forward scenario. One of these scenarios involved an event that occurred as a complete surprise, when participants were unaware both that a backing system was on the vehicle and that they would encounter an event. Subsequent trials were treated as “alerted” trials, since participants knew that the vehicle was equipped with a special system and that they may encounter events. Table F- 8 displays brake reaction times for the two expected event trials and one surprise trial (means and standard deviations). Note how much longer the surprise (unexpected event) took for the driver to respond.

Table F- 8. Brake reaction time for expected and unexpected events in the Llaneras et al. study. Taken from Llaneras, McLaughlin, et al. (proprietary).

Trial	Reaction Time (s)	Standard deviation (s)
First Expected Event	0.61	0.37
Second Expected Event	0.54	0.20
Unexpected event with AB system	0.94	0.63

Table F- 9 shows means and standard deviations for non-alerted (surprise) Driver Brake Reaction Times and Latencies to Brake following an automatic braking engagement, as a function of key independent variables in the study. The only significant effect among these variables was for "Experimental Condition" (i.e., between the conditions in which automatic braking was and was not active). Neither age nor gender gave rise to significant main effects, nor did backing scenario.

Table F- 9. Means and Standard Deviations for Key Measures and Independent Variables: Surprise (Non-Alerted) Event Trial. Taken from Llaneras, McLaughlin, et al. (proprietary).

Non-alerted Trials		Driver Brake RT		Latency to Brake	
	N	Mean	Std Dev	Mean	Std Dev
Overall	88	0.90	0.46	0.47	0.35
Experimental Condition					
No AB	12	1.33	0.79	.	.
With AB	76	0.82	0.34	0.47	0.35
Age					
Young	22	0.86	0.29	0.54	0.23
Middle 1	21	0.94	0.44	0.58	0.54
Middle 2	23	0.80	0.25	0.39	0.22
Older	22	1.00	0.74	0.39	0.33
Gender					
Male	44	0.86	0.25	0.49	0.24
Female	44	0.93	0.60	0.44	0.45
Scenario					
Long Backing	30	0.94	0.63	0.39	0.30
Driveway Backing	27	1.02	0.43	0.67	0.48

Table F- 10 shows the effects for *alerted* trials (when participants were both aware that their vehicle was equipped with automatic braking and that they may experience an event). For alerted trials, there were no significant effects of the independent variables on Driver Brake Reaction Time. While the effects of age were not significant, it is perhaps worth noting that while older drivers tended to be a bit slower to respond to surprise events, this was not the case on alerted trials. In fact, on alerted trials, there was a tendency for the younger drivers to respond a bit more slowly (while the middle-age and older drivers responded more quickly). Again, these tendencies were not significant as main effects of age in separately done ANOVAs on surprise versus alerted trials – but the possibility of an interaction between age and type of trial (alerted or surprise) may be an issue to be monitored in future research.

Table F- 10. Means and standard deviations for key measures and independent variables: Alerted event trials. Taken from Llaneras, McLaughlin, et al. (proprietary).

Alerted Trials		**Driver Brake RT**		**Latency to Brake**	
	N	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Overall	176	0.71	0.56	0.31	0.48
Age					
Young	44	0.88	0.76	0.41	0.50
Middle 1	42	0.67	0.50	0.34	0.52
Middle 2	46	0.61	0.23	0.23	0.24
Older	44	0.66	0.56	0.26	0.59
Gender					
Male	88	0.78	0.75	0.35	0.63
Female	88	0.63	0.22	0.27	0.25
Scenario					
Long Backing	49	0.60	0.27	0.21	0.27
Driveway Backing	51	0.75	0.43	0.40	0.46

1.1.4.2 Llaneras, Neurauter, et al.

A proprietary study further investigated driver reactions to an automatic braking system. It included 36 drivers who were exposed to an automatic emergency braking system in a number of different scenarios (including three surprise trials). Several backing maneuvers were performed, but drivers were asked to let the vehicle brake by itself for certain maneuvers, potentially altering their 'typical' backing behavior. However, collapsed across the two surprise events, 91.5 % of the participants braked as a reaction to the onset of the automatic braking while 8.5% did not brake. Of those who did brake, they managed to do so within approximately 2.5 seconds (90th percentile value) while most drivers braked within 1.5 seconds of onset and some drivers did so nearly instantly. Figure F- 3 below shows a brake reaction time profile in response to the automatic braking system. "Surprise event 1" had a mean brake reaction time of 1.37 seconds while "surprise event 2" had a mean brake reaction time of 0.92 seconds.

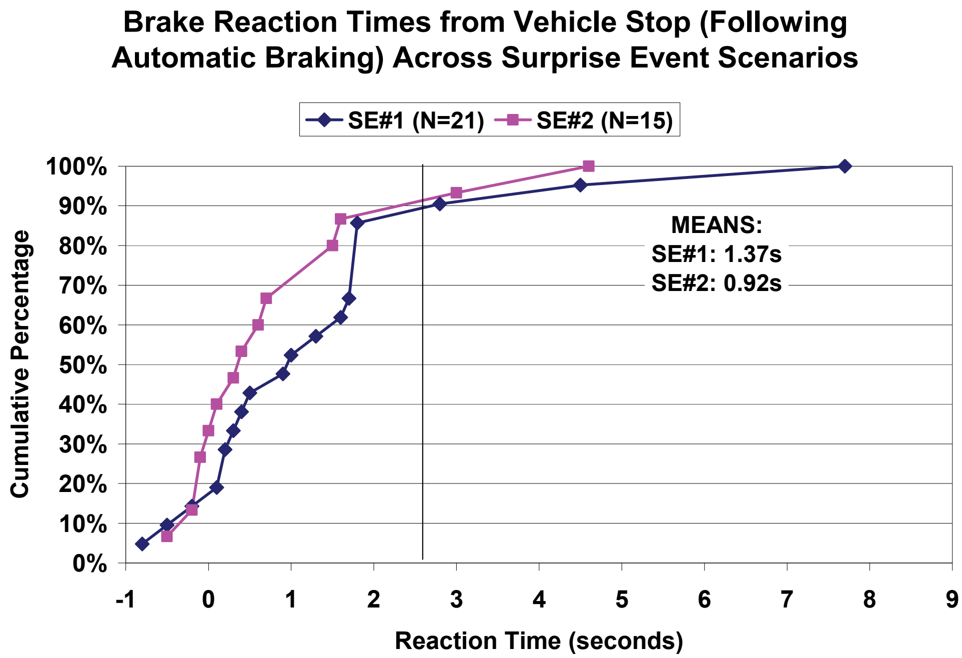

Figure F- 3. Cumulative percentage distribution of brake reaction times for surprise events 1 and 2. Taken from Llaneras, Neurauter, et al. (proprietary).

Surprise events included in this Llaneras, Neurauter, Doerzaph, & Green (proprietary) study are of particular interest. There were three of them that were used:

- Garage Urgency Event
- Cozy Coupe Event
- Cone Behind Vehicle Event

The "garage urgency trial" occurred while backing out of a garage. The automatic braking function was triggered by an experimenter to bring the vehicle to a stop while the garage door was closing. The "Cozy Coupe" trial (also called "Surprise Event #1") occurred while backing adjacent to a semi-trailer. A Cozy Coupe was pulled into the path of the vehicle. The second surprise event (or "cone behind vehicle" trial, "Surprise Event #2") occurred at the end of the study when a cone was placed behind the experimental vehicle when the participant was not aware. The participant was then told to back the car away from the building and park in a different spot. Table F- 11 displays the mean brake reaction times and their standard deviations for each type of surprise event. These reaction times reflect braking in response to surprise trials (but they also reflect driver braking in conjunction with – and in response to – the action of the automatic braking system in the context of the scenario). Note that they reveal that event type can have different magnitudes of effect on brake reaction times (ranging from 0.575 s to 1.964s).

Table F- 11. Brake Reaction time values calculated from Llaneras, Neurauter et al. (proprietary) data for the Surprise Events.

Surprise Event	Brake Reaction Time (s)	
	Mean	Std
Garage Urgency Trial	1.964	1.519
Surprise Event #1- Cozy Coupe	0.575	0.126
Surprise Event #2 – cone behind	1.270	1.290

1.1.4.3 Llaneras, Singer, Green, Huey, & Lerner (2002)

A study was conducted to investigate a rear object detection system intended for use as a parking aid. Data were collected through vehicle instrumentation, video, and questionnaires. Values below reflect those at the moments of a surprise backing event where a toy car was moved into the path of the backing vehicle. Table F- 12 below shows several percentile values for brake reaction time. Note that some trials had no brake reaction time at all (since the driver hit the obstacle). In fact, for some alert conditions, these trials without driver response represented a majority. Therefore, the values below are not representative of the full study sample.

Table F- 12. Alerted brake reaction time percentile values for the Llaneras, Singer, Green, Huey, & Lerner (2002) study.

Dependent Measures	Percentile Values				
	5th	10th	50th	90th	95th
Brake Reaction Time	0.23 s	0.03 s	0.60 s	1.00 s	1.10 s

Figure F- 4 shows the distributions of alerted backing brake reaction time for each timing algorithm (combining data across Minivan and Sedan vehicles utilized).

Table F- 13 below shows the further breakdown of each of the trials which had different levels of speed instruction ("normal" and "hurried") and trial. These values are also shown as a function of vehicles used (i.e., Minivan versus Sedan).

Table F- 14 displays brake reaction time means and standard deviations for each of the independent variables investigated in this study, including vehicle type. Significant effects were Vehicle Type, Age, Gender, Speed Instruction, and Timing. Table F- 15 gives these data from just the Minivan vehicle. Note again in both that the tendency is for younger drivers to be the ones responding a bit more slowly on the alerted trials (while the older and middle aged drivers responded with similar brake reaction times). This study thus replicates a tendency revealed in the previously reported study by Llaneras, McLaughlin, et al. (proprietary).

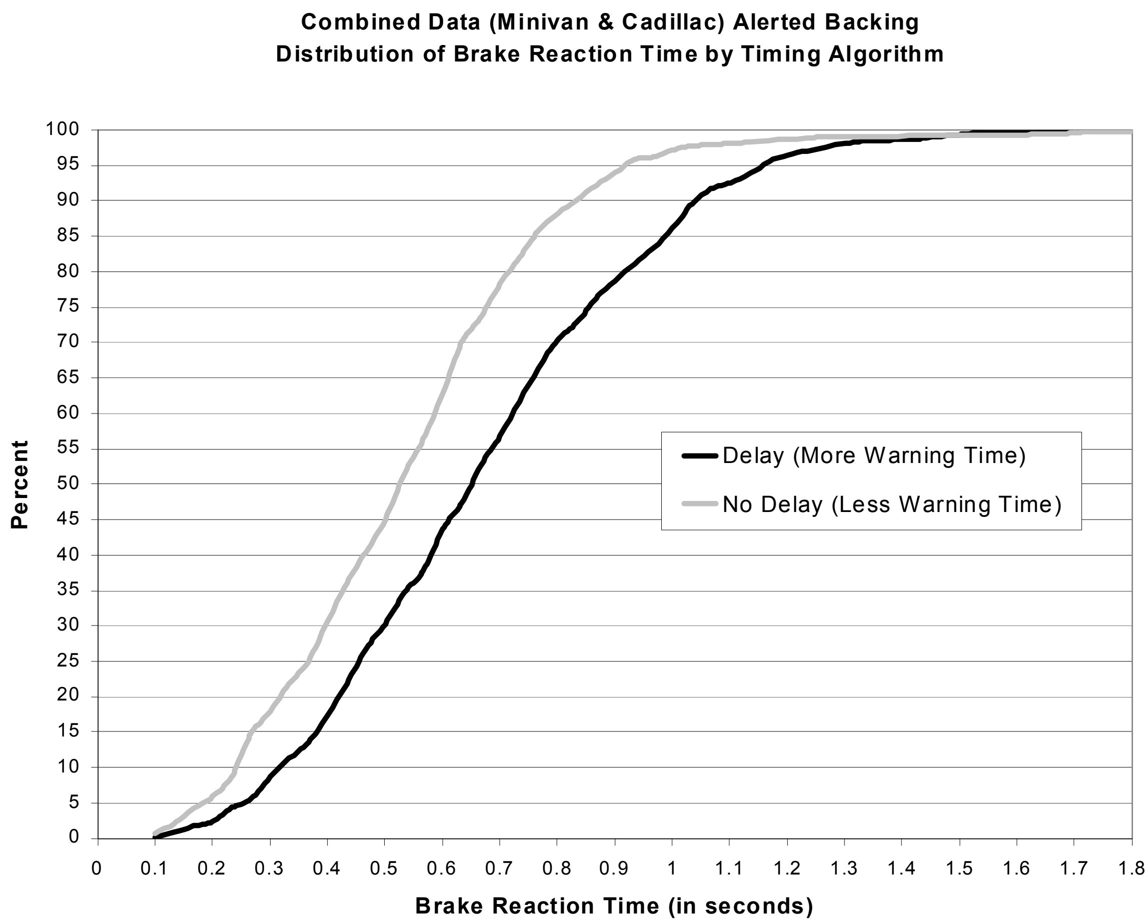

Figure F- 4. Distribution of alerted Brake Reaction Times by Timing Algorithm. Taken from Llaneras, Singer, Green, Huey, & Lerner (2002).

Table F- 13. Brake reaction time percentile values by trial and vehicle type. Taken from Llaneras, Singer, Green, Huey, & Lerner (2002).

Trial	Percentile Values (s)									
	Minivan					Sedan				
	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
All trials	0.37 s	0.43 s	0.70 s	1.03 s	1.17 s	0.17 s	0.23 s	0.43 s	0.77 s	0.97 s
Alerted backing, normal speed instruction	0.40 s	0.43 s	0.73 s	1.13 s	1.23 s	0.17 s	0.23 s	0.43 s	0.73 s	0.90 s
Alerted backing, fast speed instruction	0.33 s	0.43 s	0.67 s	0.93 s	1.00 s	0.17 s	0.23 s	0.47 s	0.80 s	1.00 s
Alerted backing, 50 ft normal speed instruction	0.40 s	0.47 s	0.77 s	1.17 s	1.30 s	0.17 s	0.20 s	0.40 s	0.67 s	0.70 s
Alerted backing, 50 ft fast speed instruction	0.43s	0.50 s	0.73 s	0.97 s	1.03 s	0.23 s	0.27 s	0.50 s	0.70 s	0.77 s
Alerted backing, 150 ft normal speed instruction	0.37s	0.43 s	0.70 s	1.10 s	1.17 s	0.20 s	0.27 s	0.47 s	0.83 s	1.03 s
Alerted backing, 150 ft fast speed instruction	0.27s	0.33 s	0.63 s	0.90 s	0.97 s	0.17 s	0.20 s	0.40 s	0.97 s	1.07 s

Table F- 14. Minivan & Sedan data: Means and standard deviations for key measures and main effects. Taken from Llaneras, Singer, Green, Huey, & Lerner (2002).

		Brake Reaction Time (s)	
	N	**Mean**	**Std Dev**
Vehicle			
Minivan	632	0.73	0.25
Sedan	539	0.48	0.25
Age			
Young	378	0.71	0.3
Middle	430	0.61	0.26
Old	377	0.56	0.25
Gender			
Male	591	0.60	0.26
Female	594	0.65	0.29
Backing Maneuver			
50 ft Straight Backing	596	0.64	0.28
150 ft Straight Backing	589	0.61	0.27
Speed Instruction			
Normal Speed	595	0.65	0.31
Fast Speed	590	0.60	0.27
Timing			
Delay	624	0.69	0.29
No Delay	561	0.55	0.25
Target			
Person	589	0.62	0.27
Wall	596	0.62	0.27
Interface			
Five Beep	469	0.60	0.26
Eight Beep	214	0.75	0.25
CAMP	216	0.70	0.25
Two Stage	286	0.49	0.28

Table F- 15. Minivan data: Means and standard deviations for key measures and main effects. Taken from Llaneras, Singer, Green, Huey, & Lerner (2002).

		Brake Reaction Time (s)	
	N	**Mean**	**Std Dev**
Age			
Young	215	0.84	0.25
Middle	238	0.69	0.22
Old	191	0.65	0.22
Gender			
Male	333	0.68	0.23
Female	311	0.79	0.25
Backing Maneuver			
50 ft Straight Backing	323	0.77	0.24
150 ft Straight Backing	321	0.69	0.24
Speed Instruction			
Normal Speed	322	0.78	0.28
Fast Speed	322	0.68	0.2
Timing			
Delay	321	0.81	0.25
No Delay	323	0.65	0.22
Target			
Person	320	0.74	0.24
Wall	324	0.72	0.25
Interface			
Five Beep	214	0.73	0.24
Eight Beep	214	0.75	0.25
CAMP	216	0.7	0.25
Two Stage	644	0.73	0.25

1.1.4.4 Singer, Llaneras, Rahman, & Green (2005)

Further investigation into the rear obstacle detection system was accomplished through an examination of different alerts that included a "Brake Pulse", in response to the lack of success with audible and visual alert combinations. A single stage alert (imminent collision alert plus brake pulse) and a two stage alert (initial alert and imminent collision alert plus brake pulse) were used. Both were evaluated in a condition where the event was a surprise and in a condition where participants had a priori knowledge of the braking system. Table F- 16 provides the mean latency of braking onsets (together with the range of braking onsets) for each type of alert explored. Note that the findings revealed that brake reaction times were shortened only by alerts occurring close in time to the need for braking. (With the two stage alerts, drivers had more time to brake to the obstacle, and took more time to do so). A similar effect was found by Harpster, Huey, Lerner, et al. (1996).

Table F- 16. Latency (in seconds) of braking onset following alert onset. Taken from Singer, Llaneras, Rahman, & Green (2005).

Configuration	Average (s)	Range (s)	N
Single Stage (No Delay)	0.7	0.4 – 1.2	9
Single Stage	0.6	0.2 – 0.9	7
Two Stage	2.1	0.2 – 4.9	16

1.2 Braking Performance Distribution

In determining how to represent deceleration in the SIM, backing studies which measured deceleration as a separate dimension of performance were examined. Several issues emerged from this review as important considerations for the SIM.

First, it is important to determine which deceleration metric(s) to use in representing deceleration (is it most appropriate to use "peak deceleration during maneuver," or a measure representing "average deceleration"?). The two metrics describe slightly different properties of deceleration, and are sometimes affected by different variables. More appropriate than either of these two metrics is "required deceleration" which uses distance traveled and velocity difference to represent the slowing as a constant deceleration during a braking period. This constant deceleration can then be used in kinematics equations. Unfortunately, "required deceleration" is not typically reported for backing maneuvers, experimental or otherwise.

Second, it is critical to understand which factors most significantly influence deceleration as it might be applied and used within the SIM. In terms of this second issue, several factors appear to be particularly important for deceleration:

1. Identifying the system element that is applying the brakes (the countermeasure system, the driver, or both)
2. The type of backing maneuver (and its kinematics)
3. The type of run – surprise or alerted
4. The type of alert/timing
5. Vehicle Type

Additional factors can sometimes modulate deceleration, but usually do so with smaller magnitude effects when they are present at all. These include: Age, Gender, and their interaction. Due to their lack of practical significance in their effect size, these factors are not described in this brief summary of the literature.

1.2.1 Review of Deceleration Data Available in Prior Literature

1.2.1.1 <u>Estimates and Ranges Used for Deceleration in Prior Work</u>

Paine & Henderson (2001). Paine and Henderson evaluated backing technologies to help reduce risk to young pedestrians. For their analysis of stopping distance with respect to an alarm (in a simulation), they assumed a mean deceleration of 0.5 g; in contrast, Eberhard et al. used a range of 0.65g to 0.75g

(C. Eberhard, Moffa, Young, & Allen, 1995). Based on these values, a probability of avoiding a collision was calculated.

It is also important to examine studies in which empirical data have been acquired during actual backing maneuvers (both with and without countermeasure assistance), to compare such data to the estimates that have been previously used. The key studies are described in turn. Note that in examining the results of these studies, it is important to remember that deceleration depends on which system element(s) (e.g., automatic braking, driver, both) is performing the braking.

1.2.1.2 Llaneras, McLaughlin, et al.

A proprietary study looked at participants' reactions to an automatic braking system. Brake reactions were taken from two separate surprise event scenarios (a third was used in the experiments, but it involved driving forward). Several tables below show means, standard deviations, and percentiles for deceleration following braking in various conditions executed in the study. The median peak deceleration level during the surprise event trial was 0.61 *g* and an inter-quartile range of 0.40 *g* to 0.72 *g*. Note that while these represent peak decelerations, the range would appear to correspond rather well with Paine and Henderson (2001), and especially Eberhard et al. (1995). Drivers with the automatic braking system tended to brake harder than those without the system, achieving more deceleration (0.63 *g* versus 0.49 *g* respectively). Below (in Figure F- 5) is a profile plot of deceleration levels for each condition, with and without automatic braking.

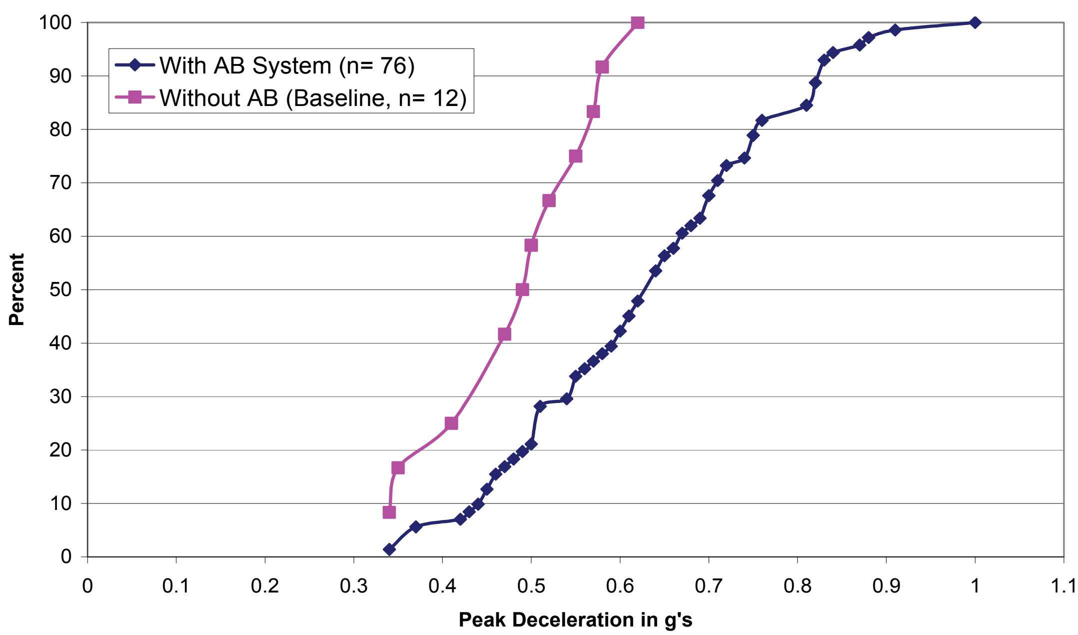

Figure F- 5. Cumulative frequency plot of peak decelerations from Llaneras, McLaughlin, et al. (proprietary).

The maximum deceleration achieved by the automatic braking system alone before driver intervention (i.e., braking) was 0.58 *g*, with a median deceleration of 0.33 *g* and an inter-quartile range of 0.12 to 0.40 *g* (Figure F- 6). In other words, the Autonomous Braking system was able to apply a brake force resulting in a median maximum deceleration of 0.33 *g* *before* drivers were able to respond to the imminent threat with supplemental braking.

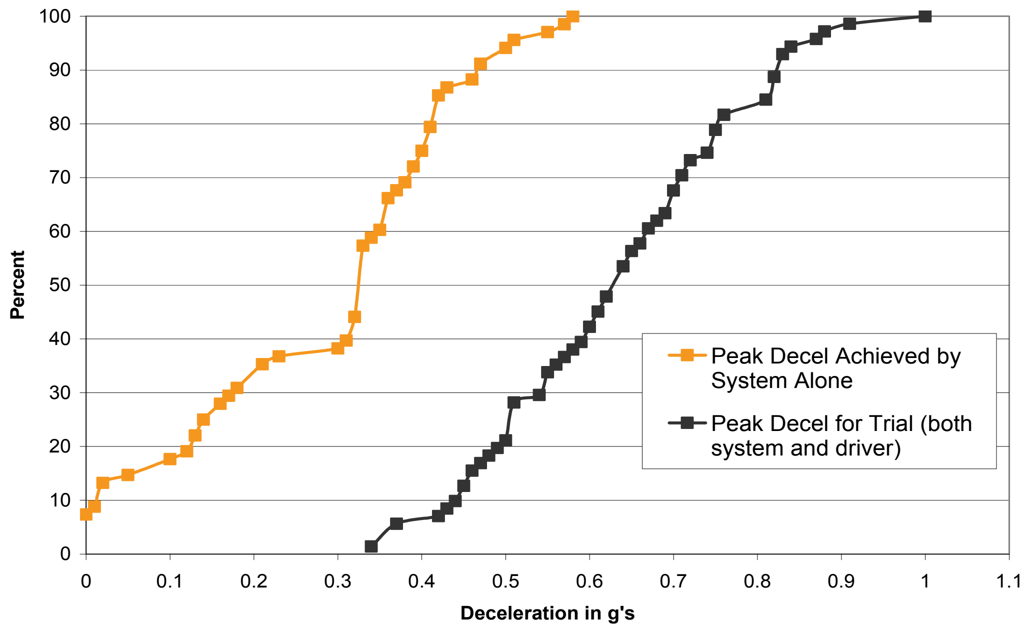

Figure F- 6. Cumulative frequency plot for conditions in which the autonomous braking system was engaged, showing peak decelerations for system alone and system + driver in the surprise event trial. Taken from Llaneras, McLaughlin, et al. (proprietary).

Two additional key points from this study, illustrated in Figure F- 7, are:

(1) Levels of maximum deceleration for backing are below those for forward maneuvers (due to the lower speeds at which backing maneuvers occur). Backing maneuvers were characterized by median maximum deceleration levels of 0.63 and 0.49 *g* for long and driveway backing, respectively – contrasting with higher deceleration rates associated with forward driving scenarios (median maximum deceleration of 0.77 *g*).

(2) Maximum deceleration levels were greatly affected by backing scenarios (when combined braking by system and driver is considered).

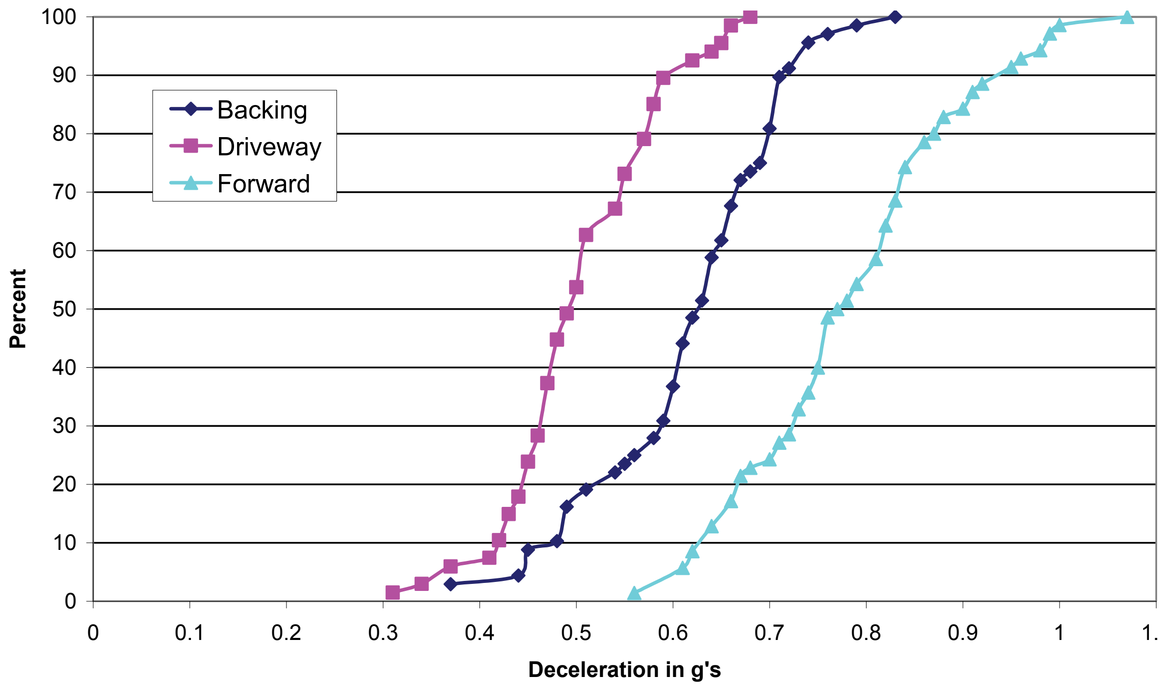

Figure F- 7. Peak deceleration observed across all trials (expected and unexpected), driver and system braking combined, by scenario. Taken from Llaneras, McLaughlin, et al. (proprietary).

When braking by just the system alone was considered at driver brake contact, the shapes of distributions for deceleration were similar, regardless of different backing maneuvers (i.e., long backing and driveway backing) – but when the combined response of the driver and system working together was considered, the distribution shapes differed by backing maneuver. This can be seen in Table F- 17.

Table F- 17. Percentile values for peak deceleration during different maneuvers examined in Llaneras, McLaughlin et al. (proprietary).

Task	Percentile Values				
	10th	25th	50th	75th	90th
Long Backing					
Peak Decel at Driver Brake Contact	0.00	0.13	0.33	0.40	0.50
Peak Trial Decel (Both Driver & System)	0.44	0.55	0.62	0.68	0.71
Driveway Backing					
Peak Decel at Driver Brake Contact	0.02	0.10	0.33	0.42	0.51
Peak Trial Decel (Both Driver & System)	0.37	0.43	0.48	0.51	0.57
Overall					
Peak Decel at Driver Brake Contact (g)	0.01	0.12	0.33	0.40	0.47
Peak Trial Decel (Both Driver & System) (g)	0.43	0.50	0.61	0.72	0.82

Surprise versus Alerted trials were separately analyzed. When considering just the peak deceleration achieved by the human driver acting alone – the typical effect of surprise versus alerted state can be seen. Surprise trials led to higher decels (near 0.35 *g* due to drivers braking later) and alerted trials produced less deceleration (around 0.22-0.31 *g*). Beyond this effect, peak deceleration levels were significantly affected by type of driving scenario (long backing versus driveway backing) – and by the presence or absence of autonomous braking. Table F- 18 provides the mean peak decelerations for expected versus surprise events, as a function of event types. What is most salient is that the factor influencing peak decelerations for all event types was Backing Scenario (long backing versus driveway backing). Long backing led to higher peak decelerations, on average, than driveway backing during both surprise and alerted events of all types.

Table F- 18. Mean Peak Decelerations for combined system + driver, driver-alone, and system-alone as a function of event types. Taken from Llaneras, McLaughlin, et al. (proprietary).

Trial	Mean Peak Deceleration (stdev) in *g*	Mean Peak Deceleration (human only) (stdev) in *g*	Mean Peak Deceleration (system only) (stdev) in *g*
Expected Event 1 – long backing	.61 (.10)	.31 (.15)	.30 (.20)
Expected Event 1 – driveway	.53 (.08)	.26 (.18)	.25 (.23)
Expected Event 2 – long backing	.64 (.08)	.22 (.16)	.42 (.21)
Expected Event 2 - driveway	.51 (.07)	.28 (.15)	.23 (.18)
Surprise Event – long backing	.64 (.10)	.35 (.16)	.29 (.20)
Surprise Event - driveway	.47 (.06)	.35 (.15)	.12 (.15)

For surprise trials, on peak trial deceleration there was no gender or age effect; only whether braking was assisted or not – and type of backing maneuver / scenario. Driveway backing led to slower travel speeds, lower peak decelerations, and no age or gender effects. Table F- 19 provides the means and standard deviations for the factors analyzed in the study.

Table F- 19. Means and standard deviations for key measures and independent variables: Surprise event trial. Taken from Llaneras, McLaughlin, et al. (proprietary).

Surprise Event Trial		Speed At Launch		Peak Decel		Peak AB Decel	
	N	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Overall	88	8.78	4.10	0.61	0.15	0.27	0.17
Experimental Condition							
No Automatic Braking	12	9.62	4.31	0.49	0.09	.	.
Automatic Braking	76	8.64	4.08	0.63	0.15	0.29	0.16
Age							
Young	22	9.41	4.30	0.62	0.15	0.28	0.17
Middle 1	21	9.26	3.76	0.63	0.11	0.31	0.17

Middle 2	23	8.40	3.91	0.61	0.18	0.23	0.17
Older	22	8.08	4.51	0.59	0.15	0.25	0.18
Gender							
Male	44	8.69	4.00	0.62	0.15	0.30	0.16
Female	44	8.78	4.24	0.60	0.15	0.23	0.18
Scenario							
Long Backing	30	8.32	2.74	0.61	0.11	0.28	0.18
Driveway Backing	27	4.34	0.93	0.48	0.08	0.27	0.19

For alerted trials, on peak trial deceleration, there was also an effect for type of backing maneuver or scenario. There was still no age effect, but there was a small gender effect and interaction in which females drove slower, producing lower peak decelerations (except for the females between ages 46-59, who performed similarly to their male counterparts). Table F- 20 displays the means and standard deviations for the factors analyzed in the study.

Table F- 20. Means and standard deviations for key measures and independent variables: Alerted event trials. Taken from Llaneras, McLaughlin, et al. (proprietary).

Alerted Event Trial		**Speed At Launch**		**Peak Decel**		**Peak AB Decel**	
	N	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Overall	176	7.75	3.84	0.64	0.15	0.16	0.17
Age							
Young	44	8.39	3.58	0.64	0.15	0.18	0.19
Middle 1	42	7.55	4.00	0.65	0.13	0.17	0.16
Middle 2	46	7.89	3.59	0.66	0.16	0.19	0.18
Older	44	7.07	4.24	0.60	0.16	0.11	0.15
Gender							
Male	88	8.40	3.86	0.66	0.15	0.14	0.17
Female	88	7.10	3.73	0.61	0.16	0.18	0.18
Scenario							
Long Backing	49	7.27	2.92	0.61	0.10	0.16	0.19
Driveway Backing	51	4.11	0.91	0.51	0.08	0.20	0.17

1.2.1.3 Llaneras et al. (2002)

A backing study was conducted by Westat in which a rear near-object detection system was evaluated. Values below reflect those at the moments of a surprise backing event where a toy car was moved into the path of the backing vehicle under different scenarios varying in length of backing and backing speed instructions. The table below (Table F- 21) shows percentile values for several vehicle dynamics metrics, including Actual (averaged) deceleration that occurred and Maximum (peak) deceleration. Note that this study did not consider an automatic braking countermeasure. Therefore, the values tend to be lower than those for Llaneras, McLaughlin, et al. (proprietary) because only the driver is braking. Note that in this study deceleration was expressed as a negative value. That convention is maintained in our description of this study and in describing the percentile values. Note also that the figures reported in this section are for drivers receiving and responding to an alert, as opposed to drivers deciding when and how to brake while backing. Results for the latter will be presented in a subsequent section.

Noteworthy findings from this study include the fact that patterns of findings for peak versus averaged deceleration differed somewhat. Peak deceleration was significantly affected by vehicle type and backing maneuver. In contrast, Actual (averaged) deceleration was significantly affected by vehicle type but not by backing maneuver. Both metrics (peak and actual deceleration) were significantly affected by speed instructions and timing, as well as by age and gender.

Table F- 21. Percentile values for maximum and actual deceleration values (averaged across vehicle types). Taken from Llaneras et al. (2002).

Dependent Measures	Percentile Values				
	5th	10th	50th	90th	95th
Maximum Deceleration (g)	-0.53	-0.48	-0.33	-0.18	-0.17
Actual Deceleration (g)	-0.41	-0.34	-0.27	-0.19	-0.17

Data are separately provided for each of the two different vehicles used in this study (Minivan versus Sedan) in Table F- 22 (which shows Maximum, or Peak, Deceleration) for each of the backing scenario conditions and in Table F- 23 (which shows Actual, or Averaged, Deceleration).

Table F- 22. Percentile values for Maximum (peak) deceleration as a function of Conditions and Vehicle Type. Taken from Llaneras et al. (2002).

Trial	Percentile Values for maximum deceleration (g)									
	Minivan					Sedan				
	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
All trials	-0.41	-0.38	-0.24	-1.70	-1.60	-0.58	-0.54	-0.40	-0.31	-0.29
Alerted backing – normal speed instruction	-0.33	-0.29	-0.22	-0.16	-0.15	-0.51	-0.46	-0.37	-0.29	-0.28
Alerted backing – fast speed instruction	-0.45	-0.41	-0.33	-0.23	-0.22	-0.61	-0.57	-0.45	-0.34	-0.33
Alerted backing – 50 ft, normal speed	-0.44	-0.39	-0.29	-0.20	-0.18	-0.47	-0.44	-0.36	-0.29	-0.27
Alerted backing – 50 ft, fast speed	-0.38	-0.36	-0.29	-0.19	-0.18	-0.56	-0.54	-0.43	-0.34	-0.31
Alerted backing – 150 ft, normal speed	-0.40	-0.37	-0.28	-0.20	-0.19	-0.53	-0.50	-0.37	-0.30	-0.29
Alerted backing – 150 ft, fast speed	-0.43	-0.42	-0.32	-0.22	-0.20	-0.64	-0.61	-0.47	-0.36	-0.34

Table F- 23. Percentile values for Actual (averaged) deceleration shown as a function of Conditions and Vehicle Type. Taken from Llaneras et al. (2002).

Dependent Measures	Percentile Values for actual deceleration (g)									
	Minivan					Sedan				
	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
All trials	-0.43	-0.40	-0.30	-0.21	-0.20	-0.37	-0.33	-0.24	-0.17	-0.16
Alerted backing – normal speed instruction	-0.41	-0.38	-0.28	-0.20	-0.19	-0.31	-0.29	-0.21	-0.16	-0.15
Alerted backing – fast speed instruction	-0.42	-0.40	-0.30	-0.20	-0.19	-0.39	-0.36	-0.27	-0.20	-0.18
Alerted backing – 50 ft, normal speed	-0.27	-0.25	-0.20	-0.15	-0.14	-0.30	-0.28	-0.21	-0.16	-0.15
Alerted backing – 50 ft, fast speed	-0.36	-0.31	-0.19	-0.12	-0.11	-0.25	-0.23	-0.17	-0.11	-0.10
Alerted backing – 150 ft, normal speed	-0.37	-0.33	-0.23	-0.17	-0.16	-0.32	-0.30	-0.22	-0.17	-0.16
Alerted backing – 150 ft, fast speed	-0.36	-0.33	-0.21	-0.14	-0.13	-0.33	-0.31	-0.20	-0.13	-0.12

Table F- 24 displays the means and standard deviations for maximum and actual deceleration for the combined Minivan and Sedan data, on each of the variables analyzed with Analysis of Variance in the study. As previously mentioned, both metrics were significantly affected by vehicle type, speed instructions, timing, age and gender – and maximum deceleration was additionally affected by maneuver type. Table F- 25 shows the same analysis for Minivan data alone.

Table F- 24. Combined minivan & sedan data: Means and standard deviations for key measures and independent variables (main effects). Taken from Llaneras et al. (2002).

	N	Maximum Deceleration		Actual Deceleration	
		Mean	Std Dev	Mean	Std Dev
Vehicle					
Minivan	632	-0.31	0.08	-0.26	0.08
Sedan	539	-0.41	0.09	-0.25	0.06
Age					
Young	378	-0.31	0.11	-0.26	0.08
Middle	430	-0.34	0.11	-0.29	0.07
Old	377	-0.34	0.16	-0.29	0.07
Gender					
Male	591	-0.34	0.11	-0.29	0.08
Female	594	-0.32	0.12	-0.27	0.07
Backing Maneuver					
50 ft straight	596	-0.31	0.11	-0.28	0.08
150 ft straight	589	-0.35	0.12	-0.28	0.07
Speed Instruction					
Normal	595	-0.29	0.10	-0.26	0.07
Fast	590	-0.37	0.11	-0.31	0.07
Timing					
Delay	624	-0.32	0.11	-0.27	0.08
No Delay	561	-0.34	0.11	-0.29	0.07
Target					
Person	589	-0.33	0.11	-0.28	0.08
Wall	596	-0.33	0.11	-0.28	0.08
Interface					
Five Beep	469	-0.34	0.11	-0.28	0.08
Eight Beep	214	-0.26	0.08	-0.31	0.08
CAMP	216	-0.26	0.07	-0.30	0.07
Two-Stage	286	-0.41	0.10	-0.25	0.07

Table F- 25. Minivan data: Means and standard deviations for key measures and independent variables (main effects). Taken from Llaneras et al. (2002).

	N	Maximum Deceleration		Actual Deceleration	
		Mean	Std Dev	Mean	Std Dev
Age					
Young	215	-0.25	0.08	-0.29	0.08
Middle	238	-0.28	0.08	-0.32	0.07
Old	191	-0.25	0.06	-0.32	0.07
Gender					
Male	333	-0.28	0.08	-0.32	0.08
Female	321	-0.24	0.07	-0.29	0.07
Backing Maneuver					
50 ft straight	323	-0.24	0.07	-0.32	-0.29
150 ft straight	321	-0.28	0.08	-0.30	0.07
Speed Instruction					
Normal	322	-0.22	0.06	-0.29	0.07
Fast	322	-0.30	0.07	-0.33	0.07
Timing					
Delay	321	-0.25	0.08	-0.30	0.08
No Delay	323	-0.27	0.08	-0.32	0.07
Target					
Person	320	-0.26	0.08	-0.31	0.07
Wall	324	-0.26	0.08	-0.31	0.08
Interface					
Five Beep	214	-0.26	0.08	-0.31	0.08
Eight Beep	214	-0.26	0.08	-0.31	0.08
CAMP	216	-0.26	0.07	-0.30	0.07
Two-Stage	644	-0.26	0.08	-0.31	0.08

Table F- 26 provides unadjusted means for maximum deceleration and actual deceleration by Vehicle Type – for each of two studies performed using the rear near-object detection system. Minivan drivers tended to brake later during alerted trials, leading to higher levels of actual **(averaged)** deceleration. Sedan drivers achieved higher ***peak*** decelerations.

Table F- 26. Unadjusted Means and (Standard Deviations) for Key Dependent Measures by Study and Vehicle. Taken from Llaneras et al. (2002).

	Study 1		**Study 2**	
	Minivan	**Sedan**	**Minivan**	**Sedan**
Actual Deceleration	-0.26 (0.08)	-0.19 (0.08)	-0.31 (0.07)	-0.25 (0.06)
Maximum Deceleration	-0.22 (0.09)	-0.29 (0.12)	-0.26 (0.08)	0.41 (0.09)

1.2.1.4 Llaneras et al. (2001)

This was the first study of three where a rear obstacle detection system was evaluated by Westat. Drivers executed several parking and extended backing maneuvers using an instrumented vehicle. These results are consistent with those of Llaneras, Singer, Green, Huey, Lerner (2002). Llaneras et al. indicate (p. 54) that in this first study, the alerts from the rear obstacle detection system were not used, and drivers used their own judgment on when to brake on alerted trials. This makes these deceleration data different in nature from the "alerted" trials of Llaneras et al. (2002).

Table F- 27 presents percentile data for Maximum Deceleration from this study, whereas Table F- 28 presents Actual Deceleration data. Table F- 29 presents means and standard deviations for the effects analyzed using data combined across Minivan and Sedan, whereas Table F- 30 provides the Minivan data.

Table F- 27. Maximum (peak) deceleration percentile values as a function of type of backing maneuver, and shown separately for each vehicle type (Minivan versus Sedan). Taken from Llaneras et al. (2001).

Trial	Percentile Values for Maximum Deceleration (g)									
	Minivan					Sedan				
	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
Extended Backing – All trials	-0.38	-0.34	-0.19	-0.10	-0.09	-0.55	-0.45	-0.26	-0.14	-0.13
50 ft straight backing instructed trials	-0.37	-0.35	-0.22	-0.13	-0.09	-0.53	-0.46	-0.30	-01.3	-0.12
150 ft straight backing instructed trials	-0.43	-0.40	-0.22	-0.12	-0.10	-0.53	-0.46	-0.27	-0.16	-0.13
Curved backing Instructed trials	-0.38	-0.35	-0.25	-0.16	-0.14	-0.46	-0.43	-0.26	-0.13	-0.13
50 ft straight backing uninstructed trials	-0.18	-0.14	-0.09	-0.08	-0.08	-0.32	-0.20	-0.13	-0.10	-0.10
150 ft straight backing uninstructed trials	-0.17	-0.12	-0.09	-0.08	-0.08	-0.32	-0.23	-0.16	-0.10	-0.10
Curved backing uninstructed trials	-0.20	-0.14	-0.09	-0.08	-0.07	-0.26	-0.23	-0.13	-0.10	-0.10
Parallel parking – backing into space	-0.10	-0.10	-0.08	-0.07	-0.06	-0.33	-0.32	-0.13	-0.09	-0.07
Parallel parking – backing out of space	-0.15	-0.13	-0.08	-0.07	-0.06	-0.39	-0.29	-0.13	-0.10	-0.09
Perpendicular parking – backing into space	-0.10	-0.09	-0.08	-0.07	-0.06	-0.19	-0.19	-0.13	-0.09	-0.06
Perpendicular parking – backing out of space	-0.15	-0.12	-0.09	-0.08	-0.07	-0.23	-0.21	-0.16	-0.09	-0.09
Maximum braking trials – normal speed	-0.39	-0.38	-0.32	-0.24	-0.23	-0.63	-0.59	-0.53	-0.40	-0.36
Maximum braking trials – fast speed	-0.44	-0.43	-0.39	-0.34	-0.32	-0.72	-0.69	-0.59	-0.45	-0.43

Table F- 28. Actual (averaged) deceleration percentile values for actual decelerations (shown separately for Minivan and Sedan) as a function of type of backing maneuver. Taken from Llaneras et al. (2001).

Trial	Percentile Values for Actual Deceleration (g)									
	Minivan					Sedan				
	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
Extended Backing – All trials	-0.39	-0.36	-0.24	-0.16	-0.13	-0.32	-0.28	-0.17	-0.05	-0.04
50 ft straight backing instructed trials	-0.40	-0.38	-0.27	-0.17	-0.16	-0.34	-0.31	-0.21	-0.10	-0.07
150 ft straight backing instructed trials	-0.41	-0.38	-0.24	-0.16	-0.12	-0.33	-0.30	-0.19	-0.09	-0.06
Curved backing Instructed trials	-0.35	-0.32	-0.20	-0.12	-0.10	-0.32	-0.28	-0.18	-0.08	-0.06

Table F- 29. Means and standard deviations for main effects (combined across Minivan and Sedan). Taken from Llaneras et al. (2001).

	N	Maximum Deceleration		Actual Deceleration	
		Mean	Std Dev	Mean	Std Dev
Vehicle					
Minivan	996	-0.22	0.09	-0.26	0.08
Cadillac	1362	-0.26	0.12	-0.17	0.09
Age					
Young	717	-0.25	0.11	-0.21	0.09
Middle	811	-0.25	0.12	-0.21	0.10
Old	830	-0.24	0.11	-0.22	0.10
Gender					
Male	1256	-0.26	0.12	-0.22	0.10
Female	1102	-0.23	0.10	-0.20	0.08
Backing Maneuver					
50 ft straight	784	-0.25	0.12	-0.22	0.10
150 ft straight	792	-0.26	0.12	-0.21	0.09
Curved Backing	782	-0.23	0.10	-0.20	0.09
Speed Instruction					
No Instruction	384	-0.14	0.07	-0.08	0.05
Normal	1048	-0.21	0.09	-0.21	0.08
Fast	1051	-0.30	0.11	-0.24	0.09
Braking Instruction					
No Instruction	642	-0.16	0.08	-0.12	0.07
Normal Braking	1044	-0.20	0.08	-0.18	0.07
Hard Braking	1055	-0.31	0.11	-0.27	0.08
Repetition					
First Trial	1176	-0.25	0.11	-0.21	0.09
Second Trial	1182	-0.25	0.11	-0.21	0.10

Table F- 30. Minivan deceleration data. Taken from Llaneras et al. (2001).

	N	Maximum Deceleration		Actual Deceleration	
		Mean	Std Dev	Mean	Std Dev
Age					
Young	300	-0.24	0.09	-0.26	0.08
Middle	334	-0.22	0.08	-0.27	0.08
Old	362	-0.22	0.09	-0.26	0.08
Gender					
Male	572	-0.24	0.09	-0.28	0.08
Female	424	-0.20	0.08	-0.24	0.07
Backing Maneuver					
50 ft straight	331	-0.23	0.03	-0.18	0.08
150 ft straight	332	-0.24	0.06	-0.25	0.09
Curved Backing	333	-0.21	0.09	-0.27	0.08
Speed Instruction					
No Instruction	125	-0.10	0.03	-0.18	0.08
Normal	499	-0.18	0.06	-0.25	0.07
Fast	497	-0.27	0.09	-0.27	0.09
Braking Instruction					
No Instruction	249	-0.13	0.06	-0.19	0.05
Normal Braking	496	-0.22	0.09	-0.26	0.08
Hard Braking	500	-0.23	0.09	-0.26	0.08
Repetition					
First Trial	496	-0.22	0.09	-0.26	0.08
Second Trial	500	-0.23	0.09	-0.26	0.08

1.3 Glances Distribution

Glance behaviors during backing maneuvers can be described in terms of the locations and durations of glances made by the driver, as well as the sequence (or pattern of glances) during the period of the maneuver. SIM model development took these parameters into account based on backing task:

- Glance direction (or location)
- Glance duration
- Glance direction at time 0 of backing maneuver

1.3.1 Key factors and Secondary Factors

An examination of studies done on backing maneuvers identified a small number of factors which exert key influences on glance behavior. These include:

- Type of Backing Task
- Presence of countermeasure elements that affect glance behavior (e.g., displays and other cues that affect glance patterns)

In addition, more general studies of glance behavior have suggested that visual scan patterns during a driving task can be affected also by workload or distraction. Consideration of this particular factor, however, is outside the scope of this work. Furthermore, there are data concerning instances of drivers looking at a particular display where an obstacle is visible and missing the presence of that obstacle within the display. Data pertinent to this factor and the three key factors described above are described herein.

The literature on glance behavior during backing additionally revealed the presence of individual differences between participants, along with differences by age group (young versus older) and (in some instances) gender.

- Age of driver (age groups – "younger" versus "older")
- Gender

Each of these secondary factors will likewise be discussed below, and when data tables are provided, sources will be identified to document where the values originated.

1.3.2 Glance Direction/ Duration

All the data presented below are the result of a backing task performed in a fully-functional vehicle on a closed-course or a parking lot with minimal vehicle and pedestrian traffic. Three studies provided the glance data for the following tables (unless otherwise noted). GM studies with relevant data for glance direction and/or duration typically include different events and/or countermeasures, and are therefore discussed in a subsequent section focusing on those specific factors.

- Huey, Harpster, & Lerner (1995)
    - Participants completed a series of backing tasks in their own private vehicles (cars, SUVs, and trucks). Twenty-one participants completed six backing tasks (*1. extended curved backing (2 instances), 2. parallel parking (2 instances), 3. backing out of a perpendicular slot, 4. backing into a perpendicular slot, 5. backing to a wall, and 6. backing out of an angled slot*).
- Lerner et al. (1997)
    - Twelve participants drove their own private vehicles over a route that contained several backing tasks. Eight different backing tasks were used (2 were repeated) (*1. Out of an angled parking space, 2. Parallel parking (2), 3. Extended curvilinear driveway (2), 4. Into perpendicular parking space, 5. Out of perpendicular parking space, and 6. Backing to a wall)*
- Mazzae, Barickman, Baldwin, & Ranney (2008)
    - Thirty-seven participants drove their own personal vehicles equipped with varying backing countermeasures while data were collected for a period of 4

weeks. Eye glance analyses were performed on a large subset of the naturalistic backing maneuvers for which data were collected.

Huey, Harpster, & Lerner (1995) evaluated direction of glances during backing for 21 participants by manually extracting glance directions from the on-board video. The means in Table F- 31 show that the distribution of drivers' glances across different locations (or directions of glance) varied substantially during backing.

Table F- 31. Average glance direction collapsed across all participants and all backing tasks performed. Taken from Huey, Harpster, & Lerner (1995).

Glance Direction	Percent glance direction collapsed across participant and task	Minimum	Maximum	Standard Deviation (s)
Forward	10.6%	0.6%	28.7%	1.0734
Dash	0.0 %	0.0%	0.1%	0.0063
Driver's mirror	8.2%	2.8%	14.7%	1.1790
Rear mirror	4.5%	1.7%	7.3%	0.5366
Right mirror	9.2%	2.7%	19.3%	0.7957
Right window	2.3%	0.1%	5.1%	0.2633
Left window	1.0%	0.0%	4.9%	0.1625
Shifter	1.0%	0.0%	3.2%	0.1090
Left shoulder	10.7%	4.2%	27.3%	2.9890
Right shoulder	50.9%	23.6%	78.2%	7.2951

1.3.3 Type of Backing Task – Effects on Glance Patterns

Furthermore, glance direction was heavily influenced by the backing task – as can be seen in Table F- 32. For example, while backing out of an angled slot, participants looked forward 28.7% of the time, but while backing around an extended curve, they only looked forward 0.6% of the time. As another example, the percentage of time looking at the driver's side mirror ranged from 2.8% to 14.7% depending on the type of backing task being done. These data show that the backing task influences the direction/s in which the driver looks (Huey et al., 1995; N. Lerner et al., 1997). This has very important implications for the SIM in estimating effectiveness for a rear-collision warning system. One element of effectiveness may be determined by whether a system/display associated with a rear-collision warning system will be visible to the driver when it is most useful - and this will depend upon the direction of glances, and the sequence of glances typically used during the backing tasks it is intended to assist, as well as on its location relative to these scan paths.

Table F- 32. Glance direction and duration broken down by task and location for all backing tasks in Lerner et al. (1997).

Location	Task	% time	time (s)	St dev of time (s)
driver's mirror	backing out of an angled slot	6	0.558	1.1790
	parallel parking	3.6	0.5328	
	extended curved backing	8.4	2.982	
	backing out to a wall	7.7	0.9933	
	backing out of a perpendicular parking slot	14.7	1.4406	
	backing into a perpendicular parking slot	11.6	1.7864	
	parallel parking	2.8	0.462	
	extended curved backing	11	3.575	
left window	backing out of an angled slot	1.5	0.1395	0.1625
	parallel parking	0.2	0.0296	
	extended curved backing	0.2	0.071	
	backing out to a wall	0.2	0.0258	
	backing out of a perpendicular parking slot	4.9	0.4802	
	backing into a perpendicular parking slot	1.3	0.2002	
	parallel parking	0	0	
	extended curved backing	0	0	
left shoulder	backing out of an angled slot	21.6	2.0088	2.9890
	parallel parking	4.2	0.6216	
	extended curved backing	27.3	9.6915	
	backing out to a wall	6	0.774	
	backing out of a perpendicular parking slot	14	1.372	
	backing into a perpendicular parking slot	14.4	2.2176	
	parallel parking	5.2	0.858	
	extended curved backing	7.2	2.34	
right shoulder	backing out of an angled slot	23.6	2.1948	7.2951
	parallel parking	47	6.956	
	extended curved backing	56.2	19.951	
	backing out to a wall	78.2	10.0878	
	backing out of a perpendicular parking slot	24.7	2.4206	
	backing into a perpendicular parking slot	62.7	9.6558	
	parallel parking	47.2	7.788	
	extended curved backing	67.3	21.8725	
shifter	backing out of an angled slot	3.2	0.2976	0.1090
	parallel parking	0.7	0.1036	
	extended curved backing	0	0	
	backing out to a wall	0.4	0.0516	
	backing out of a perpendicular parking slot	2.1	0.2058	

Location	Task	% time	time (s)	St dev of time (s)
	backing into a perpendicular parking slot	0	0	
	parallel parking	1.1	0.1815	
	extended curved backing	0.1	0.0325	
right window	backing out of an angled slot	3	0.279	0.2633
	parallel parking	3.6	0.5328	
	extended curved backing	0.1	0.0355	
	backing out to a wall	0.3	0.0387	
	backing out of a perpendicular parking slot	5.1	0.4998	
	backing into a perpendicular parking slot	1.2	0.1848	
	parallel parking	4.6	0.759	
	extended curved backing	0.4	0.13	
right mirror	backing out of an angled slot	7.1	0.6603	0.7957
	parallel parking	17.8	2.6344	
	extended curved backing	2.7	0.9585	
	backing out to a wall	3.7	0.4773	
	backing out of a perpendicular parking slot	5.1	0.4998	
	backing into a perpendicular parking slot	1.2	0.1848	
	parallel parking	4.6	0.759	
	extended curved backing	0.4	0.13	
rear-view mirror	backing out of an angled slot	4.7	0.4371	0.5366
	parallel parking	7.3	1.0804	
	extended curved backing	4	1.42	
	backing out to a wall	1.7	0.2193	
	backing out of a perpendicular parking slot	4.5	0.441	
	backing into a perpendicular parking slot	2.5	0.385	
	parallel parking	6.3	1.0395	
	extended curved backing	5.1	1.6575	
forward	backing out of an angled slot	28.7	2.6691	1.0734
	parallel parking	16.9	2.5012	
	extended curved backing	0.6	0.213	
	backing out to a wall	1.8	0.2322	
	backing out of a perpendicular parking slot	18.1	1.7738	
	backing into a perpendicular parking slot	3	0.462	
	parallel parking	14.1	2.3265	
	extended curved backing	1.9	0.6175	
dash	backing out of an angled slot	0.1	0.0093	0.0063
	parallel parking	0	0	
	extended curved backing	0	0	
	backing out to a wall	0	0	
	backing out of a perpendicular parking slot	0	0	

Location	Task	% time	time (s)	St dev of time (s)
	backing into a perpendicular parking slot	0	0	
	parallel parking	0.1	0.0165	
	extended curved backing	0	0	

In addition to effects due to type of backing task, it is important to note that Huey, Harpster, & Lerner (1995) found large individual differences between their participants both within and between tasks.

1.3.3.1 Age

Huey, Harpster, & Lerner (1995) found a couple of reliable differences between younger participants (ages 20-31, mean = 22.5 yrs) and older participants (ages 67-81, mean = 73 yrs). Younger participants looked over their right shoulder 59.9% of the time while elderly participants only looked over their right shoulder 37.4% of the time (both while traveling in reverse). Elderly drivers were more likely to use their mirrors than younger participants. Glances to the three mirrors accounted for about 34% of older driver's time while only accounting for less than 15% of younger driver's time. Table F- 33 below shows the percentage of time drivers of different age groups spent looking in given directions (Huey et al., 1995; N. Lerner et al., 1997). In addition to looking over their shoulders less, and using their mirrors more, older drivers spent a higher percentage of time looking at the shifter than younger drivers.

Table F- 33. Glance direction and duration from Lerner et al. (1997) by age group. Statistically significant results are denoted with a double asterisk (**).

Glance Direction	Young (20-31 yrs)	Elderly (67-81)
Forward	9.9%	11.8%
Dash	0.0%	0.0%
Driver's mirror	4.3%	15.0% **
Rear mirror	3.3%	7.1%**
Right mirror	7.7%	12.1%
Left window	0.7%	1.5%
Right window	2.1%	2.1%
Shifter	0.4%	1.8%**
Left shoulder	12.8%	12.3%
Right shoulder	59.9%	37.4%**

For each of the eight backing tasks in Lerner et al. (1997), glance direction and duration were evaluated by age group. Younger drivers (20-31 yrs old) and older drivers (67-81 yrs old) were compared. In general, older drivers spent more time looking in each direction to complete the task. The data are provided separately for each Backing Task Type, in Table F- 34 through Table F- 41.

Table F- 34. Glance Data for Backing Task 1 – Backing out of an angled slot, total time = 9.1 s for young drivers and 9.7 s for elderly drivers. Taken from Lerner et al. (1997).

Glance Direction	Young % time	Young time (s)	Elderly % time	Elderly time (s)
Forward	25.7%	2.339	32.7%	3.1719
Dash	0.2%	.0182	0.0%	0
Driver's mirror	3.7%	.3367	9.0%	.8730
Rear mirror	3.6%	.3276	6.1%	.5917
Right mirror	6.7%	.6097	7.6%	.7372
Left window	2.5%	.2275	0.3%	.0291
Right window	2.9%	.2639	3.1%	.3007
Shifter	0.1%	.0091	7.3%	.7081
Left shoulder	25.6%	2.3296	16.3%	1.5811
Right shoulder	28.1%	2.5571	17.5%	1.6975

Table F- 35. Glance Data for Backing Task 2 – Parallel parking, total time = 14.9 s for young drivers and 14.7 s for elderly drivers. Taken from Lerner et al. (1997).

Glance Direction	Young % time	Young time (s)	Elderly % time	Elderly time (s)
Forward	15.9%	2.3691	18.3%	2.6901
Dash	0.0%	0	0.0%	0
Driver's mirror	2.9%	.4321	4.7%	.6909
Rear mirror	4.9%	.7301	11.0%	1.617
Right mirror	11.9%	1.7731	26.8%	3.9396
Left window	0.3%	.04470	0.0%	0
Right window	3.0%	.4470	4.5%	.6615
Shifter	0.2%	.0298	1.4%	.2058
Left shoulder	5.8%	.8642	1.8%	.2646
Right shoulder	57.4%	8.5526	31.5%**	4.6305

Table F- 36. Glance Data for Backing Task 3- Extended curve backing – total time = 24.9 s for younger drivers and 53.8 s for elderly drivers. Taken from Lerner et al. (1997).

Glance Direction	Young % time	Young time (s)	Elderly % time	Elderly time (s)
Forward	0.1%	.0249	1.4% **	.7532
Dash	0.0%	0	0.0%	0
Driver's mirror	5.5%	1.3695	13.5%	7.2630
Rear mirror	0.3%	.0747	10.3% **	5.4140
Right mirror	2.3%	.5727	3.5%	1.8830
Left window	0.0%	0	0.6 %	.3228
Right window	0.0%	0	0.2%	.1076
Shifter	0.0%	0	0.0%	0
Left shoulder	24.5%	6.1005	32.1%	17.2698
Right shoulder	67.3%	16.7577	37.1%	19.9598

Table F- 37. Glance Data for Backing Task 4- Backing out to a wall – total time = 11.7 s for younger drivers and 114.6 s for elderly drivers. Taken from Lerner et al. (1997).

Glance Direction	Young % time	Young time (s)	Elderly % time	Elderly time (s)
Forward	0.1%	.0117	4.2% **	4.8132
Dash	0.0%	0	0.0%	0
Driver's mirror	0.9%	.1053	17.7% **	20.2842
Rear mirror	3.9%	.4563	3.5%	4.011
Right mirror	1.8%	.2106	6.4%	7.3344
Left window	0.0%	0	0.5%	.5730
Right window	0.0%	0	0.8%	.9168
Shifter	0.0%	0	0.9%	1.0314
Left shoulder	5.5%	.6435	6.6%	7.5636
Right shoulder	91.2%	10.6704	60.3%	69.1038

Table F- 38. Glance Data for Backing Task 5- Backing out of a perpendicular parking spot – total time = 9.5 s for younger drivers and 10.3 s for elderly drivers. Taken from Lerner et al. (1997).

Glance Direction	Young % time	Young time (s)	Elderly % time	Elderly time (s)
Forward	20.9%	1.9855	13.9%	1.4317
Dash	0.0%	0	0.0%	0
Driver's mirror	8.1%	.7695	24.5% **	2.5235
Rear mirror	3.7%	.3515	5.8%	.5974
Right mirror	7.8%	.7410	21.7%	2.2351
Left window	2.8%	.2660	7.7%	.7931
Right window	4.8%	0.4560	5.4%	.5562
Shifter	2.2%	.2090	1.9%	.1957
Left shoulder	21.3%	2.0235	3.0% **	.3090
Right shoulder	28.6%	.2717	18.8%	1.9364

Table F- 39. Glance Data for Backing Task 6 – Backing into a perpendicular parking spot – total time = 13.3 for younger drivers and 17.7 for elderly drivers. Taken from Lerner et al. (1997).

Glance Direction	Young % time	Young time (s)	Elderly % time	Elderly time (s)
Forward	3.0%	.399	3.0%	.5310
Dash	0.0%	0	0.0%	0
Driver's mirror	5.8%	.7714	18.6%	3.2922
Rear mirror	2.1%	.2793	2.2%	.3894
Right mirror	3.2%	.4256	2.2%	.3894
Left window	0.0%	0	2.7%	.4779
Right window	1.2%	.1596	1.2%	.2124
Shifter	0.2%	.0266	0.5%	.0885
Left shoulder	11.2%	1.4896	18.0%	3.186
Right shoulder	73.4%	9.7622	50.8%	8.9916

Table F- 40. Glance Data for Backing Task 7- Parallel parking – total time = 16.6 s for younger drivers and 16.3 s for elderly drivers. Taken from Lerner et al. (1997).

Glance Direction	Young % time	Young time (s)	Elderly % time	Elderly time (s)
Forward	13.0%	2.158	15.7%	2.5591
Dash	0.0%	0	0.2%	.0326
Driver's mirror	1.3%	.2158	4.7%	.7661
Rear mirror	2.4%	.3984	11.5% **	1.8745
Right mirror	22.7%	3.7682	14.7%	2.3961
Left window	0.0%	0	0.0%	0
Right window	7.8%	1.2984	0.2%	.0326
Shifter	0.5%	.0830	1.9%	.3097
Left shoulder	5.1%	.8466	5.4%	.8802
Right shoulder	48.3%	8.0178	45.7%	7.4491

Table F- 41. Glance Data for Backing Task 8 – Extended Curve Backing- total time = 25.1 s for younger drivers and 47.2 s for elderly drivers. Taken from Lerner et al. (1997).

Glance Direction	Young % time	Young time (s)	Elderly % time	Elderly time (s)
Forward	1.0%	.2510	14.2% **	6.7024
Dash	0.0%	0	0.0%	0
Driver's mirror	2.7%	.6777	27.7% **	13.0744
Rear mirror	5.0%	1.2550	5.3%	2.4016
Right mirror	4.1%	1.0291	13.4%	6.3248
Left window	0.0%	0	0.0%	0
Right window	0.1%	.0251	1.0%	.4720
Shifter	0.0%	0	0.3%	.1416
Left shoulder	3.0%	.7530	15.5%	7.3160
Right shoulder	85.1%	21.3601	31.7% **	14.9624

1.3.3.2 Gender

Huey, Harpster, & Lerner (1995) evaluated glance direction by gender and found that for the most part, gender did not play a large role. Gender was found to have an effect on the percentage of time looking at the driver's mirror, rearview mirror and over the left shoulder, only when data were collapsed across all tasks, but not when analyzed by each task (in that case no results for gender were statistically significant).

1.3.3.3 Glance Direction at time 0 when backing

Huey, Harpster, & Lerner (1995) investigated glance direction upon first starting to back a vehicle up. Table F- 42 below shows the number of glances in a particular direction and the percentage of total number of glances at time = 0 (backing first initiated) that fell in that direction. In the tables below, which are all related to glance directions at time=0 when backing, the overall data for glance directions are first presented (Table F- 42). Then, data are provided separately by age group (Table F- 43) using the metrics of glance number (a count of glances). Next, data are again provided by age groups (Table F- 44) but using the metric of percent of glances in each direction. Finally, data are shown by backing task (averaged across age groups) (Table F- 45).

Table F- 42. Glance direction (both count and % of total glances) at time = 0 when starting to backup. Taken from Huey, Harpster, & Lerner (1995).

Glance Direction	Time = 0 (count)	Time = 0 (percentage of total glances)
Forward	10	6.4%
Driver's mirror	9	5.8%
Rear mirror	10	6.4%
Right mirror	6	3.9%
Right window	3	1.9%
Left window	0	0%
Dash	0	0%
Shifter	7	4.5%
Right shoulder	89	57.1%
Left shoulder	22	14.1%

Table F- 43. Glance direction (count and % of total glance) at time = 0 by age group (20-31 as 'young' and 67-81 as 'elderly'). Taken from Huey, Harpster, & Lerner (1995).

Glance Direction	T=0 (count (%) elderly)	T=0 (count (%) young)
Forward	7 (10.9%)	3 (3.3%)
Driver's mirror	7 (10.9%)	2 (2.2%)
Rear mirror	8 (12.5%)	2 (2.2%)
Right mirror	3 (4.7%)	3 (3.3%)
Right window	2 (3.1%)	1 (1.1%)
Left window	0 (0%)	0 (0%)
Dash	0 (0%)	0(0%)
Shifter	6 (9.4%)	1 (1.1%)
Right shoulder	25 (39.1%)	64 (69.7%)
Left shoulder	6 (9.4%)	16 (17.4%)

Table F- 44. Percent of glances in each direction by age group (denotes statistical significance at p <.05 level). Taken from Huey, Harpster, & Lerner (1995).**

Glance Direction	Younger (20-31 yrs)	Older (67-81)	All
Forward	9.9%	11.8% **	10.6%
Dash	0	0	0
Driver's mirror	4.3%	15.0% **	8.2%
Rear mirror	3.3%	7.1%	4.5%
Right mirror	7.7%	12.1%	9.2%
Left window	.7%	1.5%	2.3%
Right window	2.1%	2.1%	1.0%
Shifter	.4%	1.8%	1.0%
Left shoulder	12.8%	12.3%	10.7%
Right shoulder	59.9%	37.4% **	50.9%

Table F- 45. Glance Direction % of time by backing task at time = zero. Taken from Huey, Harpster, & Lerner (1995).

Glance Direction	Out of angled parking space	Parallel parking (1st instance)	Parallel parking (2nd instance)	Extended curvilinear driveway (1st instance)	Extended curvilinear driveway (2nd instance)	Into perpendicular parking space	Out of perpendicular driving space	Close to wall
Forward	28.7%	16.5%	14.1%	.6%	1.8%	3.0%	18.1%	1.8%
Dash	.1%	0	.1%	0	0	0	0	0
Driver's mirror	6.0%	3.6%	2.8%	8.4%	11.0%	11.6%	14.7%	7.8%
Rear mirror	4.7%	7.4%	6.3%	4.0%	5.1%	2.5%	4.5%	1.7%
Right mirror	7.1%	17.8%	19.3%	2.7%	7.2%	2.7%	13.4%	3.7%
Left window	1.5%	.2%	0	.2%	0	1.3%	4.9%	.2%
Right window	3.0%	3.6%	4.6%	.1%	.4%	1.2%	5.1%	.3%
Shifter	3.2%	.7%	1.1%	0	.1%	.3%	2.1%	.4%
Left shoulder	21.6%	4.2%	5.2%	27.3%	7.2%	14.4%	14.0%	6.0%
Right shoulder	23.6%	47%	47.2%	56.2%	67.3%	62.7%	24.7%	78.2%

Mazzae et al. (2008) provide initial glance data based on their naturalistic assessments. Their data is broken down by the backing countermeasure available to the driver, however, so the discussion is reserved for a later section. Given their naturalistic element and the large number of samples, these data are extremely compelling in spite of the main drawback, which is that it is not broken down by type of maneuver.

1.3.3.4 Presence of Events and Countermeasure Elements That Affect Glance Patterns

When a visual display is added for use during backing, it has the potential to change scan and dwell patterns during backing. Likewise, other cues or alerts that are introduced during backing, and affect the driver's attention, may also have effects on glance patterns, since the brain networks which control attention and those which control eye movements are closely related and partially overlapping. Finally, the appearance of an obstacle to be detected (if it is visible either directly out the vehicle windows, or indirectly through mirrors or through a countermeasure display) has the potential to change glance patterns during backing. The SIM will reflect some of these effects to the extent that supporting data are available and/or can be obtained from the driver-in-the-loop objective tests. The studies in the next section pertain to these types of effects.

1.3.3.5 Llaneras, McLaughlin, et al. – location of glance when barrel first moved

A study was conducted that looked at driver acceptance of automatic braking systems in a variety of situations, two of which were backing scenarios. One of the backing scenarios included traveling through a mock construction zone. One of the barrels on the side of the road was launched into the path of the vehicle as it backed. The vehicle had an automatic braking countermeasure active. The obstacle was not directly visible to the driver except through Enhanced Vision. Table F- 46 shows the distribution of glances at the time of the surprise event.

Table F- 46. Location of participants' glances and time when the barrel first moved (surprise event). Taken from Llaneras, McLaughlin, et al. (proprietary).

Direction	% time
Driver's Mirror	22%
Passenger's Mirror	5%
Interior Mirror	2%
Forward	35%
Over Shoulder	36%

1.3.3.6 Llaneras, Neurauter, et al.

Another study was conducted as a follow-up to the acceptance of automatic braking in which two surprise events occurred while backing; the first surprise event included a toy coupe that crossed the vehicle's backing path and the second was a cone placed behind the vehicle when the participant was distracted. The vehicle was equipped with a backing countermeasure (including Enhanced Vision).

A Garage urgency backing task was also used to evaluate participants' response to automatic braking. In this task, as participants were backing out of a garage, the door began to shut down on the car and the automatic braking engaged. What follows is participants' (N=36) glance behavior as a result of the automatic braking during this urgency task. For those who did glance at the Enhanced Vision monitor after the automatic braking fired, the glance lasted for an average of 3.12 seconds with a standard deviation of 1.022 seconds and a range (5^{th} -95^{th} percentile) of 0.155 seconds to 2.96 seconds. The results in Table F- 47 illustrate that the onset of autonomous braking triggered glances to the Enhanced

Vision monitor slightly over 72% of the time. Thus, two elements of the countermeasure system affected glance behavior: the autonomous braking cues, and the Enhanced Vision monitor.

Table F- 47. Glance behavior as a response to the garage urgency task. Taken from Llaneras, Neurauter, et al. (proprietary).

Those that…	Percentage
Glanced at rearview monitor before backing	36.11%
Did not glance at rearview monitor before backing	63.89%
Glanced at rearview monitor while backing	50%
Did not glance at rearview monitor while backing	50%
Glanced at rearview monitor after AB fired	72.22%
Did not glance at rearview monitor after AB fired	27.77%

During the surprise toy coupe event, participants would initiate backing down a road with various obstacles off to the sides; when a certain point was reached, a small toy coupe was launched into the path of travel of the participants. What follows is the glance behavior of participants during this event. The results in Table F- 48 indicate that glances to the rearview monitor tend to most often occur prior to backing –or else following the onset of autonomous braking. This informs the SIM, indicating at what points in backing glance behaviors need to be generated/modeled.

Table F- 48. Glance behavior as a response to the cozy coupe. Taken from Llaneras, Neurauter, et al. (proprietary).

Those that…	Percentage
Glanced at rearview monitor following AB onset	50%
Did not glance at rearview monitor following AB onset	50%
Glanced at rearview monitor while backing	20%
Did not glance at rearview monitor while backing	80%

The final ruse of this study consisted of a traffic cone placed behind the experimental vehicle. Participants were taken to the front of a building to fill out some paperwork, but upon arrival another experimenter told them they had to move the car (the ruse). A cone was then placed behind the vehicle without the participants' knowledge. What follows in Table F- 49 is the glance behavior related to the ruse. These results again confirm that most drivers do not look at the rearview monitor while backing – but 71% glance at it following the onset of autonomous braking. The data can contribute to the distributions used by the SIM for probabilities of glances to locations based on phase of backing.

Table F- 49. Glance behavior as a response to the cone placed behind the vehicle. Taken from Llaneras, Neurauter, et al. (proprietary).

Those that…	Percentage
Glanced at rearview monitor following AB onset	71%
Did not glance at rearview monitor following AB onset	29%
Glanced at rearview monitor while backing	35%
Did not glance at rearview monitor while backing	65%

1.3.3.7 McLaughlin, Hankey, Green, & Kiefer (2003)

Four levels of parking aids were examined during a study using 32 participants in two age groups balanced by gender. The four levels of parking aids were: none, Proximity Information, Enhanced Vision and a combination of Enhanced Vision and Proximity Information. The age groups were divided by between 45 and 55 (18) and 60 and older (14). Participants performed five different parking tasks, three of which corresponded to backing (entering a parallel and perpendicular parking space and backing to a trailer hitch). Of particular salience for the SIM was the finding that the total eye glance times to different areas were contingent on the countermeasure system. See for example, in Table F- 50, the increase in glances to the "RV" (Enhanced Vision monitor) row for the two rightmost column configurations to which the Enhanced Vision monitor had been added.

Table F- 50. Number of glances to location by rear-assist configuration – perpendicular parking task. Taken from McLaughlin, Hankey, Green, & Kiefer (2003).

Location	Traditional	URPA	RV	URPA + RV
Left Mirror	7.53	7.53	8.03	8.06
Left Window	1.33	1.50	0.93	0.94
Left Rear	0.63	0.63	0.53	0.38
Windshield	6.17	5.77	6.03	5.72
Mirror	1.30	2.73	0.93	2.22
IP	2.97	3.23	3.70	4.09
RV	0.07	0.13	5.97	5.56
Right Window	1.53	2.23	1.53	1.25
Right Rear	3.20	4.23	2.73	3.88
Backlite	1.63	1.73	1.10	1.16
Right Mirror	6.40	6.40	6.97	8.41

These data are meaningful by backing task as well. Several tables below (Table F- 51 through Table F-57) give numbers of glances/total times for glances for each of the four configurations by location.

Table F- 51. Number of glances to location by rear- assist configuration - backing to a trailer task. Taken from McLaughlin, Hankey, Green, & Kiefer (2003).

Location	Traditional	URPA	RV	URPA + RV
Left Mirror	10.31	9.23	7.44	6.53
Left Window	2.09	1.65	1.13	0.94
Left Rear	0.94	0.84	0.69	0.78
Windshield	7.59	7.29	5.50	5.41
Mirror	2.66	4.61	1.41	2.78
IP	6.00	6.74	4.16	4.72
RV	0.03	0.29	6.84	7.19
Right Window	1.19	1.90	0.50	0.41
Right Rear	1.91	2.97	1.31	1.22
Backlite	1.88	1.55	1.16	1.19
Right Mirror	5.19	5.94	3.00	3.78

Table F- 52. Number of glances by configuration and location – parallel parking task. Taken from McLaughlin, Hankey, Green, & Kiefer (2003).

Location	Traditional	URPA	RV	URPA + RV
Left Mirror	4.84	4.81	3.78	4.06
Left Window	0.16	0.23	0.16	0.31
Left Rear	0.09	0.06	0	0.34
Windshield	8.28	8.74	8.19	8.97
Mirror	1.50	3.71	1.38	1.91
IP	4.47	4.10	3.47	4.13
RV	0.16	0.39	6.19	5.75
Right Window	2.13	2.39	1.78	2.16
Right Rear	3.03	2.71	2.34	2.25
Backlite	3.18	4.06	1.54	2.77
Right Mirror	6.19	6.32	5.56	6.59

Table F- 53. Number of glances by configuration and location – ruse. Taken from McLaughlin, Hankey, Green, & Kiefer (2003).

Location	Traditional	URPA	RV	URPA + RV
Left Mirror	0.14	0.86	1.11	0.83
Left Window	0.00	0.57	0.33	0.00
Left Rear	0.00	0.14	0.00	0.17
Windshield	2.14	2.29	2.44	2.17
Mirror	0.71	0.86	0.67	0.83
IP	0.43	0.86	1.22	1.33
RV	0.00	0.00	0.44	0.17
Right Window	0.29	0.14	0.11	0.00
Right Rear	0.71	0.14	0.67	0.17
Backlite	0.57	0.29	0.00	0.00
Right Mirror	1.00	0.43	1.33	0.50

Table F- 54. Percentage of people who glanced to each location by configuration collapsed across backing task. Taken from McLaughlin, Hankey, Green, & Kiefer (2003).

Location	Traditional	URPA	RV	URPA + RV
Left Mirror	14	57	56	67
Left Window	0	57	22	0
Left Rear	0	14	0	17
Windshield	100	100	100	100
Mirror	43	57	33	50
IP	43	71	67	100
RV	0	0	33	17
Right Window	14	14	11	0
Right Rear	43	14	44	17
Backlite	43	29	0	0
Right Mirror	57	43	67	33

Table F- 55. Total Glance time (s) by configuration and location – parallel parking task. Taken from McLaughlin, Hankey, Green, & Kiefer (2003).

Location	Traditional	URPA	RV	URPA + RV
Left Mirror	8.65	9.75	5.5	7.44
Left Window	0.22	0.3	0.18	0.27
Left Rear	0.37	0.07	0	0.97
Windshield	26.26	26.64	21.71	24.02
Mirror	1.48	5.8	2.15	2.3
IP	7.18	7.81	6.05	7.81
RV	0.23	0.41	15.52	12.08
Right Window	3.78	4.42	2.51	3.98
Right Rear	4.31	4.83	3.39	4.36
Backlite	3.1803	4.0577	1.5431	2.7725
Right Mirror	16.96	15.51	12.07	15.79

Table F- 56. Total Glance time (s) by configuration and location – perpendicular parking task. Taken from McLaughlin, Hankey, Green, & Kiefer (2003).

Location	Traditional	URPA	RV	URPA + RV
Left Mirror	18.89	17.84	15.94	17.25
Left Window	1.84	1.91	1.08	1.05
Left Rear	0.68	0.6	0.54	0.32
Windshield	10.35	10.22	11.19	11.02
Mirror	1.22	5.71	0.85	2.86
IP	5	6.42	6.43	7.82
RV	0.03	0.19	16.11	12.27
Right Window	2	3.03	1.81	2.19
Right Rear	4.56	7.11	5.82	7.52
Backlite	4.94	3.83	2.13	2.15
Right Mirror	14.7	13.62	13.55	16.62

Table F- 57. Total glance time(s) by configuration and location – backing to a trailer. Taken from McLaughlin, Hankey, Green, & Kiefer (2003).

Location	Traditional	URPA	RV	URPA + RV
Left Mirror	42.41	32.98	16.38	18.5
Left Window	2.93	2.2	0.88	1.11
Left Rear	3.82	2.81	2.05	2.78
Windshield	11.95	13.28	10.11	8.77
Mirror	3	10.84	1.39	4.59
IP	10.88	13.31	7	10.38
RV	0.04	0.18	50.62	49.8
Right Window	2.22	2.89	0.56	0.32
Right Rear	2.72	8.15	2.75	1.79
Backlite	5.1	8.37	3.69	3
Right Mirror	10.51	10.21	6.73	7.41

1.3.3.8 Mazzae et al. (2008)

Mazzae et al. (2008) summarize data on a large number of naturalistic backing events. Although the events are not classified according to the type of maneuver or in relation to the activation of any countermeasure, they are broken down based on the countermeasures that were available in the vehicle. Table F- 58 provides the observed distribution of first glance locations.
Table F- 59 provides information about the Weibull distribution parameters for the different glance locations evaluated. These authors also report data on the probabilities of subsequent glance locations based on current glance location length of the glance. These tables are reprinted below; three different tables are provided there based on the availability of sensor and/or video to the participants.

Table F- 58. Probability of first glance location. Taken from Mazzae et al. (2008).

Glance Direction	No Countermeasure	Enhanced Vision	Enhanced Vision and Proximity Information
Over left shoulder	10.9%	5.5%	7.6%
Forward	8.9%	9.2%	4.2%
Instrument panel	4.3%	4.8%	4.2%
Left	10.2%	16.8%	15.4%
Rearview mirror	8.5%	8.1%	6.2%
Other	0.2%	0.3%	0.2%
Other	3.8%	6.4%	4.7%
Over right shoulder	32.5%	20.9%	26.7%
Right	20.2%	15.9%	17.7%
Rearview video screen	0.6%	12.1%	13.1%

Table F- 59. Weibull distribution parameters for glance durations. Taken from Mazzae et al. (2008).

Eyeglance Location	Mean and (Standard Deviation)	Location Parameter	Scale Parameter	Shape Parameter
Over Left Shoulder	4.59 (4.97)	0.07	4.325	0.911
Forward	1.83 (3.21)	0.07	0.748	0.944
Instrument Panel	2.24 (3.62)	0.07	1.519	0.626
Left Mirror	2.02 (3.32)	0.07	1.339	0.615
Center Mirror	1.54 (2.58)	0.07	0.98	0.601
Other	2.12 (3.60)	0.05	1.39	0.605
Over Right Shoulder	3.29 (4.80)	0.08	2.487	0.687
Proximity Display	2.05 (1.59)	0	2.289	1.664
Right Mirror	1.88 (3.45)	0.05	1.13	0.568
Enhanced Vision	2.40 (3.97)	0.08	1.58	0.612

1.3.3.9 Mazzae et al. (2008) Glance Sequence Probabilities

The codes in the following three tables (Tables F-60 to F-62) are based on the following legend table. As denoted in each of the tables, the first corresponds to participants that had no enhanced video or proximity information, the second to participants who only had enhanced vision available, and the third table to participants who had both enhanced vision and proximity information available.

Key	Location
4 (D)	Over left shoulder
6 (F)	Forward
9 (I)	Instrument panel
12 (L)	Left
13 (M)	Rearview mirror
14 (N)	Other
15 (O)	Other
16 (P)	Over right shoulder
18 (R)	Right
22 (V)	Rearview video screen

Table F- 60. Glance probability for drivers without enhanced video or proximity information.

	No Video, No sensors Subjects								
	Probability of next Glance								
Current Glance within x.xx seconds	Glance 4 (D)	Glance 6 (F)	Glance 9 (I)	Glance 12 (L)	Glance 13 (M)	Glance 14 (N)	Glance 15 (O)	Glance 16 (P)	Glance 18 (R)	Glance 22 (V)
4 (D) < 1.75		0.255137	0.015411	0.347603	0.035959	0.000000	0.027397	0.056507	0.255137	0.006849
6 (F) < 1.75	0.055358		0.029099	0.383960	0.104329	0.000000	0.050390	0.088006	0.279631	0.009226
9 (I) < 1.75	0.052174	0.278261		0.113043	0.147826	0.000000	0.043478	0.069565	0.260870	0.034783
12 (L) < 1.75	0.286745	0.315600	0.013526		0.039675	0.000000	0.045086	0.076646	0.213706	0.009017
13 (M) < 1.75	0.025281	0.323034	0.030899	0.199438		0.000000	0.053371	0.092697	0.266854	0.008427
14 (N) < 1.75	0.000000	0.000000	0.000000	0.000000	0.000000		0.000000	0.000000	1.000000	0.000000
15 (O) < 1.75	0.033784	0.304054	0.047297	0.118243	0.037162	0.000000		0.074324	0.371622	0.013514
16 (P) < 1.75	0.027957	0.265591	0.011828	0.109677	0.037634	0.000000	0.041935		0.491398	0.013978
18 (R) < 1.75	0.030475	0.371368	0.022679	0.182140	0.061658	0.000000	0.048193	0.270730		0.012757
22 (V) < 1.75	0.038462	0.365385	0.057692	0.057692	0.057692	0.000000	0.076923	0.076923	0.269231	
4 (D) < 3.00		0.086957	0.000000	0.282609	0.065217	0.000000	0.043478	0.282609	0.217391	0.021739
6 (F) < 3.00	0.138211		0.008130	0.252033	0.048780	0.000000	0.073171	0.252033	0.227642	0.000000
9 (I) < 3.00	0.000000	0.181818		0.181818	0.000000	0.000000	0.181818	0.181818	0.272727	0.000000
12 (L) < 3.00	0.343750	0.179688	0.000000		0.039063	0.000000	0.054688	0.140625	0.234375	0.007813
13 (M) < 3.00	0.051282	0.410256	0.076923	0.128205		0.000000	0.076923	0.128205	0.128205	0.000000
14 (N) < 3.00	0.000000	0.000000	0.000000	0.000000	0.000000		0.000000	0.000000	0.000000	0.000000
15 (O) < 3.00	0.045455	0.636364	0.000000	0.136364	0.045455	0.000000		0.000000	0.136364	0.000000
16 (P) < 3.00	0.111111	0.185185	0.024691	0.123457	0.012346	0.000000	0.049383		0.493827	0.000000
18 (R) < 3.00	0.069767	0.226744	0.017442	0.197674	0.046512	0.000000	0.034884	0.406977		0.000000
22 (V) < 3.00	0.000000	0.333333	0.166667	0.333333	0.000000	0.000000	0.166667	0.000000	0.000000	
4 (D) >= 3.00		0.083333	0.000000	0.083333	0.083333	0.000000	0.000000	0.333333	0.416667	0.000000
6 (F) >= 3.00	0.188679		0.000000	0.113208	0.000000	0.000000	0.075472	0.358491	0.264151	0.000000
9 (I) >= 3.00	0.200000	0.000000		0.100000	0.100000	0.000000	0.000000	0.400000	0.200000	0.000000
12 (L) >= 3.00	0.372093	0.139535	0.023256		0.000000	0.000000	0.093023	0.162791	0.186047	0.023256
13 (M) >= 3.00	0.062500	0.187500	0.062500	0.062500		0.000000	0.000000	0.500000	0.125000	0.000000
14 (N) >= 3.00	0.000000	0.000000	0.000000	0.000000	0.000000		0.000000	0.000000	0.000000	0.000000
15 (O) >= 3.00	0.000000	0.250000	0.000000	0.166667	0.000000	0.000000		0.166667	0.333333	0.083333
16 (P) >= 3.00	0.181818	0.045455	0.000000	0.090909	0.045455	0.000000	0.045455		0.590909	0.000000
18 (R) >= 3.00	0.078947	0.078947	0.013158	0.144737	0.026316	0.000000	0.078947	0.578947		0.000000
22 (V) >= 3.00	0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	

Table F- 61. Glance probabilities for drivers with enhanced video only.

	Video only Subjects									
	Probability of next Glance									
Current Glance within x.xx seconds	Glance 4 (D)	Glance 6 (F)	Glance 9 (I)	Glance 12 (L)	Glance 13 (M)	Glance 14 (N)	Glance 15 (O)	Glance 16 (P)	Glance 18 (R)	Glance 22 (V)
6 (F) < 1.75	0.032979		0.037234	0.335106	0.130851	0.000000	0.088298	0.042553	0.210638	0.122340
9 (I) < 1.75	0.000000	0.292683		0.235772	0.113821	0.000000	0.081301	0.032520	0.056911	0.186992
12 (L) < 1.75	0.206081	0.270270	0.018018		0.056306	0.000000	0.031532	0.052928	0.228604	0.136261
13 (M) < 1.75	0.011142	0.194986	0.036212	0.147632		0.000000	0.050139	0.044568	0.362117	0.153203
14 (N) < 1.75	0.500000	0.000000	0.500000	0.000000	0.000000		0.000000	0.000000	0.000000	0.000000
15 (O) < 1.75	0.013937	0.386760	0.062718	0.087108	0.041812	0.000000		0.073171	0.257840	0.076655
16 (P) < 1.75	0.007463	0.160448	0.009950	0.078358	0.018657	0.000000	0.016169		0.579602	0.129353
18 (R) < 1.75	0.017087	0.267697	0.021969	0.138324	0.091945	0.000000	0.056957	0.276648		0.129373
22 (V) < 1.75	0.010471	0.184991	0.041885	0.157068	0.078534	0.000000	0.076789	0.101222	0.349040	
4 (D) < 3.00		0.166667	0.000000	0.166667	0.095238	0.000000	0.023810	0.142857	0.333333	0.071429
6 (F) < 3.00	0.087248		0.026846	0.375839	0.033557	0.000000	0.073826	0.134228	0.214765	0.053691
9 (I) < 3.00	0.000000	0.240000		0.280000	0.040000	0.000000	0.120000	0.120000	0.040000	0.160000
12 (L) < 3.00	0.185484	0.104839	0.008065		0.040323	0.000000	0.024194	0.185484	0.354839	0.096774
13 (M) < 3.00	0.062500	0.166667	0.000000	0.166667		0.000000	0.020833	0.187500	0.229167	0.166667
14 (N) < 3.00	0.000000	0.000000	0.000000	0.000000	0.000000		0.000000	0.000000	0.000000	0.000000
15 (O) < 3.00	0.000000	0.317073	0.000000	0.097561	0.000000	0.000000		0.146341	0.317073	0.121951
16 (P) < 3.00	0.067416	0.112360	0.000000	0.112360	0.000000	0.000000	0.067416		0.382022	0.258427
18 (R) < 3.00	0.052133	0.146919	0.009479	0.189573	0.023697	0.000000	0.056872	0.426540		0.094787
22 (V) < 3.00	0.009804	0.098039	0.019608	0.245098	0.000000	0.000000	0.078431	0.333333	0.215686	
4 (D) >= 3.00		0.166667	0.000000	0.333333	0.000000	0.000000	0.250000	0.083333	0.166667	0.000000
6 (F) >= 3.00	0.072464		0.000000	0.246377	0.028986	0.000000	0.043478	0.304348	0.173913	0.130435
9 (I) >= 3.00	0.000000	0.000000		0.750000	0.000000	0.000000	0.000000	0.125000	0.000000	0.125000
12 (L) >= 3.00	0.323077	0.107692	0.000000		0.030769	0.000000	0.046154	0.123077	0.323077	0.046154
13 (M) >= 3.00	0.000000	0.000000	0.050000	0.250000		0.000000	0.050000	0.350000	0.100000	0.200000
14 (N) >= 3.00	0.000000	0.000000	0.000000	0.000000	0.000000		0.000000	0.000000	0.000000	0.000000
15 (O) >= 3.00	0.000000	0.368421	0.000000	0.000000	0.000000	0.000000		0.315789	0.157895	0.157895
16 (P) >= 3.00	0.090909	0.045455	0.000000	0.181818	0.000000	0.000000	0.090909		0.363636	0.227273
18 (R) >= 3.00	0.117021	0.095745	0.000000	0.148936	0.000000	0.000000	0.074468	0.510638		0.053191
22 (V) >= 3.00	0.019231	0.076923	0.000000	0.307692	0.019231	0.000000	0.019231	0.403846	0.153846	

Table F- 62. Glance probabilities for drivers with both enhanced video and proximity information.

	Video & Sensors Subjects									
	Probability of next Glance									
Current Glance within x.xx seconds	Glance 4 (D)	Glance 6 (F)	Glance 9 (I)	Glance 12 (L)	Glance 13 (M)	Glance 14 (N)	Glance 15 (O)	Glance 16 (P)	Glance 18 (R)	Glance 22 (V)
6 (F) < 1.75	0.034213		0.042033	0.341153	0.125122	0.000000	0.088954	0.094819	0.192571	0.081134
9 (I) < 1.75	0.008333	0.216667		0.225000	0.175000	0.000000	0.150000	0.058333	0.033333	0.133333
12 (L) < 1.75	0.230833	0.294312	0.018137		0.095631	0.000000	0.043693	0.070899	0.179720	0.066777
13 (M) < 1.75	0.019068	0.201271	0.029661	0.192797		0.000000	0.040254	0.057203	0.385593	0.074153
14 (N) < 1.75	0.000000	0.000000	0.000000	0.000000	0.000000		0.000000	0.000000	1.000000	0.000000
15 (O) < 1.75	0.010345	0.375862	0.062069	0.124138	0.051724	0.000000		0.079310	0.196552	0.100000
16 (P) < 1.75	0.033294	0.214031	0.011891	0.092747	0.033294	0.000000	0.033294		0.488704	0.092747
18 (R) < 1.75	0.030408	0.233710	0.009557	0.229366	0.153779	0.000000	0.043440	0.234579		0.065161
22 (V) < 1.75	0.024155	0.198068	0.038647	0.178744	0.135266	0.000000	0.079710	0.123188	0.222222	
4 (D) < 3.00		0.064516	0.000000	0.290323	0.032258	0.000000	0.048387	0.354839	0.193548	0.016129
6 (F) < 3.00	0.155738		0.008197	0.450820	0.040984	0.000000	0.049180	0.163934	0.106557	0.024590
9 (I) < 3.00	0.000000	0.086957		0.391304	0.000000	0.000000	0.173913	0.130435	0.043478	0.173913
12 (L) < 3.00	0.395833	0.140625	0.005208		0.036458	0.000000	0.020833	0.156250	0.192708	0.052083
13 (M) < 3.00	0.031746	0.079365	0.047619	0.412698		0.000000	0.031746	0.174603	0.206349	0.015873
14 (N) < 3.00	0.000000	0.000000	0.000000	0.000000	0.000000		0.000000	0.000000	0.000000	0.000000
15 (O) < 3.00	0.000000	0.509804	0.019608	0.156863	0.000000	0.000000		0.098039	0.176471	0.039216
16 (P) < 3.00	0.226667	0.146667	0.000000	0.373333	0.013333	0.000000	0.040000		0.173333	0.026667
18 (R) < 3.00	0.157576	0.169697	0.000000	0.254545	0.090909	0.000000	0.018182	0.278788		0.030303
22 (V) < 3.00	0.161290	0.064516	0.016129	0.274194	0.000000	0.000000	0.032258	0.419355	0.032258	
4 (D) >= 3.00		0.076923	0.000000	0.615385	0.076923	0.000000	0.000000	0.153846	0.000000	0.076923
6 (F) >= 3.00	0.192308		0.038462	0.346154	0.076923	0.000000	0.096154	0.134615	0.076923	0.038462
9 (I) >= 3.00	0.000000	0.100000		0.500000	0.100000	0.000000	0.200000	0.000000	0.000000	0.100000
12 (L) >= 3.00	0.564516	0.064516	0.000000		0.032258	0.000000	0.064516	0.145161	0.112903	0.016129
13 (M) >= 3.00	0.040000	0.040000	0.040000	0.520000		0.000000	0.160000	0.160000	0.040000	0.000000
14 (N) >= 3.00	0.000000	0.000000	0.000000	0.000000	0.000000		0.000000	0.000000	0.000000	0.000000
15 (O) >= 3.00	0.000000	0.250000	0.000000	0.375000	0.000000	0.000000		0.187500	0.125000	0.062500
16 (P) >= 3.00	0.400000	0.200000	0.000000	0.100000	0.000000	0.000000	0.000000		0.300000	0.000000
18 (R) >= 3.00	0.065217	0.086957	0.000000	0.326087	0.000000	0.000000	0.065217	0.434783		0.021739
22 (V) >= 3.00	0.076923	0.000000	0.000000	0.346154	0.038462	0.000000	0.153846	0.346154	0.038462	

1.3.4 Looking and Not Seeing Probabilities

A number of studies have examined the probability of looking and not seeing within an Enhanced Vision display. Lee, Hankey, & Green (2003) reported that 17% of drivers looked at the enhanced vision display during a surprise event and hit the object anyway. In Llaneras, Neurauter, & Green (2008), again during a surprise event, 3 out 7 drivers (43%) who looked at the enhanced vision display during the maneuver failed to detect the obstacle in the display. Data from Tsimhoni, Flannagan, & Green (2006) suggest that the probability of detection of an object given the display size used in the SIM scenarios should be above 85% (therefore suggesting a look-did-not-see value below 15%). In general these results suggest a potential look-did-not-see value for enhanced vision systems around 15%.

1.4 Driver Trust

Note that only surprise trials from these studies are considered, since otherwise drivers that expect an obstacle to be placed in their path while backing (experimentally) would be expected to have high levels of trust for any alerts that they received.

1.4.1 McLaughlin et al. (2003)

In this study 29 participants experienced a surprise event (plastic pylon behind the vehicle) with no countermeasure present, enhanced video by itself, proximity information by itself, and proximity information combined with rear video. Twenty-four participants out of 29 hit the obstacle, including all of those who were aided only by proximity information.

1.4.2 Lee et al. (2003)

Lee et al. (2003) had a surprise trial where a cone was placed behind the vehicle at a short distance without participant knowledge. Participants had proximity information cues available to them, along with an enhanced vision system that had the capability of highlighting a detected threat. Forty-eight participants performed the surprise trial after extensive exposure and testing with these two systems. These researchers found, on average, a 65% avoidance rate with the combination of technologies. Their eye glance analysis suggested that participants who hit the test object glanced at the Enhanced Vision display only once; those who successfully avoided the obstacle did so multiple times. Unfortunately, the presence of the rear vision system does not allow the determination of separate effects for Proximity Information alert exposure.

1.4.3 Llaneras et al. (2002)

Llaneras et al. (2002) exposed 41 drivers to a surprise event, where Backing Warnings with Auditory and Visual components were provided to drivers. Collapsed across the different factors they considered, they found that 44% of drivers responded by braking, 12% by tapping the brake, 12% by covering the brake, and 32% had no reaction. However, only 12% of drivers avoided the obstacle. If it is assumed that only drivers who avoid the obstacle exhibit sufficient trust in the countermeasure, this suggests that only 12% of drivers exhibited this trust.

1.4.4 Singer et al. (2005)

Singer et al. (2005) also included a surprise in their study (after repeated backing trials with Proximity Information), which tested mainly Backing Warning with Auditory and Visual components and Backing Warning with Auditory, Visual, and Haptic components. Three different warning configurations were used, with little change in overall outcome (the Two-Stage warning tended to elicit higher avoidance, but the difference was not statistically significant and may have been due to slight changes in the trial characteristics for this particular warning). Drivers performed a distraction task in combination with the backing maneuver. While detailed breakdowns of reasons for crashes with the obstacle are not provided, these researchers indicate that most participants who hit the obstacle interpreted the warnings as a malfunction or as if they'd backed over something unimportant (e.g., a bump) and chose to ignore it. Outcomes from the surprise trial suggest about a 67% avoidance rate, which in turn can be used to infer trust in the countermeasure by 67% of users.

1.4.5 Llaneras, McLaughlin, et al.

Llaneras, McLaughlin et al. (proprietary) tested an Automatic Braking countermeasure under surprise trial conditions. They found that 83% of drivers in a driveway backing scenario (n=27) and 96% of drivers in a long backing scenario (n=30) reacted to the warning by either maintaining their foot on the brake or putting the car into park. The remaining participants in each of these backing maneuvers attempted to accelerate the vehicle. This suggests fairly high acceptance and trust of the automatic braking countermeasure, on average 89.8%.

1.4.6 Llaneras, Neurauter, et al.

Llaneras, Neurauter, et al. (proprietary) continued the work of Llaneras, McLaughlin, et al. (proprietary) by testing drivers' responses to automatic braking countermeasures under a wider range of situations. They exposed drivers to different surprise events. The first surprise event, which occurred during extended backing, had 18% and 27% of drivers (n=11 in each case) responding to the activation of automatic braking by releasing the brakes and then accelerating. Trial outcome on these cases heavily depended on the availability of Enhanced Vision. This suggests an override rate of 22.5%, and a corresponding trust level of 77.5%. The second surprise event, which simulated backing out of a parking space, had 29% of 17 participants receiving automatic braking releasing the brakes and accelerating, implying an associated trust level of 71% (combined average across the two surprise scenarios is 74.7%). These lower figures than those observed for Llaneras, McLaughlin, et al. (proprietary) may be due to differences in the number of exposures to the system. Participants in this study were allowed to substantially exercise the automatic braking countermeasure prior to presentation of the surprise events.

1.5 Literature on Backing Kinematics

This section describes the results of a literature review used to summarize published and previously proprietary data related to the kinematics followed by a vehicle while backing. These kinematics represent a very important part of the SIM model.

1.5.1 Vehicle Kinematics Profile

Most backing maneuvers are characterized by low speeds and exhibit a substantial amount of variability between drivers and, to some extent, between backing tasks (e.g., parking versus straight backing). The backing simulation within the SIM requires a representation of the variability and shape of the backing speed profile as one of its inputs. This representation is achieved by the following parameters, distributions of which will be provided to the SIM as a function of a number of different typical backing maneuvers:

- Maximum speed attained during the backing maneuver
- Duration of backing maneuver
- Minimum Time-to-Collision (TTC) during the backing maneuver (when backing to a known obstacle)
- Time from reverse gear engagement to first backward movement
- Presence of time constraint on backing maneuver (discrete variable)
- Planned backing travel distance
- Minimum distance to object

Each of these will be discussed briefly to establish the sources of information explored to estimate them and where the values used in the SIM arise from. Not all of them are applicable to every backing maneuver. These exclusions will be articulated within each section.

Three important aspects in assessing the data that are available to describe these different backing speed parameters are the type of instruction provided to the driver (if any), the level of assistance provided by existing backing devices, and the realism of the environment in which the maneuver was performed. For the purposes of the estimation of the speed profiles, the following assumptions regarding these aspects are made. First, the instruction provided to the driver could affect their backing speed; therefore, only data obtained from 'normal backing' conditions will be considered (unless information about a different behavior, e.g., 'hurried' backing, is explicitly desired). Second, it is assumed that any sensitivity of backing profiles to the presence of backing aids is overshadowed by the variability in profiles within and between drivers. Note, however, that there were no formal tests of such an effect within the literature surveyed. The implication of this assumption is that, when made possible by other similarities, speed profiles from drivers with and without a backing aid will be combined. Third, it is assumed that backing speed profiles obtained under real-world closed course environments are representative of real-world environments in live traffic. If this traffic is detected, then the backing maneuver is paused and resumed when the driver deems it is safe to do so. For the purposes of the scenarios within the SIM, this does not represent a conflict. If the traffic is not detected, then it is a reasonable assumption that the driver would use their typical speed profile for the backing scenario of interest, and this is believed to be captured in the closed-course tests.

The primary sources consulted for the figures presented in this document were the various GM studies completed in the span of the previous five or six years. These studies include:

- Rear Near Obstacle Detection System Study (Llaneras et al., 2001): This study had 96 drivers perform six different backing maneuvers in a controlled environment with different levels of guidance (including ‘back as you normally would’) and no assistance from backing devices. Both a minivan and a sedan were tested. All of these maneuvers are relevant to provide information for each of the variables of interest cited above.

- Rear Video Study I (McLaughlin et al., 2003): This study tested more than 30 drivers and their performance with and assessment of Rear Video and Ultrasonic Detection backing aid systems. Included within this data set were five backing maneuvers performed with various levels of assistance from these devices and a ‘back as you normally would’ instruction. However, since the examination of vehicle kinematics was not a primary goal of this study, these variables are not available at sufficient resolution for use in the SIM.
- Rear Video Study II (Lee et al., 2003): This study tested 40 drivers, 20 of whom performed parallel parking maneuvers and 20 of whom performed perpendicular parking maneuvers, under several different conditions of rear video assistance. Vehicle kinematics collected for this experiment were of finer resolution than those used the Rear Video Study I, and thus are relevant to provide information for some of the variables of interest cited above.
- Rear Object Detection Study II (Llaneras et al., 2005): This study included 48 drivers that were exposed to various alert types and timings. The parking trials in this study and extended backing practice provide information for some of the variables of interest cited above.
- Rear Object Detection Study III (Llaneras et al., 2005): While not the focus of the study, this experiment included practice trials for 33 drivers performing backing into and out of a perpendicular parking space and four extended backing trials to 50 and 150 feet. These trials provide information for some of the variables of interest cited above.
- Automatic Emergency Stop Driver Acceptance (Llaneras, McLaughlin et al., proprietary): Included 88 drivers that were exposed to an initial surprise presentation of an early auto braking countermeasure and afterwards completed alerted trials using the countermeasure. In both surprise and alerted trials, a barrel was launched into the rear path of the vehicle. The introduction of an incurring obstacle early in the backing maneuver, however, does not allow for characterization of ‘typical’ backing behavior to be inferred from this data set.
- Automatic Emergency Stop Driver Acceptance II (Llaneras, Neurauter et al., proprietary): Included 36 drivers who were exposed to an automatic emergency braking system in a number of different scenarios (including a surprise trial near the end of the experimental session). Several backing maneuvers were performed, but drivers were asked to let the vehicle brake by itself for those maneuvers, potentially altering their ‘typical’ backing behavior. Therefore, the data set will not be useful to establish the desired speed profile parameters
- General Motors Corporation (GM, proprietary): This study examined naturalistic maneuvers of drivers backing out of a perpendicular space. These drivers were not accompanied by an experimenter and were subject to varying conditions on the various parking lots they visited.

In our discussion of speed profile parameters, it is helpful to understand that there may be differences in the distribution and value of these parameters as a function of the backing scenario (i.e., different scenarios may require different backing maneuvers). The scenarios for which the SIM will be exercised are cited below, grouped based on the type of backing maneuver required:

- **Backing out of a perpendicular parking space**
    - Pedestrian Scenario 1: 2-year-old pedestrian standing ~5' directly behind vehicle backing out of a parking space
    - Pedestrian Scenario 5: 5-year-old pedestrian incurring from the left ~ 5' behind vehicle backing out of parking space
    - Vehicle Scenario 3: Vehicle backing out of parking space strikes vehicle parked behind
- **Backing into a parallel parking space**
    - Pedestrian Scenario 2: 2-year-old pedestrian sitting on curb ~ 30' behind parallel parking vehicle departing roadway
- **Short backing (represented, due to lack of better data, by Wall condition (~50 ft) below)**
    - Pedestrian Scenario 3: 2-year-old pedestrian lying prone 2' offset from center line on driveway ~ 15' behind vehicle backing out of a driveway
    - Pedestrian Scenario 4: 5-year-old pedestrian incurring from the right ~ 15' behind vehicle backing out of driveway
    - Pedestrian Scenario 6: 5-year-old pedestrian incurring from the left ~ 30' behind vehicle driving in reverse down alleyway or long driveway
    - Vehicle Scenario 1: Vehicle protrudes into roadway; driver decides to rectify but strikes a parallel path vehicle directly behind
    - Vehicle Scenario 2: Vehicle backing out of driveway strikes a vehicle in motion on roadway
    - Fixed Object Scenario: Vehicle backing out of driveway strikes a utility pole

The following discussion will focus on these three particular backing maneuvers. Information for other backing maneuvers, however, will also be presented to allow for potential future expansion of the SIM to a wider range of kinematic scenarios.

1.5.2 Maximum speed attained during the backing maneuver

Llaneras, Huey, Lerner, DeLeonardis, and Singer (2001) collected backing data on maneuvers similar to those used by Huey et al. (1995). These data were obtained on a closed course environment, for a sizable number of drivers (96), and using two vehicle types similar to those owned by participants (Table F- 63). There was no significant difference in maximum speed between vehicles.

Table F- 63. Distribution of maximum speeds (in mph) from Llaneras, et al. (2001) across various applicable backing maneuvers.

Backing Maneuver	Vehicle Type	Overall Minimum	50th Percentile	Overall Maximum	10th Percentile	90th Percentile
1. Parallel parking condition	**Minivan**	0.95	2.29	3.93	1.53	3.08
	Sedan	1.21	2.33	4.46	1.57	3.58
2. Extended curve backing condition	**Minivan**	1.41	4.30	6.70	2.74	6.21
	Sedan	2.29	4.46	9.03	3.25	7.23
3. Wall condition (~50 ft)	**Minivan**	1.86	4.47	8.01	2.26	6.05

	Sedan	2.29	5.00	7.71	3.01	6.87
4. Backing out of a perpendicular parking slot	**Minivan**	0.84	2.13	9.22	0.95	3.53
	Sedan	0.96	3.59	10.70	2.05	5.42
5. Backing into a perpendicular parking slot	**Minivan**	0.87	2.00	4.51	1.04	3.08
	Sedan	0.82	2.59	4.46	1.81	3.49
6. Wall condition (~150 ft)	**Minivan**	1.98	6.01	12.27	3.62	10.05
	Sedan	2.41	7.59	14.09	4.10	11.45

Another large contributor of information for this and other parameters of the speed profile was the work of Huey, Harpster, and Lerner (Harpster, Huey, & Lerner, 1996; Huey et al., 1995; N. Lerner et al., 1997). Their research examined drivers as they performed a series of backing maneuvers on live traffic environments with no experimenter guidance. Drivers performed eight maneuvers, resulting in the maximum speed values shown in Table F- 64. Note that maneuvers 1 and 2 include combined data from Huey et al.'s original sites 2 and 7, and 3 and 8, respectively. The distributions parameters selected for each maneuver were based on goodness-of-fit tests of driver-level data available in their report's appendices. In all cases, the normal distribution selected was statistically similar to the actual distribution observed in the data.

Table F- 64. Distribution of maximum speeds (in mph) from Huey et al. (1995) across various different backing maneuvers.

Backing Maneuver	Normal distribution parameters:
1. Parallel parking condition	μ=2.91 mph, σ=1.06 mph
2. Extended curve backing condition	μ=8.30 mph, σ=3.41 mph
3. Wall condition (~50 ft)	μ=3.43 mph, σ=0.78 mph
4. Backing out of a perpendicular parking slot	μ=2.90 mph, σ=1.76 mph
5. Backing into a perpendicular parking slot	μ=2.97 mph, σ=0.68 mph
6. Wall condition (~150 ft)	Not tested
7. Angled parking condition	μ=2.93 mph, σ=1.11 mph

The values in Table F- 64 are similar to those reported in Tsimhoni, Flannagan, and Green (2006), who examined backing maneuvers observed within a naturalistic data set. These authors reported a 50th percentile maximum speed of 3.13 mph, with corresponding 75th, 85th, and 95th percentiles of 4.47, 4.92, and 6.93 mph, respectively. As a comparison, corresponding percentiles for the first backing maneuver in Table F- 64 would be 3.68, 4.08, and 4.76 mph. Note that the Tsimhoni et al. data set was not broken down by backing maneuver, therefore a wider spread of values is observed. Naturalistic observations from the ORSDURVS study (Mazzae et al., 2008) suggested a maximum speed of 3.64 mph, with a standard deviation of 1.51mph. Similar to the Tsimhoni et al. data set, no breakdown by maneuver was provided.

A study by GM (proprietary) also provided real-world data from which information on naturalistic observation of maneuvers for backing out of a perpendicular parking spot could be extracted. The maximum speeds were modeled by a normal distribution relatively well, with parameters μ=3.355 mph and σ=1.065 mph, which are similar to those observed for the sedan in Llaneras et al. (2001) but slightly higher than values obtained by Huey et al. (1995).

1.5.3 Duration of backing maneuver

Data on durations of typical backing maneuvers are available from Tsimhoni, Flannagan, and Green (2006). They report duration of motion with a 50th percentile of 4.85 sec, and 75th, 85th and 95th percentiles of 7.4, 9.8, and 15.8 seconds. A fit for a normal distribution for this sequence of values suggested parameters of μ=4.85 sec and σ=4.78 sec. These values may be of limited applicability, however, since they are not broken down by maneuver, and it would be expected that there would be differences in duration between different types of maneuvers. Huey et al. (1995) reported backing durations for each of their maneuvers (Table F- 65).

Table F- 65. Distribution of backing durations (in mph) from Huey, et al. (1995) across various different backing maneuvers.

Backing Maneuver	Mean	Standard Deviation	Minimum	Maximum
1. Parallel parking condition	15.7	3.0	4.4	30.9
2. Extended curve backing condition	34.2	9.4	14.3	87.3
3. Wall condition (~50 ft)	12.9	6.1	7.5	35.5
4. Backing out of a perpendicular parking slot	9.8	3.3	6.2	17.4
5. Backing into a perpendicular parking slot	15.4	4.5	8.2	22.9
6. Wall condition (~150 ft)	Not tested			
7. Angled parking condition	9.3	2.4	5.7	15.3

Data from GM (proprietary) provides information on real-world duration of maneuvers backing out of a perpendicular space. The distribution of durations was well fitted with a normal distribution of parameters, μ=11.867 sec and σ=22.459 sec. Note that the mean value is slightly higher than the value obtained by Huey et al. (1995) and that the standard deviation is substantially higher. This may be due to the naturalistic nature of the maneuvers, which may have been influenced by passing traffic.

Values for the ORSDURVS study (Mazzae et al., 2008) were similar, with a mean duration of 10.08 sec (SD = 6.44 sec). However, no breakdown of durations across different types of maneuvers was provided.

1.5.4 Minimum TTC during the backing maneuver

When drivers are backing towards known obstacles (e.g., Pedestrian Scenario 2, where the driver is parallel parking towards a parked vehicle), the presence of that obstacle affects the distance and speed of the backing maneuver. Those two measures are combined into a minimum TTC to that obstacle, which can be quantified to constrain how fast a driver will approach an obstacle as a function of the distance between the obstacle and the driver. Note that this measure is different from TTC thresholds that may be used by countermeasures to issue alerts and is applicable only to backing maneuvers where the driver is backing towards a target object that has been detected, since it represents the level of comfort with the driver as he/she approaches a known obstacle. For other backing maneuvers, other parameters (e.g., planned backing distance, see below) may be considered more applicable.

As previously mentioned, Llaneras et al. (2001) included some conditions relevant to this parameter (Table F- 66). These data include extended curve backing since an obstacle was placed in the driver's path for this condition. Minimum TTC was significantly different across vehicle types. Data from Huey and colleagues are also available for this measure (Table F- 67).

Table F- 66. Minimum TTC (in sec) from Llaneras, et al. (2001) across various applicable backing maneuvers.

Backing Maneuver	Vehicle Type	Overall Minimum	50th Percentile	Overall Maximum	10th Percentile	90th Percentile
1. Parallel parking condition	**Minivan**	0.47	3.00	9.09	0.81	5.39
	Sedan	0.31	2.18	7.71	0.45	4.91
2. Extended curve backing condition	**Minivan**	0.41	1.63	4.11	0.48	2.83
	Sedan	0.33	1.93	6.41	1.13	3.61
3. Wall condition (~50 ft)	**Minivan**	0.51	1.72	6.00	0.68	3.47
	Sedan	0.40	2.44	5.63	1.54	4.26
5. Backing into a perpendicular parking slot	**Minivan**	0.38	2.88	7.23	0.63	6.45
	Sedan	0.32	2.04	12.49	0.47	3.25
6. Wall condition (~150 ft)	**Minivan**	0.32	2.22	7.98	0.94	4.59
	Sedan	1.20	2.60	6.62	1.77	4.36

Table F- 67. Minimum TTC (in sec) from Huey, et al. (1995) across various applicable backing maneuvers.

Backing Maneuver	Overall Minimum	Mean	Overall Maximum	10th Percentile
1. Parallel parking condition*	1.0 & 2.0	3.4 & 3.7	6.3 & 6.3	1.3 &2.1
3. Wall condition (~50 ft)	1.1	2.4	3.9	1.5
5. Backing into a perpendicular parking slot	1.7	3.0	4.3	1.9

* This condition was repeated at two different sites, hence the two values for each category

1.5.5 Time from reverse gear engagement to first backward movement

Data from Lee et al. (2003) were used to estimate time from reverse gear engagement to first backward movement for parallel parking and backing into a perpendicular parking spot (Table F- 68). The mean time for the parallel parking backing maneuver was 3.0 sec (SD=2.1). The corresponding time for the perpendicular backing maneuver was 2.2 sec (SD=1.7). Both time distributions were observed to be fit by a lognormal distribution relatively well.

Table F- 68. Distribution parameters for time from reverse gear engagement to first backward movement, taken from Lee et al. (2003) across various backing maneuvers.

Backing Maneuver	LogNormal distribution parameters:
1. Parallel parking condition	μ=0.861, σ=0.735
5. Backing into a perpendicular parking slot	μ=0.536, σ=0.732

Data from GM (proprietary) were used to obtain a real-world distribution for time to reverse gear engagement to first backward movement for maneuvers involving backing out of a perpendicular space. The average values for these times were somewhat higher than those observed by Lee et al. (2003), which were obtained in a controlled (i.e., traffic-less) environment. The mean time was 4.34 sec, with a standard deviation of 2.74 sec. The empirical values were well-modeled with a generalized extreme value distribution with parameters k=0.031, μ=3.334, and σ=1.719.

Mazzae, Barickman, Baldwin, & Ranney (2008) break this time down based on the availability of rear video and rear parking sensor systems, finding a longer time for drivers that had rear video, or rear video and rear parking sensors, than for drivers without these sensors. They attribute the finding to the slight delay that rear video systems have in showing the rear view. Table F- 69, below, was created from Table 8 in their report. The average percent increase from the No System condition compared to the two conditions with a system was also calculated. The overall average increase was 11.4%.

Table F- 69. Distribution of time (in seconds) from reverse gear engagement to first backward movement from Mazzae, et al. (2008). Results are broken down by the backing system available.

Percentile	None (N=576)	Rear Video (N=862)	Rear Video and Rear Parking Sensor System (N=948)	Average Percent Increase from No System to RV and RV + RPS
100% (Maximum)	25.77	29.44	31.56	--
99%	17.51	17.07	21.62	11.1%
95%	9.81	10.07	10.21	3.4%
90%	6.33	7.11	7.09	12.2%
75%	3.28	4.08	4.28	27.6%
50%	2.09	2.39	2.58	19.1%
25%	1.58	1.69	1.73	8.3%
10%	1.21	1.36	1.35	12.0%
5%	1.03	1.15	1.16	12.2%
1%	0.94	0.82	1.00	-2.7%
0% (Minimum)	0.42	0.62	0.76	--

1.5.6 Presence of time constraint on backing maneuver

While this parameter is discrete, it has implications for other previously discussed parameters. For example, during rushed conditions the driver may wait less time to start moving after the engagement of reverse gear. To study the extent of this effect, Llaneras et al. (2001) had drivers perform trials in which they backed faster than they usually would, pretending to be 'late for an important meeting.' There were significant differences between speed instructions for the maximum speed and minimum TTC (Table F- 70 and Table F- 71) selected by drivers.

Table F- 70. Distribution of maximum speeds (in mph) from Llaneras, et al. (2001) across various applicable backing maneuvers for the faster speed condition.

Backing Maneuver	Vehicle Type	Overall Minimum	Mean	Overall Maximum	10th Percentile	50th Percentile	90th Percentile
2. Extended curve backing condition	**Minivan**	3.38	8.54	14.37	5.60	8.69	11.69
	Sedan	0.96	8.64	15.30	5.27	8.31	12.89
3. Wall condition (~50 ft)	**Minivan**	4.57	8.61	11.72	6.67	8.82	10.21
	Sedan	1.32	8.73	13.73	6.03	8.80	11.45
6. Wall condition (~150 ft)	**Minivan**	0.93	13.28	21.95	8.67	13.22	17.52
	Sedan	1.81	13.47	21.69	8.00	13.73	19.16

Table F- 71. Distribution of TTC (in sec) from Llaneras et al. (2001) across various applicable backing maneuvers for the faster speed condition.

Backing Maneuver	Vehicle Type	Overall Minimum	Mean	Overall Maximum	10th Percentile	50th Percentile	90th Percentile
2. Extended curve backing condition	**Minivan**	0.07	0.94	5.08	0.25	0.80	1.81
	Sedan	0.25	1.55	13.75	0.59	1.25	2.40
3. Wall condition (~50 ft)	**Minivan**	0.05	0.74	2.41	0.18	0.58	1.58
	Sedan	0.26	1.32	5.58	0.67	1.13	2.03
6. Wall condition (~150 ft)	**Minivan**	0.12	1.16	5.67	0.36	0.92	2.18
	Sedan	0.37	1.77	12.50	0.85	1.50	2.85

1.5.7 Planned backing travel distance

This parameter will be used to represent a goal for the backing maneuver when there is no perceived obstacle in the driver's path. The assumption is made that the driver is aware (although not necessarily conscious) that he needs to back until a certain location in order to be able to initiate or resume normal (i.e., forward) driving. The parameter will be dependent on the driving maneuver and, therefore, the scenario being analyzed. On an aggregate basis (i.e., across all backing maneuvers), Tsimhoni, Flannagan, and Green (2006) reported a 50th percentile distance of backing maneuver of 14.83 ft, with corresponding 75th, 85th, and 95th percentiles of 26.80, 40.39, and 74.28 ft, respectively. Other information about typical values could not be found in the literature, as most relevant studies set this as one of the characteristics of the trials that are run. Llaneras et al. (2001), for example, had backing maneuvers that required the vehicle to travel over 150 ft. Huey et al. (1995) had an extended curved backing condition that required the vehicle to travel over 200 ft. GM (proprietary) provides data on the backing distance for naturalistic maneuvers involving backing out of a perpendicular parking spot. The average distance recorded was 20.94 feet, with a standard deviation of 7.19 ft. Data from the ORSDURVS study (Mazzae et al., 2008) show naturalistic travel distances of 33.97 ft (SD = 25.96 ft). However, the data are not broken down by type of maneuver.

1.5.8 Minimum distance to object

When there is a perceived obstacle that is being attentively backed into, TTC provides an indication of the dynamic characteristics of the approach, but fails to represent where the vehicle stops with respect to the obstacle and the backing maneuver can be considered complete. Llaneras et al. (2001) characterized this distance for several backing maneuvers (Table F- 72).

Table F- 72. Minimum distance to object (in feet) from Llaneras, et al. (2001) across various applicable backing maneuvers.

Backing Maneuver	Vehicle Type	5th Percentile	10th Percentile	50th Percentile	90th Percentile	95th Percentile
1. Parallel parking condition	Minivan	0.53	1.08	2.20	3.77	4.00
	Sedan	0.36	0.56	1.48	2.99	3.97
2. Extended curve backing condition	Minivan	1.12	1.18	2.07	5.32	5.55
	Sedan	1.22	2.17	3.76	8.14	10.07
3. Wall condition (~50 ft)	Minivan	0.85	1.06	2.81	6.11	6.78
	Sedan	2.17	3.55	5.50	8.66	10.27
5. Backing into a perpendicular parking slot	Minivan	0.59	1.35	2.28	3.84	4.07
	Sedan	0.40	1.05	2.69	3.87	4.23
6. Wall condition (~150 ft)	Minivan	1.18	1.64	4.01	6.50	7.25
	Sedan	2.89	3.55	5.81	10.37	11.85

1.5.9 Shape of speed profile

Huey et al. (1995) show samples of speed profiles in their report, but do not provide the full data set that would be necessary to characterize these profiles. Other reports (e.g., Llaneras et al.,2001) provide summary measures for speed, but not a time-history of such speed. These time-histories are not typically provided as they are well summarized by the different measures that are derived from them. However, the time-histories are important for the SIM because they provide information about the shape of these profiles, which provides information about speed variations (and, consequently, acceleration). The proof-of-concept SIM employed a bell-shaped curve (adjusted with a number of the aforementioned parameters) to provide the profile framework. However, observation of data from Huey et al. (1995) suggests that this approach may not be correct, at least for some subset of backing maneuvers.

For example, in addition to observation of speed variations in continuous backing, it is also important to understand how successive starts and stops factor into the completion of a backing maneuver. For some maneuvers (e.g., parking), it is not unrealistic that a driver would stop while several glances are directed to different areas, and then continue the maneuver once the driver is satisfied that it is safe to do so. It could also be expected that the characteristics of successive accelerations and decelerations would vary based on the closeness of the vehicle to the target location. The Lee et al. (2003) data were used to model the average and standard deviation of duration, maximum speed attained, and duration of pauses for start-stop events as a function of successive start-stop maneuvers. While the number of such maneuvers can also be obtained from the data, this number is believed to be a function of the kinematic characteristics of the successive start-stop maneuvers and the intended distance of the maneuver (see Planned Backing Distance, above), and therefore was not modeled. Note that the average number of successive reverse movements for a parallel parking maneuver was 3.58 (SD=2.11); the corresponding average value for a perpendicular parking maneuver was 3.98 (SD=2.68). There were distinct relationships between values for most variables and the succession of events. These parameters were captured for functions that fit the empirical data well (Table F- 73). The equations are valid for the interval [1,10]; successions higher than 10 start-stop events should be modeled as the 10th event.

Table F- 73. Distribution parameters describing the mean and standard deviation of various profile speed shape descriptors as a function of successive start and stop events, taken from Lee et al. (2003).

Backing Maneuver	Duration of Movement* Mean	Duration of Movement* SD	Maximum Speed** Mean	Maximum Speed** SD	Duration of Pause** Mean	Duration of Pause** SD
1. Parallel parking condition	*a=6.479, b=-0.235*	*a=6.282, b=-0.234*	p_1=-0.008, p_2=-0.192, p_3=1.741	p_1=0.019, p_2=-0.264, p_3=1.149	p_1=-0.038, p_2=0.453, p_3=1.137	*2.384 (constant)*
5. Backing into a perpendicular parking slot	*a=7.325, b=-0.128*	*a=6.820, b=-0.133*	p_1=-0.016, p_2=-0.228, p_3=1.486	p_1=0.000, p_2=-0.065, p_3=0.940	p_1=0.000, p_2=0.241, p_3=1.849	*2.140 (constant)*

* Modeled using an exponential equation: $F(x) = a \times e^{bx}$, where x is the succession of maneuver

** Modeled using a quadratic equation: $F(x) = p_1x^2 + p_2x + p_3$, where x is the succession of maneuver

Naturalistic data from the ORSDURVS study (Mazzae et al., 2008) indicated, on average, 1.34 (SD = 0.81) movements, but maneuvers for which these values were calculated were not specified. Analysis of a subset of these data completed for this project provided more detailed distributions describing backing maneuvers with more than one movement. Results of that analysis are summarized in Table F- 74. It is assumed that the majority of these observations would come from parallel parking maneuvers, since the analysis was constrained to backing maneuvers that exhibited more than one start-stop sequence.

Table F- 74. Distribution parameters describing the Weibull scale and shape parameters for duration, maximum speed, and duration of pause for the first five movements calculated using data from the ORSDURVS study (Mazzae et al., 2008).

Variable	Movement (Weibull distribution; a = scale, b = shape) 1st	2nd	3rd	4th	5th and higher
Duration (sec)	*Mean=6.48 SD=6.48 (a= 6.477, b= 1.000)*	*Mean=5.16 SD=6.60 (a= 4.507, b= 0.789)*	*Mean=6.14 SD=6.41 (a= 6.025, b= 0.958)*	*Mean=4.65 SD=3.65 (a= 5.020, b= 1.282)*	*Mean=3.42 SD=3.54 (a= 3.362, b= 0.965)*
Maximum Speed (m/s)	*Mean=3.25 SD=3.38 (a= 3.190, b= 0.960)*	*Mean=2.78 SD=2.68 (a= 2.823, b= 1.038)*	*Mean=2.42 SD=1.56 (a= 2.237, b= 1.335)*	*Mean=1.60 SD=1.05 (a= 1.779, b= 1.557)*	*Mean=0.99 SD=0.14 (a= 1.112, b= 2.912)*
Duration of Pause (sec)	*Mean=2.49 SD=2.79 (a= 2.352, b= 0.892)*	*Mean=2.07 SD=2.10 (a= 2.059, b= 0.985)*	*Mean=2.25 SD=2.26 (a= 2.249, b= 0.998)*	*Mean=1.15 SD=0.57 (a= 1.301, b= 2.138)*	*Mean=1.15 SD=0.57 (a= 1.301, b= 2.138)*

Data from GM (proprietary) provide speed profile shape information for maneuvers for backing out of a perpendicular spot. In this data set, however, over 95% of the maneuvers involved only a single start-stop event. Therefore, the relationships presented in Table F- 74 are not applicable and parameters can be modeled regardless of the sequence in the maneuver. The duration of the movement was well-modeled with a normal distribution of parameters μ=2.707 sec and σ=1.78 sec. Maximum speed achieved was described in a previous section, and the duration of the pause was not applicable (there were too few instances to infer a distribution).

The data in Lee et al. (2003) were of insufficient resolution to infer acceleration rates for these starts and stops, and such data were not available in the literature surveyed. Data from GM (proprietary), however, show maximum deceleration values during a naturalistic backing out of a perpendicular space maneuver that can be modeled with a normal distribution with parameters μ=0.1407 g and σ=0.0348 g, with limits of 0.06 g and 0.21 g. Corresponding maximum acceleration values can be modeled with the generalized extreme value distribution, parameters k=-1.0210, μ=-0.0608, and σ=0.0519, mean and standard deviation were 0.0612 g and 0.0523 g, respectively. Limits were 0.0100 g and 0.2600 g. Data from the ORSDURVS study (Mazzae et al., 2008) were used to isolate acceleration and braking portions of the backing motions. Average acceleration and decelerations were calculated and Weibull distributions fit to represent their relative frequencies. Scale and shape parameters for acceleration portions of the backing maneuvers were 0.045 and 0.888. Corresponding values for deceleration portions were 0.028 and 0.641.

APPENDIX G:

MatLab Simulation Code

Advanced Crash Avoidance Technologies Program (ACAT)
Backing crash Countermeasures Project

SIMcontrollerNHTSA.m

```
%% Documentation
% This main Matlab script can be functionally summarized as follows:
%  -Create a main loop that runs the entire Monte Carlo simulation twice,
once with the selected countermeasures active and once with all
countermeasures inactive.  This allows direct calculation of the System
Effectiveness for a "scenario"
%  -Define constants
%  -Define the characteristics of the Monte Carlo cycles (number of runs and
number of iterations per run)
%  -For each individual run
%       -Initialize the random number seed (to prevent run replications)
%  -For each iteration within each run
%       -Set up and run the simulation and gather results
%  -Save results
%  -Calculate summary statistics of interest

%% Main Body of Control Code
% Clear variables in workspace
clear;
% Start clock to calculate simulation run time
tic;
% Initialize Matrix of outcomes
FullOutcomeMatrix=[];
FullOutcomeMatrixNC=[];

%***************************************************************************
*****
% START USER INPUT FOR THIS SECTION
%***
%***************************************************************************
*****
% Path to location of model file (i.e., the directory)
%***
FilePath='C:\Documents and Settings\raja.ranganathan\My
Documents\ACAT\GM_VTTI\SIM model\'   %***

%***
% Scenario Generation (1 for random selection amongst possible scenarios )
%***
ScenarioGen=0;
%***
% Matrix of possible scenarios, each column represents one scenario, from
%***
% 1 through 10, 0 would be inactive, 1 would be active;
%***
PossibleScenarios=[1,0,0,0,0,0,0,0,0,0];
%***
                                                                       %***
```

```
% Define initial parameters
%***
Parameters; % DO NOT CHANGE THIS LINE
%***
                                                                        %***
% Probability that the backing maneuver is performed under time
%***
% constraints
%***
HurriedBacking=0.10;
                                                                 %***

%***
% Obstacle Type and Characteristics
%***
NoObstacle=0; % If set to 1,then some trials will have no obstacle
%***
NoObstacleProbability=1; % Probability that no obstacle will be present
%***

%***
% Monte Carlo Cycle
%***
NumberofRuns=1;
%***
NumberofIterations=10; % for each of the runs
%***
                                                                              %***
for wholeindex=1:2 % DO NOT CHANGE THIS LINE
%***
    % Countermeasures Available (second parameter is 1 if it is)
%***
    VehicleApproach=[0,0];
%***
    EnhancedVisibility=[0,1];
%***
    ProximityInformation=[0,1];
%***
    WarningStage1=[0,1];
%***
    WarningStage2=[0,1];
%***
    AutomaticBraking=[0,1];
%***

%***
%***************************************************************************
*****
% END OF USER INPUT FOR THIS SECTION
%***
%***************************************************************************
*****

    if wholeindex==2 % No countermeasures, to generate baseline for system
effectiveness estimation
```

```
        VehicleApproach=[0,0];
        EnhancedVisibility=[0,0];
        ProximityInformation=[0,0];
        WarningStage1=[0,0];
        WarningStage2=[0,0];
        AutomaticBraking=[0,0];
    end;

    % Separation between backing initiation and active backing
    BackInitSpeedThreshold=[0,1.78816]; % in m/s; based on 4 mph threshold
for proximity information; known from system specifications

    for i=1:NumberofRuns
        OutcomeMatrix=zeros(NumberofIterations,26);
        % Random number seed (use the second RandomSeed command if the
simulation is real)
        % RandomSeed=207937;
        RandomSeed=floor(sum(100*clock));
        rand('twister',RandomSeed);
        randn('seed',RandomSeed);

        for j=1:NumberofIterations;
            OTInputs;

            if ScenarioGen %Random selection amongst possible scenarios

SelectedScenarios=(PossibleScenarios'.*[1:size(PossibleScenarios,2)]')';
                SelectedScenarios(:,find(SelectedScenarios(1,:)==0))=[];

SelectedScenarios=SelectedScenarios(1,ceil(rand()*size(SelectedScenarios,2)))
;
            else

SelectedScenarios=(PossibleScenarios'.*[1:size(PossibleScenarios,2)]')';
                SelectedScenarios=find(SelectedScenarios(1,:)~=0,1,'first');
            end;

            % Looked-but-did-not-see percentage
            if SelectedScenarios==1 | SelectedScenarios==2 |
SelectedScenarios==3 % Taken from driver in the loop test for Ped 3 scenario
                LookedDidNotSeeEnhancedVision=[0,0.22];
                LookedDidNotSeeLeftMirror=[0,0.22];
                LookedDidNotSeeRightMirror=[0,0.22];
                LookedDidNotSeeRearViewMirror=[0,0.22];
                LookedDidNotSeeOverShoulder=[0,0.22];
                LookedDidNotSeeVisualDVI=[0,0.0];
            end;
            if SelectedScenarios==4 | SelectedScenarios==6 % Taken from
driver in the loop test for Ped 4 scenario
                LookedDidNotSeeEnhancedVision=[0,0.50];
                LookedDidNotSeeLeftMirror=[0,0.50];
                LookedDidNotSeeRightMirror=[0,0.50];
                LookedDidNotSeeRearViewMirror=[0,0.50];
                LookedDidNotSeeOverShoulder=[0,0.50];
                LookedDidNotSeeVisualDVI=[0,0.0];
            end;
```

```
            if SelectedScenarios==5 % Taken from driver in the loop test for
Ped 5 scenario
                LookedDidNotSeeEnhancedVision=[0,0.0];
                LookedDidNotSeeLeftMirror=[0,0.0];
                LookedDidNotSeeRightMirror=[0,0.0];
                LookedDidNotSeeRearViewMirror=[0,0.0];
                LookedDidNotSeeOverShoulder=[0,0.0];
                LookedDidNotSeeVisualDVI=[0,0.0];
            end;
            if SelectedScenarios==7 % Taken from driver in the loop test for
Veh-Veh 1 scenario
                LookedDidNotSeeEnhancedVision=[0,0.0];
                LookedDidNotSeeLeftMirror=[0,0.0];
                LookedDidNotSeeRightMirror=[0,0.0];
                LookedDidNotSeeRearViewMirror=[0,0.0];
                LookedDidNotSeeOverShoulder=[0,0.0];
                LookedDidNotSeeVisualDVI=[0,0.0];
            end;
            if SelectedScenarios==8 | SelectedScenarios==9 |
SelectedScenarios==10 % Taken from driver in the loop test for Veh-FO 1
scenario
                LookedDidNotSeeEnhancedVision=[0,0.11];
                LookedDidNotSeeLeftMirror=[0,0.11];
                LookedDidNotSeeRightMirror=[0,0.11];
                LookedDidNotSeeRearViewMirror=[0,0.11];
                LookedDidNotSeeOverShoulder=[0,0.11];
                LookedDidNotSeeVisualDVI=[0,0.0];
            end;

            Visibility;

            % Consider obstruction effects on the visibility of objects
            % within the mirrors
            if SelectedScenarios==1 | SelectedScenarios==5 |
SelectedScenarios==9
                LeftMirrorOTProxGrid(:,:,1:30)=zeros(6,110,30);
                LeftMirrorOTProxGrid(:,:,41:70)=zeros(6,110,30);
                RightMirrorOTProxGrid(:,:,1:30)=zeros(6,110,30);
                RightMirrorOTProxGrid(:,:,41:70)=zeros(6,110,30);
                OvertheShoulderOTProxGrid(:,:,1:30)=zeros(6,110,30);
                OvertheShoulderOTProxGrid(:,:,41:70)=zeros(6,110,30);
                RearViewMirrorOTProxGrid(:,:,1:30)=zeros(6,110,30);
                RearViewMirrorOTProxGrid(:,:,41:70)=zeros(6,110,30);
            end;
            if SelectedScenarios==2
                RightMirrorOTProxGrid(:,:,1:30)=zeros(6,110,30);
                RightMirrorOTProxGrid(:,:,41:70)=zeros(6,110,30);
                OvertheShoulderOTProxGrid(:,:,41:70)=zeros(6,110,30);
                RearViewMirrorOTProxGrid(:,:,41:70)=zeros(6,110,30);
            end;
            if SelectedScenarios==6
                LeftMirrorOTProxGrid(:,:,1:30)=zeros(6,110,30);
                LeftMirrorOTProxGrid(:,:,41:70)=zeros(6,110,30);
                OvertheShoulderOTProxGrid(:,:,1:30)=zeros(6,110,30);
                RearViewMirrorOTProxGrid(:,:,1:30)=zeros(6,110,30);
            end;
```

```
            % Variables used to specify the obstacle and the scenario
            % Is the obstacle static? (Use 0 for Static)
                % ObstacleStatic=[0, 0];
            % Initial Location Boundaries (in meters, from rear bumper, min
            % longitudinal, max longitudinal, min lateral, max lateral)
            % Applies only to STATIC objects
                % ObstaclePositionLimits=[1.524,1.524,0,0];
            % Point in the vehicle's track, expressed in terms of
            % approximate percentage of bumper width where a DYNAMIC
            % obstacle will be hit, the percentage is constrained to the
            % central 90% of the vehicle width (expressed as 90% of each
half)
            % to avoid boundary conditions
                % sign=(rand()>0.5); number=rand()*0.90;
ObstacleStrikingPoint=[0,((sign==0)*-1*number)+((sign==1)*1*number)];
clear('sign','number');
            % Initial Target Position (in meters, from rear bumper, min
            % longitudinal, max longitudinal, min lateral, max lateral)
            % Applies only to scenarios where backing towards a perceived
            % object occurs
                % TargetPosition=[9.144,9.144,VehicleWidth,VehicleWidth];

            % For the table of obstacle lookup characteristics - Column index
represents
            % obstacle type (see above), Row indices: 1) Width (in m), 2)
Height
            % (in m)

            ObstaclePositionLimits=[];
            ObstacleStrikingPoint=[];
            TargetPosition=[];
            ObstacleAbsence=0;
            if NoObstacle ObstacleAbsence=rand()<NoObstacleProbability; end;
            if SelectedScenarios==1 %Two-year old pedestrian standing
                ObstacleType=[0, 1];
                ObstacleStatic=[0, 0];
                ObstaclePositionLimits=[1.524,1.524,0,0]; %5'
            elseif SelectedScenarios==2 %Two-year old pedestrian sitting
                ObstacleType=[0, 2];
                ObstacleStatic=[0, 0];

        ObstaclePositionLimits=[7.62,7.62,2.5*VehicleWidth(1,2),2.5*VehicleWi
dth(1,2)]; %25'

TargetPosition=[9.144,9.144,2*VehicleWidth(1,2),2*VehicleWidth(1,2)]; %30'
            elseif SelectedScenarios==3 %Two-year old pedestrian lying prone
                ObstacleType=[0, 3];
                ObstacleStatic=[0, 0];
                ObstaclePositionLimits=[4.572,4.572,-0.6096,-0.6096]; %15',-
2'
            elseif SelectedScenarios==4 %Five-year old standing pedestrian
                ObstacleType=[0, 4];
                ObstacleStatic=[0, 1];
                sign=(rand()>0.5); number=rand()*0.90;
ObstacleStrikingPoint=[0,((sign==0)*-1*number)+((sign==1)*1*number)];
clear('sign','number');
            elseif SelectedScenarios==5 %Five-year old standing pedestrian
```

```
                ObstacleType=[0, 4];
                ObstacleStatic=[0, 1];
                sign=(rand()>0.5); number=rand()*0.90;
ObstacleStrikingPoint=[0,((sign==0)*-1*number)+((sign==1)*1*number)];
clear('sign','number');
            elseif SelectedScenarios==6 %Five-year old standing pedestrian
                ObstacleType=[0, 4];
                ObstacleStatic=[0, 1];
                sign=(rand()>0.5); number=rand()*0.90;
ObstacleStrikingPoint=[0,((sign==0)*-1*number)+((sign==1)*1*number)];
clear('sign','number');
            elseif SelectedScenarios==7 %Vehicle
                ObstacleType=[0, 5];
                ObstacleStatic=[0, 0];
                ObstaclePositionLimits=[1.524,1.524,0,0]; %5'
            elseif SelectedScenarios==8 %Vehicle
                ObstacleType=[0, 5];
                ObstacleStatic=[0, 1];
            elseif SelectedScenarios==9 %Vehicle
                ObstacleType=[0, 5];
                ObstacleStatic=[0, 0];
                ObstaclePositionLimits=[7.62,7.62,0,0]; %25'

TargetPosition=[9.144,9.144,2*VehicleWidth(1,2),2*VehicleWidth(1,2)]; %30'
            elseif SelectedScenarios==10 %Pole
                ObstacleType=[0, 6];
                ObstacleStatic=[0, 0];
                ObstaclePositionLimits=[4.572,4.572,0,0]; %15'
            end

            %Take away obstacle if it is a No Obstacle Present Trial
            if ObstacleAbsence
                ObstacleStatic=[0, 0];
                ObstacleType=[0, 0];
                ObstaclePositionLimits=[exp(100),exp(100),exp(100),exp(100)];
% There is an obstacle, but it has zero dimensions and is really, really far
away
            end;

            % Initial obstacle position (for static obstacles)
            if ObstacleStatic(:,2)==0
                ObstaclePositionLong=[0,(rand()*(ObstaclePositionLimits(1,2)-
ObstaclePositionLimits(1,1)))+ObstaclePositionLimits(1,1)];
                ObstaclePositionLat=[0,(rand()*(ObstaclePositionLimits(1,4)-
ObstaclePositionLimits(1,3)))+ObstaclePositionLimits(1,3)];
            else
                ObstaclePositionLong=[];
                ObstaclePositionLat=[];
            end;

            % Target Position
            TargetPositionLong=[0, 0];
            TargetPositionLat=[0, 0];
            if ~isempty(TargetPosition)
                TargetPositionLong=[0,(rand()*(TargetPosition(1,2)-
TargetPosition(1,1)))+TargetPosition(1,1)];
```

```
                TargetPositionLat=[0,(rand()*(TargetPosition(1,4)-
TargetPosition(1,3)))+TargetPosition(1,3)];
            end;

            % Probability that the view to the obstacle will be
            % unobstructed.  Assign detection matrix accordingly.
            ProbabilityofPreviewData=[0,0,1,1,0,1,1,1,0,1];

ProbabilityofPreview=ProbabilityofPreviewData(1,SelectedScenarios);

BackingInitiationAutomaticBrakingOTProxGrid=BackingInitiationAutomaticBraking
OTProxGrid +
PBackingInitiationAutomaticBrakingOTProxGrid.*(ProbabilityofPreview) +
NoPBackingInitiationAutomaticBrakingOTProxGrid.*(1-ProbabilityofPreview);
            if ~isempty(find(BackingInitiationAutomaticBrakingOTProxGrid>1))
disp('Check improper addition'); keyboard; end;
            ActiveBackingBWStage1OTProxGrid=ActiveBackingBWStage1OTProxGrid +
PActiveBackingBWStage1OTProxGrid.*(ProbabilityofPreview) +
NoPActiveBackingBWStage1OTProxGrid.*(1-ProbabilityofPreview);
            if ~isempty(find(ActiveBackingBWStage1OTProxGrid>1)) disp('Check
improper addition'); keyboard; end;
            ActiveBackingBWStage2OTProxGrid=ActiveBackingBWStage2OTProxGrid +
PActiveBackingBWStage2OTProxGrid.*(ProbabilityofPreview) +
NoPActiveBackingBWStage2OTProxGrid.*(1-ProbabilityofPreview);
            if ~isempty(find(ActiveBackingBWStage2OTProxGrid>1)) disp('Check
improper addition'); keyboard; end;

ActiveBackingAutomaticBrakingOTProxGrid=ActiveBackingAutomaticBrakingOTProxGr
id + PActiveBackingAutomaticBrakingOTProxGrid.*(ProbabilityofPreview) +
NoPActiveBackingAutomaticBrakingOTProxGrid.*(1-ProbabilityofPreview);
            if ~isempty(find(ActiveBackingAutomaticBrakingOTProxGrid>1))
disp('Check improper addition'); keyboard; end;

            MinTTC=[0];
            HurriedBackingFlag=[];
            if HurriedBacking>=rand();
                HurriedBackingFlag=1;
            end;
            LowerBackingDistanceX=[];
            UpperBackingDistanceX=[];
            LowerBackingDistanceY=[];
            UpperBackingDistanceY=[];
            MinimumDistance=[];
            StraightBackingSegmentDistance=0;

            % Generate Vehicle Kinematics Profile
            MU=[]; SIGMA=[]; SHIFT=[];
            if SelectedScenarios==1 | SelectedScenarios==5 |
SelectedScenarios==9 %Represented by backing out of a perpendicular parking
space
                if HurriedBackingFlag
                    MeanMaxSpeed=1.83; % in m/s
                    SDMaxSpeed=0.42; % in m/s
                else
                    MeanMaxSpeed=0.95; % in m/s
                    SDMaxSpeed=0.45; % in m/s
                end;
```

```
                if SelectedScenarios==1
                    LowerBackingDistanceX=4.57; % in meters
                    UpperBackingDistanceX=7.62; % in meters
                    LowerBackingDistanceY=0; % in meters
                    UpperBackingDistanceY=0; % in meters
                elseif SelectedScenarios==5
                    LowerBackingDistanceX=4.57; % in meters
                    UpperBackingDistanceX=7.62; % in meters
                    LowerBackingDistanceY=0; % in meters
                    UpperBackingDistanceY=0; % in meters
                elseif SelectedScenarios==9
                    LowerBackingDistanceX=8.14; % in meters
                    UpperBackingDistanceX=10.67; % in meters
                    LowerBackingDistanceY=0.91; % in meters
                    UpperBackingDistanceY=1.22; % in meters
                end;
                if SelectedScenarios==9
                    MeanMinimumDistance=0.86;
                    SDMinimumDistance=0.60;

MinimumDistance=normrnd(MeanMinimumDistance,SDMinimumDistance);
                    if
MinimumDistance<norminv(0.01,MeanMinimumDistance,SDMinimumDistance);
MinimumDistance=norminv(0.01,MeanMinimumDistance,SDMinimumDistance); end;
                    if
MinimumDistance>norminv(0.99,MeanMinimumDistance,SDMinimumDistance);
MinimumDistance=norminv(0.99,MeanMinimumDistance,SDMinimumDistance); end;
                    % The following assumes that the path traveled by the
                    % vehicle will follow the shape of a parabola
                    h=LowerBackingDistanceX + (UpperBackingDistanceX-
LowerBackingDistanceX)*rand() - MinimumDistance;
                    a=LowerBackingDistanceY + (UpperBackingDistanceY-
LowerBackingDistanceY)*rand();
                    PlannedBackingDistanceX=h;
                    PlannedBackingDistanceY=a;

PlannedBackingDistance=0.5*(sqrt(a^2+4*h^2))+(a^2*(asinh((2*h+sqrt(a^2+4*h^2)
)/(a)))/(4*h)); %in meters
                    clear('h','a','temp');
                else
                    PlannedBackingDistanceX=LowerBackingDistanceX +
(UpperBackingDistanceX-LowerBackingDistanceX)*rand(); %in meters
                    PlannedBackingDistanceY=LowerBackingDistanceY +
(UpperBackingDistanceY-LowerBackingDistanceY)*rand(); %in meters
                    PlannedBackingDistance=sqrt(PlannedBackingDistanceX^2 +
PlannedBackingDistanceY^2);
                end;
                MeanBackingDuration=11.87; %in sec
                SDBackingDuration=22.46; %in sec

                BackingDurationDither=gevrnd(0.031,1.719,3.334); %in sec
                if BackingDurationDither<0.5; BackingDurationDither=0.5; end;

                MaxSpeed=normrnd(MeanMaxSpeed,SDMaxSpeed);
                if HurriedBackingFlag
                    if MaxSpeed<0.92; MaxSpeed=0.92; end;
                    if MaxSpeed>6.03; MaxSpeed=6.03; end;
```

```
                else
                    if MaxSpeed<0.38; MaxSpeed=0.38; end;
                    if MaxSpeed>4.12; MaxSpeed=4.12; end;
                end;


BackingDuration=normrnd(MeanBackingDuration,SDBackingDuration);
                if BackingDuration<6.2; BackingDuration=6.2; end;
                if BackingDuration>17.4; BackingDuration=17.4; end;

                if SelectedScenarios==9
                    if HurriedBackingFlag
                        MeanMinTTC=0.74; % in sec
                        SDMinTTC=0.55; % in sec
                    else
                        MeanMinTTC=1.72; % in sec
                        SDMinTTC=1.09; % in sec
                    end;
                    MinTTC=normrnd(MeanMinTTC,SDMinTTC);
                    if HurriedBackingFlag
                        if MinTTC<0.05; MinTTC=0.05; end;
                        if MinTTC>2.41; MinTTC=2.41; end;
                    else
                        if MinTTC<0.51; MinTTC=0.51; end;
                        if MinTTC>6.00; MinTTC=6.00; end;
                    end;
                end;

                MU=BackingDuration/2;
            elseif SelectedScenarios==2  %Represented by backing into a
parallel parking space
                LowerBackingDistanceX=9.144; % in meters
                UpperBackingDistanceX=9.144; % in meters
                LowerBackingDistanceY=1.75*VehicleWidth(1,2); % in meters
                UpperBackingDistanceY=2.25*VehicleWidth(1,2); % in meters
                MeanMinimumDistance=0.67; % in meters
                SDMinimumDistance=0.32; % in meters

MinimumDistance=normrnd(MeanMinimumDistance,SDMinimumDistance);
                if
MinimumDistance<norminv(0.01,MeanMinimumDistance,SDMinimumDistance);
MinimumDistance=norminv(0.01,MeanMinimumDistance,SDMinimumDistance); end;
                if
MinimumDistance>norminv(0.99,MeanMinimumDistance,SDMinimumDistance);
MinimumDistance=norminv(0.99,MeanMinimumDistance,SDMinimumDistance); end;

                % The following assumes that the path traveled by the
                % vehicle will follow the shape of a parabola with one half
                % being the inverted mirror image of the other
                h=(LowerBackingDistanceX + (UpperBackingDistanceX-
LowerBackingDistanceX)*rand() - MinimumDistance)/2;
                a=(LowerBackingDistanceY + (UpperBackingDistanceY-
LowerBackingDistanceY)*rand())/2;
                PlannedBackingDistanceX=2*h;
                PlannedBackingDistanceY=2*a;
```

```
PlannedBackingDistance=(sqrt(a^2+4*h^2))+(a^2*(asinh((2*h+sqrt(a^2+4*h^2))/(a
)))/(4*h)); %in meters
                clear('h','a');

                MeanBackingDuration=15.7; %in sec
                SDBackingDuration=3.0; %in sec

                BackingDurationDither=lognrnd(0.861,0.735); %in sec
                if BackingDurationDither<0.5; BackingDurationDither=0.5; end;

                if HurriedBackingFlag
                    MeanMinTTC=1.29; % in sec
                    SDMinTTC=0.90; % in sec
                else
                    MeanMinTTC=3.00; % in sec
                    SDMinTTC=1.79; % in sec
                end;
                MinTTC=normrnd(MeanMinTTC,SDMinTTC);
                if HurriedBackingFlag
                    if MinTTC<0.05; MinTTC=0.05; end;
                    if MinTTC>3.65; MinTTC=3.65; end;
                else
                    if MinTTC<0.47; MinTTC=0.47; end;
                    if MinTTC>9.09; MinTTC=9.09; end;
                end;
            elseif SelectedScenarios==3 | SelectedScenarios==4 |
SelectedScenarios==6 | SelectedScenarios==7 | SelectedScenarios==8 |
SelectedScenarios==10 %Represented by short backing (Wall backing to ~50 ft)
                if HurriedBackingFlag
                    MeanMaxSpeed=3.85; % in m/s
                    SDMaxSpeed=0.62; % in m/s
                else
                    MeanMaxSpeed=2.00; % in m/s
                    SDMaxSpeed=0.66; % in m/s
                end;
                if SelectedScenarios==3
                    LowerBackingDistanceX=7.62; % in meters
                    UpperBackingDistanceX=10.67; % in meters
                    LowerBackingDistanceY=0; % in meters
                    UpperBackingDistanceY=0; % in meters
                elseif SelectedScenarios==4
                    LowerBackingDistanceX=7.62; % in meters
                    UpperBackingDistanceX=10.67; % in meters
                    LowerBackingDistanceY=0; % in meters
                    UpperBackingDistanceY=0; % in meters
                elseif SelectedScenarios==6
                    LowerBackingDistanceX=24.38; % in meters
                    UpperBackingDistanceX=27.43; % in meters
                    LowerBackingDistanceY=0; % in meters
                    UpperBackingDistanceY=0; % in meters
                elseif SelectedScenarios==7
                    LowerBackingDistanceX=1.83; % in meters
                    UpperBackingDistanceX=3.05; % in meters
                    LowerBackingDistanceY=0; % in meters
                    UpperBackingDistanceY=0; % in meters
                elseif SelectedScenarios==8
```

```
                    LowerBackingDistanceX=6.40; % in meters, assumes backing
the 15' of driveway plus about a half-vehicle length into the roadway to
allow for the turn
                    UpperBackingDistanceX=6.40; % in meters
                    LowerBackingDistanceY=3.05; % in meters
                    UpperBackingDistanceY=4.57; % in meters
                elseif SelectedScenarios==10
                    LowerBackingDistanceX=6.40; % in meters, assumes backing
the 15' of driveway plus about a half-vehicle length into the roadway to
allow for the turn
                    UpperBackingDistanceX=6.40; % in meters
                    LowerBackingDistanceY=3.05; % in meters
                    UpperBackingDistanceY=4.57; % in meters
                end;
                PlannedBackingDistanceX=LowerBackingDistanceX +
(UpperBackingDistanceX-LowerBackingDistanceX)*rand(); %in meters
                PlannedBackingDistanceY=LowerBackingDistanceY +
(UpperBackingDistanceY-LowerBackingDistanceY)*rand(); %in meters
                PlannedBackingDistance=sqrt(PlannedBackingDistanceX^2 +
PlannedBackingDistanceY^2);

                if SelectedScenarios==8 | SelectedScenarios==10
                    % The following assumes that the path traveled by the
                    % vehicle after the first 15 ft will follow the shape of
a parabola
                    StraightBackingSegmentDistance=4.57; % the first 15 ft
will be straight backing
                    h=LowerBackingDistanceX - StraightBackingSegmentDistance
+ (UpperBackingDistanceX-LowerBackingDistanceX)*rand(); % take off the first
15 ft, which will be straight backing
                    a=LowerBackingDistanceY + (UpperBackingDistanceY-
LowerBackingDistanceY)*rand();
                    PlannedBackingDistanceX=h;
                    PlannedBackingDistanceY=a;
                    temp=h; h=a; a=temp;

PlannedBackingDistance=0.5*(sqrt(a^2+4*h^2))+(a^2*(asinh((2*h+sqrt(a^2+4*h^2)
)/(a)))/(4*h)) + StraightBackingSegmentDistance; %in meters, add the first 15
ft back again
                    clear('h','a','temp');
                end;

                MeanBackingDuration=12.9; %in sec
                SDBackingDuration=6.1; %in sec


BackingDuration=normrnd(MeanBackingDuration,SDBackingDuration);
                if BackingDuration<7.5; BackingDuration=7.5; end;
                if BackingDuration>35.5; BackingDuration=35.5; end;

                BackingDurationDither=lognrnd(0.861,0.735); %in sec
                if BackingDurationDither<0.5; BackingDurationDither=0.5;
end;

                MaxSpeed=normrnd(MeanMaxSpeed,SDMaxSpeed);
                if HurriedBackingFlag
                    if MaxSpeed<2.04; MaxSpeed=2.04; end;
```

```
                if MaxSpeed>5.24; MaxSpeed=5.24; end;
            else
                if MaxSpeed<0.83; MaxSpeed=0.83; end;
                if MaxSpeed>3.58; MaxSpeed=3.58; end;
            end;
            MU=BackingDuration/2;
        end;

        ObstacleSpeedLat=[0,0];
        ObstacleSpeedLong=[0,0];

        if EnhancedVisibility(1,2)==1
            BackingDurationDither=BackingDurationDither.*1.114; %
Increase time between reverse gear engagement to first backward movement if
enhanced vision feature is present
        end;

        if HurriedBackingFlag==1
            EnhancedVisionLatency=EnhancedVisionLatency(1,1);
        else
            EnhancedVisionLatency=EnhancedVisionLatency(1,2);
        end;

        % Define the coasting acceleration and deceleration parameters
        % (for use when needed)
        AfterCoastingAccel=[0, wblrnd(0.0454635,0.888436)];
        CoastingDecel=[0, wblrnd(0.0280876,0.64127)];

        % Define Brake Effort parameters
        BrakePeakDecelerationScale.time=0;
        BrakePeakDecelerationShape.time=0;
        BrakeAverageDecelerationScale.time=0;
        BrakeAverageDecelerationShape.time=0;

BrakePeakDecelerationScale.signals.values=[BrakeDataPeak(SelectedScenarios,1,
1),BrakeDataPeak(SelectedScenarios,2,1)];

BrakePeakDecelerationShape.signals.values=[BrakeDataPeak(SelectedScenarios,1,
2),BrakeDataPeak(SelectedScenarios,2,2)];

BrakeAverageDecelerationScale.signals.values=[BrakeDataAverage(SelectedScenar
ios,1,1),BrakeDataAverage(SelectedScenarios,2,1)];

  BrakeAverageDecelerationShape.signals.values=[BrakeDataAverage(SelectedScen
arios,1,2),BrakeDataAverage(SelectedScenarios,2,2)];

        % Find heuristic solution for the standard deviation that closely
        % allows matching of the planned travel distance, assuming no
        % obstacle in path, works for every scenario except 2
        if SelectedScenarios~=2 & SelectedScenarios~=9
            lastvalue=inf;lastk=MaxTime(1,2);
            for k=20:-0.1:0
                C = @(x) normpdf(x,MU,k).*(MaxSpeed./normpdf(MU,MU,k));
                newvalue = quad(C,-100,100)-PlannedBackingDistance;
                if abs(newvalue)>abs(lastvalue)
                    SIGMA=lastk;
                    break;
```

```
                end;
                lastk=k; lastvalue=newvalue;
            end;
            MU=MU-norminv(0.01,MU,SIGMA)+BackingDurationDither;
            SpeedMult=[0,MaxSpeed/normpdf(MU,MU,SIGMA)];
            SHIFT=[0,normpdf(0,MU,SIGMA)];
            MU=[0,MU];
            SIGMA=[0,SIGMA];
            PlannedBackingDistance=[0,PlannedBackingDistance];
            PlannedBackingDistanceX=[0,PlannedBackingDistanceX];
            PlannedBackingDistanceY=[0,PlannedBackingDistanceY];
            MinTTC=[0,MinTTC];

            %Dynamic obstacle characteristics
            if SelectedScenarios==4 & ~ObstacleAbsence
                k=SIGMA(1,2);
                D = @(x)
normpdf(x,MU(1,2),SIGMA(1,2)).*(MaxSpeed./normpdf(MU(1,2),MU(1,2),(SIGMA(1,2)
)));
                for Time=0:0.05:MaxTime(1,2)
                    junk=quad(D,0,Time);
                    if junk>=4.57 % How long it will take for the vehicle
to travel the 15 ft. in the scenario
                        break;
                    end;
                end;
                clear('junk');

                %Pick an average locomotion speed.  Assume a uniform
                %distribution based on Cavanagh, et al. (1983), who
limits
                %it between 2.8 and 5 km/h for children from 2 to 12 (and
                %subsequently into adulthood).  That is equal to 0.78 and
                %1.39 m/s, respectively
                ObstacleSpeedLat=[0,-((1.39-0.78).*rand()+0.78)]; % The -
sign implies that the obstacle will be incurring from the right
                ObstacleSpeedLong=[0,0];
                ObstaclePositionLong=[0,-4.57]; % From scenario
                ObstaclePositionLat=[0,(-
ObstacleSpeedLat(1,2).*Time)+(ObstacleStrikingPoint(1,2).*VehicleWidth(1,2))]
;
            end;

            if SelectedScenarios==5 & ~ObstacleAbsence
                k=SIGMA(1,2);
                D = @(x)
normpdf(x,MU(1,2),SIGMA(1,2)).*(MaxSpeed./normpdf(MU(1,2),MU(1,2),(SIGMA(1,2)
)));
                for Time=0:0.05:MaxTime(1,2)
                    junk=quad(D,0,Time);
                    if junk>=1.52 % How long it will take for the vehicle
to travel the 5 ft. in the scenario
                        break;
                    end;
                end;
                clear('junk');
```

```
                    %Pick an average locomotion speed.  Assume a uniform
                    %distribution based on Cavanagh, et al. (1983), who
limits
                    %it between 2.8 and 5 km/h for children from 2 to 12 (and
                    %subsequently into adulthood).  That is equal to 0.78 and
                    %1.39 m/s, respectively
                    ObstacleSpeedLat=[0,+((1.39-0.78).*rand()+0.78)]; % The +
sign implies that the obstacle will be incurring from the left
                    ObstacleSpeedLong=[0,0];
                    ObstaclePositionLong=[0,-1.52]; % From scenario
                    ObstaclePositionLat=[0,(-
ObstacleSpeedLat(1,2).*Time)+(ObstacleStrikingPoint(1,2).*VehicleWidth(1,2))]
;
                end;

                if SelectedScenarios==6 & ~ObstacleAbsence
                    k=SIGMA(1,2);
                    D = @(x)
normpdf(x,MU(1,2),SIGMA(1,2)).*(MaxSpeed./normpdf(MU(1,2),MU(1,2),(SIGMA(1,2)
)));
                    for Time=0:0.05:MaxTime(1,2)
                        junk=quad(D,0,Time);
                        if junk>=9.14 % How long it will take for the vehicle
to travel the 30 ft. in the scenario
                            break;
                        end;
                    end;
                    clear('junk');

                    %Pick an average locomotion speed.  Assume a uniform
                    %distribution based on Cavanagh, et al. (1983), who
limits
                    %it between 2.8 and 5 km/h for children from 2 to 12 (and
                    %subsequently into adulthood).  That is equal to 0.78 and
                    %1.39 m/s, respectively
                    ObstacleSpeedLat=[0,+((1.39-0.78).*rand()+0.78)]; % The +
sign implies that the obstacle will be incurring from the left
                    ObstacleSpeedLong=[0,0];
                    ObstaclePositionLong=[0,-9.14]; % From scenario
                    ObstaclePositionLat=[0,(-
ObstacleSpeedLat(1,2).*Time)+(ObstacleStrikingPoint(1,2).*VehicleWidth(1,2))]
;
                end;

                if SelectedScenarios==8 & ~ObstacleAbsence
                    k=SIGMA(1,2);
                    D = @(x)
normpdf(x,MU(1,2),SIGMA(1,2)).*(MaxSpeed./normpdf(MU(1,2),MU(1,2),(SIGMA(1,2)
)));
                    for Time=0:0.05:MaxTime(1,2)
                        junk=quad(D,0,Time);
                        if junk>=PlannedBackingDistance(1,2)-1 % How long it
will take for the vehicle to travel all but 1 m of the overall planned
distance in the scenario
                            break;
                        end;
                    end;
```

```
                    clear('junk');

                    %Pick an average vehicle speed.  Assume a 25 mph speed
                    %limit for a residential area and uniformly distributed
                    %vehicle speeds between 10 and 20 mph - 10 mph = 4.47
m/s, 20 mph = 8.94 m/s
                    ObstacleSpeedLat=[0,-((8.94-4.47).*rand()+4.47)]; % The +
sign implies that the obstacle will be incurring from the left
                    ObstacleSpeedLong=[0,0];
                    ObstaclePositionLong=[0,-
(PlannedBackingDistanceX(1,2)+StraightBackingSegmentDistance)]; % From
scenario
                    ObstaclePositionLat=[0,(-ObstacleSpeedLat(1,2).*Time)];
                end;

                %These variables are not used in these scenarios, but have
                %to be initialized anyway
                MovementDuration.time=0;
                MovementDuration.signals.values=[0,0,0,0,0,0,0,0,0,0];
                MaximumSpeed.time=0;
                MaximumSpeed.signals.values=[0,0,0,0,0,0,0,0,0,0];
                PauseDuration.time=0;
                PauseDuration.signals.values=[0,0,0,0,0,0,0,0,0,0];
                BackingDurationDither=[0,BackingDurationDither];

StraightBackingSegmentDistance=[0,StraightBackingSegmentDistance];
            elseif  SelectedScenarios==9
                lastvalue=inf;lastk=MaxTime(1,2);
                for k=20:-0.1:0
                    C = @(x) normpdf(x,MU,k).*(MaxSpeed./normpdf(MU,MU,k));
                    newvalue = quad(C,-100,100)-PlannedBackingDistance;
                    if abs(newvalue)>abs(lastvalue)
                        SIGMA=lastk;
                        break;
                    end;
                    lastk=k; lastvalue=newvalue;
                end;
                MU=MU-norminv(0.01,MU,SIGMA)+BackingDurationDither;
                SpeedMult=[0,MaxSpeed/normpdf(MU,MU,SIGMA)];
                SHIFT=[0,normpdf(0,MU,SIGMA)];
                MU=[0,MU];
                SIGMA=[0,SIGMA];

                PlannedBackingDistance=[0,PlannedBackingDistance];
                PlannedBackingDistanceX=[0,PlannedBackingDistanceX];
                PlannedBackingDistanceY=[0,PlannedBackingDistanceY];
                MinTTC=[0,MinTTC];

                %These variables are not used in these scenarios, but have
                %to be initialized anyway
                MovementDuration.time=0;
                MovementDuration.signals.values=[0,0,0,0,0,0,0,0,0,0];
                MaximumSpeed.time=0;
                MaximumSpeed.signals.values=[0,0,0,0,0,0,0,0,0,0];
                PauseDuration.time=0;
                PauseDuration.signals.values=[0,0,0,0,0,0,0,0,0,0];
                BackingDurationDither=[0,BackingDurationDither];
```

```
StraightBackingSegmentDistance=[0,StraightBackingSegmentDistance];
            elseif SelectedScenarios==2
                PlannedBackingDistance=[0,PlannedBackingDistance];
                PlannedBackingDistanceX=[0,PlannedBackingDistanceX];
                PlannedBackingDistanceY=[0,PlannedBackingDistanceY];

                MovementDuration.time=0;
                % Values based on data from Lee et al. (2003).  Replaced
                % with values from the ORSDURVs study.
                % MovementDuration.signals.values=[((6.479*exp(-
0.235*1))+randn()*(6.282*exp(-0.234*1))),...
                %                                   ((6.479*exp(-
0.235*2))+randn()*(6.282*exp(-0.234*2))),...
                %                                   ((6.479*exp(-
0.235*3))+randn()*(6.282*exp(-0.234*3))),...
                %                                   ((6.479*exp(-
0.235*4))+randn()*(6.282*exp(-0.234*4))),...
                %                                   ((6.479*exp(-
0.235*5))+randn()*(6.282*exp(-0.234*5))),...
                %                                   ((6.479*exp(-
0.235*6))+randn()*(6.282*exp(-0.234*6))),...
                %                                   ((6.479*exp(-
0.235*7))+randn()*(6.282*exp(-0.234*7))),...
                %                                   ((6.479*exp(-
0.235*8))+randn()*(6.282*exp(-0.234*8))),...
                %                                   ((6.479*exp(-
0.235*9))+randn()*(6.282*exp(-0.234*9))),...
                %                                   ((6.479*exp(-
0.235*10))+randn()*(6.282*exp(-0.234*10)))];

MovementDuration.signals.values=[(wblrnd(6.47662,1.00048)),...

                                    (wblrnd(4.50667,0.788861)),...

(wblrnd(6.02518,0.95498)),...

(wblrnd(5.01992,1.28218)),...
                                                (wblrnd(3.36238,0.964719))];
                for zz=1:size(MovementDuration.signals.values,2)
                    if MovementDuration.signals.values(zz)<1
MovementDuration.signals.values(zz)=1; end;
                end;
                % Values based on data from Lee et al. (2003).  Replaced
                % with values from the ORSDURVs study.
                % if HurriedBackingFlag
                %     MaximumSpeed.time=0;
                %     MaximumSpeed.signals.values=[((-0.008*(1)^2)+(-
0.192*(1))+(1.741))*1.92+(randn()*((0.019*(1)^2)+(-
0.264*(1))+(1.149)))*0.93,...
                %                                   ((-0.008*(2)^2)+(-
0.192*(2))+(1.741))*1.92+(randn()*((0.019*(2)^2)+(-
0.264*(2))+(1.149)))*0.93,...
                %                                   ((-0.008*(3)^2)+(-
0.192*(3))+(1.741))*1.92+(randn()*((0.019*(3)^2)+(-
0.264*(3))+(1.149)))*0.93,...
```

```
                %                                   ((-0.008*(4)^2)+(-
0.192*(4))+(1.741))*1.92+(randn()*((0.019*(4)^2)+(-
0.264*(4))+(1.149)))*0.93,...
                %                                   ((-0.008*(5)^2)+(-
0.192*(5))+(1.741))*1.92+(randn()*((0.019*(5)^2)+(-
0.264*(5))+(1.149)))*0.93,...
                %                                   ((-0.008*(6)^2)+(-
0.192*(6))+(1.741))*1.92+(randn()*((0.019*(6)^2)+(-
0.264*(6))+(1.149)))*0.93,...
                %                                   ((-0.008*(7)^2)+(-
0.192*(7))+(1.741))*1.92+(randn()*((0.019*(7)^2)+(-
0.264*(7))+(1.149)))*0.93,...
                %                                   ((-0.008*(8)^2)+(-
0.192*(8))+(1.741))*1.92+(randn()*((0.019*(8)^2)+(-
0.264*(8))+(1.149)))*0.93,...
                %                                   ((-0.008*(9)^2)+(-
0.192*(9))+(1.741))*1.92+(randn()*((0.019*(9)^2)+(-
0.264*(9))+(1.149)))*0.93,...
                %                                   ((-0.008*(10)^2)+(-
0.192*(10))+(1.741))*1.92+(randn()*((0.019*(10)^2)+(-
0.264*(10))+(1.149)))*0.93];
                % else
                %     MaximumSpeed.time=0;
                %     MaximumSpeed.signals.values=[((-0.008*(1)^2)+(-
0.192*(1))+(1.741))+(randn()*((0.019*(1)^2)+(-0.264*(1))+(1.149))),...
                %                                   ((-0.008*(2)^2)+(-
0.192*(2))+(1.741))+(randn()*((0.019*(2)^2)+(-0.264*(2))+(1.149))),...
                %                                   ((-0.008*(3)^2)+(-
0.192*(3))+(1.741))+(randn()*((0.019*(3)^2)+(-0.264*(3))+(1.149))),...
                %                                   ((-0.008*(4)^2)+(-
0.192*(4))+(1.741))+(randn()*((0.019*(4)^2)+(-0.264*(4))+(1.149))),...
                %                                   ((-0.008*(5)^2)+(-
0.192*(5))+(1.741))+(randn()*((0.019*(5)^2)+(-0.264*(5))+(1.149))),...
                %                                   ((-0.008*(6)^2)+(-
0.192*(6))+(1.741))+(randn()*((0.019*(6)^2)+(-0.264*(6))+(1.149))),...
                %                                   ((-0.008*(7)^2)+(-
0.192*(7))+(1.741))+(randn()*((0.019*(7)^2)+(-0.264*(7))+(1.149))),...
                %                                   ((-0.008*(8)^2)+(-
0.192*(8))+(1.741))+(randn()*((0.019*(8)^2)+(-0.264*(8))+(1.149))),...
                %                                   ((-0.008*(9)^2)+(-
0.192*(9))+(1.741))+(randn()*((0.019*(9)^2)+(-0.264*(9))+(1.149))),...
                %                                   ((-0.008*(10)^2)+(-
0.192*(10))+(1.741))+(randn()*((0.019*(10)^2)+(-0.264*(10))+(1.149)))];
                % end;
                if HurriedBackingFlag
                    MaximumSpeed.time=0;

MaximumSpeed.signals.values=[wblrnd(3.18976,0.960382)*1.92,...

                      wblrnd(2.82304,1.0384)*1.92,...

wblrnd(2.23688,1.33473)*1.92,...

wblrnd(1.77938,1.55665)*1.92,...

           wblrnd(1.11178,2.91187)*1.92];
                else
```

```
                    MaximumSpeed.time=0;
                    MaximumSpeed.signals.values=[wblrnd(3.18976,0.960382),...
                                                 wblrnd(2.82304,1.0384),...
                                                 wblrnd(2.23688,1.33473),...
                                                 wblrnd(1.77938,1.55665),...
                                                 wblrnd(1.11178,2.91187)];
                end;
                for zz=1:size(MaximumSpeed.signals.values,2)
                    if MaximumSpeed.signals.values(zz)<0.5
MaximumSpeed.signals.values(zz)=0.5; end;
                end;
                PauseDuration.time=0;
                % Values based on data from Lee et al. (2003).  Replaced
                % with values from the ORSDURVs study.
                % PauseDuration.signals.values=[((-
0.038*(1)^2)+(0.453*(1))+(1.137))+(randn()*2.384),...
                %                                 ((-
0.038*(2)^2)+(0.453*(2))+(1.137))+(randn()*2.384),...
                %                                 ((-
0.038*(3)^2)+(0.453*(3))+(1.137))+(randn()*2.384),...
                %                                 ((-
0.038*(4)^2)+(0.453*(4))+(1.137))+(randn()*2.384),...
                %                                 ((-
0.038*(5)^2)+(0.453*(5))+(1.137))+(randn()*2.384),...
                %                                 ((-
0.038*(6)^2)+(0.453*(6))+(1.137))+(randn()*2.384),...
                %                                 ((-
0.038*(7)^2)+(0.453*(7))+(1.137))+(randn()*2.384),...
                %                                 ((-
0.038*(8)^2)+(0.453*(8))+(1.137))+(randn()*2.384),...
                %                                 ((-
0.038*(9)^2)+(0.453*(9))+(1.137))+(randn()*2.384),...
                %                                 ((-
0.038*(10)^2)+(0.453*(10))+(1.137))+(randn()*2.384)];
                PauseDuration.signals.values=[wblrnd(2.35186,0.891772),...
                                              wblrnd(2.05865,0.985209),...
                                              wblrnd(2.2494,0.997779),...
                                              wblrnd(1.30116,2.1377),...
                                              wblrnd(1.30116,2.1377)];
                for zz=1:size(PauseDuration.signals.values,2)
                    if PauseDuration.signals.values(zz)<1
PauseDuration.signals.values(zz)=1; end;
                end;
                MinTTC=[0,MinTTC];
                BackingDurationDither=[0,BackingDurationDither];
                SpeedMult=[0,0];
                SHIFT=[0,0];
                MU=[0,0];
                SIGMA=[0,0];

StraightBackingSegmentDistance=[0,StraightBackingSegmentDistance];
            end;
            SelectedScenarios=[0,SelectedScenarios];

            % Simulate
            if strcmp(FilePath(1,size(FilePath,2)),'\')
                sim(strcat(FilePath,'BackingSIM.mdl'),[0 MaxTime(1,2)]);
```

```
            else
                sim(strcat(FilePath,'\','BackingSIM.mdl'),[0 MaxTime(1,2)]);
            end;

            %% Outcomes
            % Crash and Avoidance come from the simulation to indicate either
of those
            % occurred
            if isempty(Crash); Crash=0; end;
            if isempty(Avoidance); Avoidance=0; end;

            if Crash==Avoidance
                disp('There was no outcome out of this simulation step.
Check it out');
                return;
            end;
            if ~isempty(BrakeLevel) junk1=BrakeLevel(size(BrakeLevel,1),1);
else junk1=0; end;
            if ~isempty(BrakeLevel1)
junk2=BrakeLevel1(size(BrakeLevel1,1),1); else junk2=0; end;
            if ~isempty(BrakeLevel2)
junk3=BrakeLevel2(size(BrakeLevel2,1),1); else junk3=0; end;
            BrakeLevel=max([junk1, junk2, junk3]);
            clear('BrakeLevel1','BrakeLevel2','junk1','junk2','junk3');
            if ~isempty(ReactionTimeLeft.signals(1,1).values)
ReactionTimeLeft=ReactionTimeLeft.signals(1,1).values(size(ReactionTimeLeft.s
ignals(1,1).values,1),1); else ReactionTimeLeft=0; end;
            if ReactionTimeLeft<0 ReactionTimeLeft=0; end;

            % Outcome matrix adds some information about the characteristics
of
            % the crash or the avoidance maneuver
            % FullOutcomeMatrix indices:
            % 1 - Crash (1 if it is)
            % 2 - Avoidance (1 if it is, mutually exclusive from 1)
            % 3 4 5 - Final relative speed (negative implies vehicle and
object getting closer)
            % 6 7 8 - Final relative location (positive implies contact
between object and vehicle)
            % 9 - Countermeasure that was active at the end of the trial (0-
None, 1-Proximity, 2-ROD Stage 1, 3-ROD Stage 2, 4-Emergency Braking)
            % 10 - Type of Braking at trial end (0 for none, 1 for driver, 2
for emergency braking, 3 for both)
            % 11 - Last braking level prior to outcome
            % 12 - Final glance location (1-Forward, 2-Left Mirror, 3-Right
Mirror, 4-Center Rearview Mirror, 5-Over the Shoulder, 6-Enhanced Vision
Display, 7-Proximity Information Display)
            % 13 14 15 16 17 - Countermeasures were active at some point (1
indicates active; column 12 is Proximity Information, 13 - Automatic Braking
during Backing Initiation, 14 - Backing Warning Stage 1, 15 - Backing Warning
Stage 2, 16 - Automatic Braking during Active Backing)
            % 18 - Did the vehicle move during the trial? (1 is yes)
            % 19 - Selected Scenario
            % 20 - Was there an obstacle in the travel path of the vehicle?
            % 21 - Reaction Time Left
            % 22 23 24 - Final vehicle speed
```

```
            % 25 - Maximum longitudinal vehicle speed (positive values
indicate backing)
            % 26 - Display that triggered obstacle visualization
            OutcomeMatrix(j,:)=[Crash, Avoidance,
YOut.signals(1,1).values(size(YOut.signals(1,1).values,1),1:3),
YOut.signals(1,2).values(size(YOut.signals(1,2).values,1),4:6),
YOut.signals(1,3).values(size(YOut.signals(1,3).values,1),1),
YOut.signals(1,4).values(size(YOut.signals(1,4).values,1),1)+2.*YOut.signals(
1,4).values(size(YOut.signals(1,4).values,1),2),
BrakeLevel(size(BrakeLevel,1),1),
YOut.signals(1,5).values(size(YOut.signals(1,5).values,1),1),
max(YOut.signals(1,6).values(:,2)), max(YOut.signals(1,6).values(:,7)),
max(YOut.signals(1,6).values(:,12)), max(YOut.signals(1,6).values(:,17)),
max(YOut.signals(1,6).values(:,22)), max(-
YOut.signals(1,7).values(:,1))>0.0075, SelectedScenarios(1,2),
~ObstacleAbsence, ReactionTimeLeft,
YOut.signals(1,7).values(size(YOut.signals(1,7).values,1),1:3), max(-
YOut.signals(1,7).values(:,1)), max(YOut.signals(1,8).values(:,1))];
        end;
        if wholeindex==1
            FullOutcomeMatrix=[FullOutcomeMatrix;shiftdim(OutcomeMatrix,-1)];
        elseif wholeindex==2
            FullOutcomeMatrixNC=[FullOutcomeMatrixNC;shiftdim(OutcomeMatrix,-
1)];
        end;
        [wholeindex, i]
    end;
end;

%% Calculate Safety Benefits

%*****************************************************************************
*
% START USER INPUT FOR THIS SECTION
%***
%*****************************************************************************
*

%***
Crashes=[263;830.5;830.5;556;556;556;23297;100738;64703;9253];
%***

                              %***
Fatalities=[17;54;54;19;19;19;0;0;0;0]; % Take out fatalities
%***
                                         % from vehicular crashes (can't
%***
                                         % assess using current model).
%***
                                         % The original matrix was:
%***
                                         % [17;54;54;19;19;19;2;9;80;11];
%***
NonFatals=[0;0;0;0;0;0;0;0;0;0];
%***
FatalWeight=1; NonFatalWeight=0.0;
%***
```

```
%***
%***************************************************************************
*
% END OF USER INPUT FOR THIS SECTION
%***
%***************************************************************************
*

% Number of Crashes
NumberofScenarios=size(PossibleScenarios,2);
NumberofCrashes=zeros(NumberofScenarios,NumberofRuns,2);
NumberofConflicts=zeros(NumberofScenarios,NumberofRuns,2);
NumberofOpportunities=zeros(NumberofScenarios,NumberofRuns,2);
SE=zeros(NumberofScenarios,NumberofRuns);
TotalSE=zeros(1,NumberofRuns);

PwCSi=zeros(NumberofScenarios,NumberofRuns);
PwoCSi=zeros(NumberofScenarios,NumberofRuns);
PwSi=zeros(NumberofScenarios,NumberofRuns);
PwoSi=zeros(NumberofScenarios,NumberofRuns);

PwoSiC=[263;830.5;830.5;556;556;556;23297;100738;64703;9253]/201583;

% Take out cases where no crash was possible (Scenario 8 mainly)
for i=1:NumberofRuns
    FullOutcomeMatrix(i,:,20)=~(FullOutcomeMatrix(i,:,2)==1 &
FullOutcomeMatrix(i,:,10)==0 & FullOutcomeMatrix(i,:,18)==1);
    FullOutcomeMatrixNC(i,:,20)=~(FullOutcomeMatrixNC(i,:,2)==1 &
FullOutcomeMatrixNC(i,:,10)==0 & FullOutcomeMatrixNC(i,:,18)==1);
end;

for i=1:NumberofRuns
    for j=1:NumberofScenarios
        NumberofCrashes(j,i,1)=size((find(FullOutcomeMatrix(i,:,19)==j &
FullOutcomeMatrix(i,:,1)==1 & FullOutcomeMatrix(i,:,20)==1)),2);
        NumberofCrashes(j,i,2)=size((find(FullOutcomeMatrixNC(i,:,19)==j &
FullOutcomeMatrixNC(i,:,1)==1 & FullOutcomeMatrixNC(i,:,20)==1)),2);

        NumberofConflicts(j,i,1)=size((find(FullOutcomeMatrix(i,:,19)==j &
FullOutcomeMatrix(i,:,18)==1 & FullOutcomeMatrix(i,:,20)==1)),2);
        NumberofConflicts(j,i,2)=size((find(FullOutcomeMatrixNC(i,:,19)==j &
FullOutcomeMatrixNC(i,:,18)==1 & FullOutcomeMatrixNC(i,:,20)==1)),2);

        NumberofOpportunities(j,i,1)=size((find(FullOutcomeMatrix(i,:,19)==j
& FullOutcomeMatrix(i,:,20)==1)),2);

NumberofOpportunities(j,i,2)=size((find(FullOutcomeMatrixNC(i,:,19)==j &
FullOutcomeMatrixNC(i,:,20)==1)),2);
    end;
    PwCSi(:,i)=NumberofCrashes(:,i,1)./NumberofConflicts(:,i,1);
    PwoCSi(:,i)=NumberofCrashes(:,i,2)./NumberofConflicts(:,i,2);

    PwSi(:,i)=NumberofConflicts(:,i,1)./NumberofOpportunities(:,i,1);
    PwoSi(:,i)=NumberofConflicts(:,i,2)./NumberofOpportunities(:,i,2);

    SE(:,i)=PwoSiC.*(1-((PwSi(:,i)./PwoSi(:,i)).*(PwCSi(:,i)./PwoCSi(:,i))));
```

```
    TotalSE(:,i)=sum(SE(find(~isnan(SE(:,i))),i));
end;

AverageSE=mean(TotalSE);
StDevSE=std(TotalSE);

AverageCrashes=sum(AverageSE.*Crashes);
StDevCrashes=sum(StDevSE.*Crashes);

% Harm Reduction - Raw counts
   % '08 Tahoe dimensions - length is 202 in (5.13 m), width is 79 in (2.01
m), wheelbase is 116 in (2.95 m)
   % Assuming similar front and rear overhangs, the distance from the rear
   % bumper to the rear axle is 1.09 m.
   % This in turn suggests that if the vehicle is traveling at or faster
   % than 4.62 m/s (10.3 mph) at impact, the vehicle will not stop before the
   % pedestrian reaches the rear axle, which is expected to result in a
   % fatal crash.
   % Severity of slower impact speeds will be assessed depending on the
   % countermeasure that is active.  If autobraking is active, then the
   % distance to stop will be calculated and compared to the distance from
   % the bumper to the rear axle.  If the driver is scheduled to brake,
   % then the stopping distance (reaction time left + distance traveled
   % while decelerating) will be compared to the distance from the bumper
   % to the rear axle.

FatalHighSpeed=zeros(NumberofScenarios,NumberofRuns,2);
FatalLowSpeedAlreadyBraking=zeros(NumberofScenarios,NumberofRuns,2);
FatalLowSpeedReaction=zeros(NumberofScenarios,NumberofRuns,2);

WeightedHarm=Fatalities.*FatalWeight + NonFatals.*NonFatalWeight;
HwoCSi=repmat([WeightedHarm./sum(WeightedHarm)],1,NumberofRuns);

for i=1:NumberofRuns
    for j=1:NumberofScenarios
        FatalHighSpeed(j,i,1)=size((find(FullOutcomeMatrix(i,:,19)==j &
FullOutcomeMatrix(i,:,22)<=-4.62)),2);
        FatalHighSpeed(j,i,2)=size((find(FullOutcomeMatrixNC(i,:,19)==j &
FullOutcomeMatrixNC(i,:,22)<=-4.62)),2);


FatalLowSpeedAlreadyBraking(j,i,1)=size((find(FullOutcomeMatrix(i,:,19)==j &
((FullOutcomeMatrix(i,:,22).^2+FullOutcomeMatrix(i,:,23).^2+FullOutcomeMatrix
(i,:,24).^2)./(2.*9.81.*FullOutcomeMatrix(i,:,11)))>=1.09 &
~isinf((FullOutcomeMatrix(i,:,22).^2+FullOutcomeMatrix(i,:,23).^2+FullOutcome
Matrix(i,:,24).^2)./(2.*9.81.*FullOutcomeMatrix(i,:,11))) )),2);

FatalLowSpeedAlreadyBraking(j,i,2)=size((find(FullOutcomeMatrixNC(i,:,19)==j
&
((FullOutcomeMatrixNC(i,:,22).^2+FullOutcomeMatrixNC(i,:,23).^2+FullOutcomeMa
trixNC(i,:,24).^2)./(2.*9.81.*FullOutcomeMatrixNC(i,:,11)))>=1.09  &
~isinf((FullOutcomeMatrixNC(i,:,22).^2+FullOutcomeMatrixNC(i,:,23).^2+FullOut
comeMatrixNC(i,:,24).^2)./(2.*9.81.*FullOutcomeMatrixNC(i,:,11))) )),2);

        FatalLowSpeedReaction(j,i,1)=size((find(FullOutcomeMatrix(i,:,19)==j
& FullOutcomeMatrix(i,:,11)==0 &
((FullOutcomeMatrix(i,:,22).^2+FullOutcomeMatrix(i,:,23).^2+FullOutcomeMatrix
```

```
(i,:,24).^2)./(2.*9.81.*AutoBrakeMaximum(1,2))+(sqrt(FullOutcomeMatrix(i,:,22
).^2+FullOutcomeMatrix(i,:,23).^2+FullOutcomeMatrix(i,:,24).^2).*(FullOutcome
Matrix(i,:,21).*FullOutcomeMatrix(i,:,21)>0+inf.*FullOutcomeMatrix(i,:,21)<=0
)))>=1.09)),2);

FatalLowSpeedReaction(j,i,2)=size((find(FullOutcomeMatrixNC(i,:,19)==j &
FullOutcomeMatrixNC(i,:,11)==0 &
((FullOutcomeMatrixNC(i,:,22).^2+FullOutcomeMatrixNC(i,:,23).^2+FullOutcomeMa
trixNC(i,:,24).^2)./(2.*9.81.*AutoBrakeMaximum(1,2))+(sqrt(FullOutcomeMatrixN
C(i,:,22).^2+FullOutcomeMatrixNC(i,:,23).^2+FullOutcomeMatrixNC(i,:,24).^2).*
(FullOutcomeMatrix(i,:,21).*FullOutcomeMatrix(i,:,21)>0+inf.*FullOutcomeMatri
x(i,:,21)<=0)))>=1.09)),2);
    end;
end;

Fatal=FatalHighSpeed + FatalLowSpeedAlreadyBraking + FatalLowSpeedReaction;
Temp=((Fatal./NumberofConflicts).*FatalWeight + (1-
(Fatal./NumberofConflicts)).*NonFatalWeight);
HbarwCSi=Temp(:,:,1);
HbarwoCSi=Temp(:,:,2);
clear('Temp');

SR=HwoCSi.*(1-((PwSi./PwoSi).*(PwCSi./PwoCSi).*(HbarwCSi./HbarwoCSi)));
SR(find(isnan(SR)))=0;
TotalSR=sum(SR,1);

AverageSR=mean(TotalSR);
StDevSR=std(TotalSR);

AverageHarmReduction=AverageSR.*sum(WeightedHarm);
StDevHarmReduction=StDevSR.*sum(WeightedHarm);

if strcmp(FilePath(1,size(FilePath,2)),'\')
    save(strcat(FilePath,'ACATModelRun.mat'));
else
    save(strcat(FilePath,'\','ACATModelRun.mat'));
end;

%% Final Actions
% Stop clock to calculate simulation run time
toc;

% Return execution to the calling program (or Matlab)
return;
```

OTInputs.m

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%BEGIN OBJECTIVE TEST INPUTS%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%% Latency of the enhanced vistion system
EnhancedVisionLatency=[2.08,0.75];

%%% VISUAL DVI - relationship to representation to obstacle
```

```
VisualDVIOTProxGrid=reshape(ones(6,110,70,5),6,110,70,5);
VisualDVIOTProxGrid(1,1,:,1)=zeros(1,70);
VisualDVIOTProxGrid(1,110,:,1)=zeros(1,70);
VisualDVIOTProxGrid(1,:,1,1)=zeros(110,1);
VisualDVIOTProxGrid(1,:,70,1)=zeros(110,1);
VisualDVIOTProxGrid(1,:,:,2)=VisualDVIOTProxGrid(1,:,:,1);
VisualDVIOTProxGrid(1,:,:,3)=VisualDVIOTProxGrid(1,:,:,1);
VisualDVIOTProxGrid(1,:,:,4)=VisualDVIOTProxGrid(1,:,:,1);
VisualDVIOTProxGrid(1,:,:,5)=VisualDVIOTProxGrid(1,:,:,1);
VisualDVIOTProxGrid(2,:,:,:)=VisualDVIOTProxGrid(1,:,:,:);
VisualDVIOTProxGrid(3,:,:,:)=VisualDVIOTProxGrid(1,:,:,:);
VisualDVIOTProxGrid(4,:,:,:)=VisualDVIOTProxGrid(1,:,:,:);
VisualDVIOTProxGrid(5,:,:,:)=VisualDVIOTProxGrid(1,:,:,:);
VisualDVIOTProxGrid(6,:,:,:)=VisualDVIOTProxGrid(1,:,:,:);
VisualDVIOTProxGrid(1:6,1:110,1:70,1)=reshape(zeros(6,110,70,1),6,110,70,1);

%%% ENHANCED VISION
EnhancedVisionOTProxGrid=reshape(ones(6,26,53,1),6,26,53,1);
EnhancedVisionOTProxGrid(1,1:14,1:21,1)=[[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0];
                                         [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 1];
                                         [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 1 1];
                                         [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 1];
                                         [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1
1 1 1];
                                         [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1
1 1 1];
                                         [0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1
1 1 1];
                                         [0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1
1 1 1];
                                         [0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1
1 1 1];
                                         [0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1
1 1 1];
                                         [0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1];
                                         [0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1];
                                         [0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1];
                                         [0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1];];
EnhancedVisionOTProxGrid(1,1:15,33:53,1)=[[0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0];
                                          [1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0];
                                          [1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0];
                                          [1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0];
                                          [1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0];
```

```
                                          [1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0];
                                          [1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0
0 0 0 0];
                                          [1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0
0 0 0 0];
                                          [1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0
0 0 0 0];
                                          [1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0
0 0 0 0];
                                          [1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0
0 0 0 0];
                                          [1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0
0 0 0 0];
                                          [1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
0 0 0 0];
                                          [1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 0 0 0];
                                          [1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 0];];
% These establish boundary conditions so that only objects within the
% defined grid are considered visible.
EnhancedVisionOTProxGrid(1,26,1:53,1)=zeros(1,53);
EnhancedVisionOTProxGrid(1,1:26,1,1)=zeros(26,1);
EnhancedVisionOTProxGrid(1,1:26,53,1)=zeros(26,1);
% Copies visibility matrix across obstacles and countermeasures
EnhancedVisionOTProxGrid(2,:,:,1)=EnhancedVisionOTProxGrid(1,:,:,1);
EnhancedVisionOTProxGrid(3,:,:,1)=EnhancedVisionOTProxGrid(1,:,:,1);
EnhancedVisionOTProxGrid(4,:,:,1)=EnhancedVisionOTProxGrid(1,:,:,1);
EnhancedVisionOTProxGrid(5,:,:,1)=EnhancedVisionOTProxGrid(1,:,:,1);
EnhancedVisionOTProxGrid(6,:,:,1)=EnhancedVisionOTProxGrid(1,:,:,1);

%%% BACKING INITIATION PROXIMITY INFORMATION
BackingInitiationProximityInformationOTProxGrid=reshape(zeros(6,29,16,3,4,3,2
),6,29,16,3,4,3,2);
     % Information from Grid Test, Static Field of Regard (Test #102)
BackingInitiationProximityInformationOTProxGrid(4,1:8,5:13,1,1,2,1)=[[0 0
0.33 0 0.33 0 0 0 0];
                                                                [1 1 1 0 1
0.67 1 0.33 0];
                                                                [1 1 1 1 1
1 1 0 0];
                                                                [1 1 1 1 1
1 1 0 0];
                                                                [0.67 1 1
1 1 1 1 0 0.33];
                                                                [0.67 1 1
1 1 1 1 0 0];
                                                                [0.67 1 1
1 1 1 1 0 0];
                                                                [0 0.67
0.33 0.33 0.33 0.33 0 0 0]];
BackingInitiationProximityInformationOTProxGrid(1,1:8,5:11,1,1,2,1)=[[0 0 0 0
1 0.33 0];
                                                                [1 0.67
0.67 0.67 1 1 1];
```

```
                                                                  [1 1 1 1 1
1 1];
                                                                  [1 1 1 1 1
1 1];
                                                                  [1 1 1 1 1
1 1];
                                                                  [1 1 1 1 1
1 1];
                                                                  [0.67 1 1
1 1 1 1];
                                                                  [0 0 0 0
0.33 0 0]];
BackingInitiationProximityInformationOTProxGrid(2,1:8,5:11,1,1,2,1)=[[0 0 0 0
0 0 0];
                                                                  [0 0 0 0 0
0 0];
                                                                  [0 0 0 0 0
0.33 0];
                                                                  [0.33 1 1
0.33 1 0.67 0];
                                                                  [0.33 1 1
1 1 1 0.67];
                                                                  [0.33 1 1
1 1 1 0.67];
                                                                  [0.67 1 1
1 1 1 1];
                                                                  [0 1 0.67
0.33 0.33 0 0.33]];
BackingInitiationProximityInformationOTProxGrid(3,5:9,4:10,1,1,2,1)=[[0 0.50
0.33 0 0.67 0 0];
                                                                  [0.67 1 1
1 0 0.33 0.67];
                                                                  [0.67 1 1
1 1 1 1];
                                                                  [0 0.33
0.33 0.33 0.33 0.33 0.33];
                                                                  [0 0 0 0
0.33 0 0]];
BackingInitiationProximityInformationOTProxGrid(5,1:8,5:12,1,1,2,1)=[[0 0.33
0.33 0 0 0 0 0];
                                                                  [1 1 1
0.33 1 1 1 0];
                                                                  [1 1 1 1 1
1 1 0];
                                                                  [0.67 1 1
1 1 1 0.67 0.33];
                                                                  [0 1 1 1 1
1 1 0.33];
                                                                  [0 1 1 1 1
1 1 0.67];
                                                                  [0 1 1 1 1
1 1 1];
                                                                  [0 0.33 0
0.33 0 0.33 0 0]];
    % The following is the latency matrix, derived from the static pole
    % test (still Test #102)
Latency=reshape(ones(13,16),13,16).*0.18; % Average of all latencies measured
```

```
Latency(1:8,5:12)=[[0.18 3.77 1.10 0.18 0.18 0.18 0.18 0.18];
                   [0.07 0.07 0.07 0.18 0.07 0.03 0.07 0.18];
                   [0.07 0.07 0.03 0.07 0.07 0.07 0.10 0.18];
                   [0.18 0.07 0.07 0.10 0.07 0.07 0.07 0.18];
                   [0.18 0.07 0.07 0.07 0.07 0.07 0.07 0.18];
                   [0.18 0.07 0.07 0.07 0.07 0.10 0.10 0.07];
                   [0.18 0.23 0.07 0.10 0.10 0.07 0.07 0.03];
                   [0.18 0.18 0.18 0.18 0.18 0.03 0.18 0.18]]';
    % Information from Grid Test, Field of Regard with Incurring Obstacles
    % (Test 103)
BackingInitiationProximityInformationOTProxGrid(1,:,:,2,1,3,1)=[[0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                [0   0
0.25    0.75    0.75    0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0];
                                                                [0   0
0.25    0.75    0.75    0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0];
                                                                [0   0
0.25    1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                [0   0   0.5
1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                [0.25    0
0.5 1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                [0.25    0
0.5 1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                [0.25    0
0.5 1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                [0.25    0
0.5 1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                [0.25    0
0.75    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                [0.25    0
0.75    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                [0.25    0
0.75    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
```

```
                                                                                              [0.25   0
0.75    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0]]';
BackingInitiationProximityInformationOTProxGrid(1,:,:,2,1,1,1)=[[0.5    0
0.75    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                                              [0.5    0
0.75    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                                              [0.5    0
0.75    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                                              [0.5    0
0.75    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                                              [0.5    0
0.5 1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                                              [0  0   0.5
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                              [0  0   0.5
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                              [0  0   0.5
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                              [0  0   0.5
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                              [0  0   0.5
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                              [0  0   0
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                              [0  0   0
0.25    0.25    0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                              [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                              [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                              [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                              [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
BackingInitiationProximityInformationOTProxGrid(1,:,:,3,1,3,1)=[[0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                              [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                                                        [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                        [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                        [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                        [0  0   0
0.25    0.25    0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                        [0  0   0
0.25    0.25    0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                        [0  0
0.25    1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                        [0  0
0.25    1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                                        [0  0
0.25    1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                                        [0  0
0.25    1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                                        [0  0
  0.25    1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                                        [0  0
0.25    1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                        [0  0
0.25    1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                        [0  0
0.25    1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                        [0  0
0.25    1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0]]';
BackingInitiationProximityInformationOTProxGrid(1,:,:,3,1,1,1)=[[0  0   0
1   1   1   1   0.75    0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                                        [0  0   0
1   1   1   1   0.75    0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                                        [0  0   0
1   1   1   1   0.75    0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                                        [0  0   0
1   1   1   1   0.75    0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                                        [0  0   0
1   1   1   1   0.75    0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
```

```
                                                                                    [0   0   0
1   1   1   1   0.75    0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                                    [0   0   0
1   1   1   1   0.75    0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                                    [0   0   0
0.75    1   1   1   0.75    0.25    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                                    [0   0   0
0.25    1   0.5 1   0.5 0.25    0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                    [0   0   0
0.25    1   0.5 1   0.5 0.25    0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
BackingInitiationProximityInformationOTProxGrid(2,:,:,:,:,:,:)=BackingInitiat
ionProximityInformationOTProxGrid(1,:,:,:,:,:,:);
BackingInitiationProximityInformationOTProxGrid(3,:,:,:,:,:,:)=BackingInitiat
ionProximityInformationOTProxGrid(1,:,:,:,:,:,:);
BackingInitiationProximityInformationOTProxGrid(4,:,:,2,1,3,1)=[[0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
1   0.75    0.75    0.75    0.75    0.25    0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0];
                                                                                    [0   0   0.5
1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
```

```
[0	0	0.5
1	1	1	1	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0];
[0	0	1
1	1	1	1	1	0.25	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0];
[0	0	1
1	1	1	1	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0];
[0	0	1
1	1	1	1	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0];
[0	0	1
1	1	1	1	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0];
[0	0	1
1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0];
[0	0	1
1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0];
[0	0	1
1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0];
[0	0	1
1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0];
[0	0	1
1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0]]';
BackingInitiationProximityInformationOTProxGrid(4,:,:,2,1,1,1)=[[0	0
0.75	1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0];
[0	0
0.75	1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0];
[0	0
0.75	1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0];
[0	0
0.75	1	1	1	1	1	0.75	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0];
[0	0	0.5
1	1	1	1	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0];
[0	0	0.5
1	1	1	1	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0];
[0	0	0.5
1	1	1	1	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0];
[0	0	0.5
1	1	1	1	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0];
[0	0	0.5
1	1	1	1	1	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0];
```

```
                                                                            [0  0   0.5
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
0.25    0.25    0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                            [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
BackingInitiationProximityInformationOTProxGrid(4,:,:,3,1,3,1)=[[0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
0.25    0.25    0.75    0.75    0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0];
                                                                            [0  0   0
0.25    0.25    0.75    0.75    0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0];
                                                                            [0  0   0
0.5 0.5 1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
0.75    1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                            [0  0   0
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                            [0  0   0
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                                        [0  0   0
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0  0   0
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0  0   0
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0  0   0
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
BackingInitiationProximityInformationOTProxGrid(4,:,:,3,1,1,1)=[[0  0
0.25    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0
0.25    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0
0.25    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0
0.25    1   1   1   1   1   0.75    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0
0.25    0.75    1   1   1   1   0.75    0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0
0.25    0.75    1   1   1   1   0.25    0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0
0.25    0.75    1   1   1   1   0.25    0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0
0.25    0.75    0.75    1   1   1   0.25    0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0
0.25    0.5 0.75    1   1   1   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0
0.25    0.5 0.75    1   1   1   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0   0
0.25    0   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                        [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                                        [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
BackingInitiationProximityInformationOTProxGrid(5,:,:,2,1,3,1)=[[0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0  0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0  0   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0  0
0.75    1   0.75    0.75    0.25    0.5 0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0
0.75    1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0
0.75    1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                        [0  0   1
1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                        [0  0   1
1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                        [0  0   1
1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                        [0  0   1
1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                        [0  0   1
1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                        [0  0   1
1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                        [0  0   1
1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                        [0  0   1
1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
                                                                        [0  0   1
1   1   1   1   1   0.25    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0]]';
BackingInitiationProximityInformationOTProxGrid(5,:,:,2,1,1,1)=[[0  0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0  0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                                                                                                                        [0   0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                                                                                        [0   0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                                                                                        [0   0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                                                                                        [0   0
0.75    1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                                                                                        [0   0
0.75    1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                                                                                        [0   0
0.75    1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                                                                                        [0   0
0.75    1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0];
                                                                                                                                                        [0   0
0.75    1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                                                                                        [0   0
0.75    1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                                                                                        [0   0
0.25    0   0   0   0.25    1   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0];
                                                                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
BackingInitiationProximityInformationOTProxGrid(5,:,:,3,1,3,1)=[[0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0];
                                                                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                                                          [0   0   0
0.5 0.25    0.75    0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                          [0   0   0
0.5 0.25    0.75    0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                          [0   0   0
1   1   1   0.75    0.75    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                                          [0   0   0.5
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   0.5
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   0.5
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   0.5
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   0.5
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   0.5
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   0.5
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   0.5
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
BackingInitiationProximityInformationOTProxGrid(5,:,:,3,1,1,1)=[[0   0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   1
1   1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                          [0   0   1
0.75    1   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0];
```

```
                                                                   [0   0   0
0.75    1   1   1   0.75    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                   [0   0   0
0.75    1   1   1   0.75    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                   [0   0   0
0   0.25    0.25    0.25    0.25    0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0];
                                                                   [0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                   [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0];
                                                                   [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                   [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                   [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
BackingInitiationProximityInformationOTProxGrid(6,:,:,:,:,:,:)=BackingInitiat
ionProximityInformationOTProxGrid(5,:,:,:,:,:,:);

%%% BACKING INITIATION REAR EMERGENCY BRAKING
BackingInitiationAutomaticBrakingOTProxGrid=reshape(zeros(6,29,16,3,4,3,2),6,
29,16,3,4,3,2);
PBackingInitiationAutomaticBrakingOTProxGrid=reshape(zeros(6,29,16,3,4,3,2),6
,29,16,3,4,3,2);
NoPBackingInitiationAutomaticBrakingOTProxGrid=reshape(zeros(6,29,16,3,4,3,2)
,6,29,16,3,4,3,2);
    % Information from Grid Test, Dynamic Longitudinal (Test #104)
    % The following is the matrix derived from the vehicle dynamic / static
    % obstacle test.  The following assumptions are made: 1) the warning
    % location is substracted from the obstacle location and half a square
    % is added, and 2)the detection area is assumed to be as wide
    % as the vehicle (since the obstacle is not moving and steering input
    % is minimal, only an obstacle in the vehicle track can be hit)
BackingInitiationAutomaticBrakingOTProxGrid(1,1:3,3:13,1,2,2,1)=[[1 1 1 1 1 1
1 1 1 1 1];
                                                                    [1 1 1 1 1 1
1 1 1 1 1];
                                                                    [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(1,1:8,3:13,1,3,2,1)=[[1 1 1 1 1 1
1 1 1 1 1];
                                                                    [1 1 1 1 1 1
1 1 1 1 1];
                                                                    [1 1 1 1 1 1
1 1 1 1 1];
                                                                    [1 1 1 1 1 1
1 1 1 1 1];
                                                                    [1 1 1 1 1 1
1 1 1 1 1];
```

```
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]
                                                                [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(1,1:9,3:13,1,4,2,1)=[[1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                                [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                                [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                                [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(2,1:2,3:13,1,2,2,1)=[[0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67]];
BackingInitiationAutomaticBrakingOTProxGrid(2,1:6,3:13,1,3,2,1)=[[1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(2,1:10,3:13,1,4,2,1)=[[1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];
                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
```

```
                                                                 [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                                 [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(3,1:7,3:13,1,3,2,1)=[[1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(3,1:11,3:13,1,4,2,1)=[[1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];
                                                                 [1 1 1 1 1
1 1 1 1 1 1];

                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                 [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(4,1:4,3:13,1,2,2,1)=[[1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                                [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(4,1:7,3:13,1,3,2,1)=[[1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
                                                                [1 1 1 1 1 1
1 1 1 1 1];
```

```
                                                                 [1 1 1 1 1 1
1 1 1 1 1];
                                                                 [0.80 0.80
0.80 0.80 0.80 0.80 0.80 0.80 0.80 0.80 0.80];
                                                                 [0.20 0.20
0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20 0.20]];
BackingInitiationAutomaticBrakingOTProxGrid(4,1:8,3:13,1,4,2,1)=[[1 1 1 1 1 1
1 1 1 1 1];
                                                                 [1 1 1 1 1 1
1 1 1 1 1];
                                                                 [1 1 1 1 1 1
1 1 1 1 1];
                                                                 [1 1 1 1 1 1
1 1 1 1 1];
                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                 [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                                 [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(5,1:3,3:13,1,2,2,1)=[[1 1 1 1 1 1
1 1 1 1 1];
                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                 [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(5,1:8,3:13,1,3,2,1)=[[1 1 1 1 1 1
1 1 1 1 1];
                                                                 [1 1 1 1 1 1
1 1 1 1 1];
                                                                 [1 1 1 1 1 1
1 1 1 1 1];
                                                                 [1 1 1 1 1 1
1 1 1 1 1];
                                                                 [1 1 1 1 1 1
1 1 1 1 1];
                                                                 [1 1 1 1 1 1
1 1 1 1 1];
                                                                 [1 1 1 1 1 1
1 1 1 1 1];
                                                                 [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(5,1:10,3:13,1,4,2,1)=[[0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                 [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
```

```
                                                                    [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67
0.67];
                                                                    [0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                                    [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                                    [0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
BackingInitiationAutomaticBrakingOTProxGrid(6,:,:,:,:,:,:)=BackingInitiationA
utomaticBrakingOTProxGrid(5,:,:,:,:,:,:);
    % Information from Grid Test, Dynamic Longitudinal (Test #106)
PBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,2,2,3,1)=[[0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                                    [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,2,2,1,1)=[[1 1   1   1
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0.5   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                    [0.5   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                    [0.5   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,2,3,3,1)=[[0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [1 1   1   1
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,2,3,1,1)=[[1 1   1   1
1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
  1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0];
                                                              [1 1   1   1
1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                                              [0.5    0.5 0.5
0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                              [0.5    0.5 0.5
0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                              [0.5    0.5 0.5
0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,3,2,3,1)=[[0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                              [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
```

```
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,3,2,1,1)=[[1 1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                                  [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                  [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                  [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                  [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                  [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,3,3,3,1)=[[0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                            [1 1   1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]; 
                                                            [1 1   1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]'; 
PBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,3,3,1,1)=[[0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]; 
                                                            [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]; 
                                                            [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]; 
                                                            [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]; 
                                                            [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]; 
                                                            [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]; 
                                                            [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]; 
                                                            [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]; 
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]; 
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]; 
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]; 
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]; 
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]; 
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]; 
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]; 
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]'; 
PBackingInitiationAutomaticBrakingOTProxGrid(2,:,:,:,:,:,:)=PBackingInitiatio
nAutomaticBrakingOTProxGrid(1,:,:,:,:,:,:);
```

```
PBackingInitiationAutomaticBrakingOTProxGrid(3,:,:,:,:,:,:)=PBackingInitiatio
nAutomaticBrakingOTProxGrid(1,:,:,:,:,:,:);
PBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,2,2,3,1)=[[0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                            [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                            [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,2,2,1,1)=[[1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                              [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,2,3,3,1)=[[0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
```

```
                                                            [0 0    0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0    0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0    0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0    0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0    0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0.5    0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                            [1 1    1   1
1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,2,3,1,1)=[[1 1   1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0.5    0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                             [0.5   0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                             [0.5   0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,3,2,3,1)=[[0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [1 1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [1 1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                             [1 1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                              [1 1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,3,2,1,1)=[[1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [1 1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0.5   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                              [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,3,3,3,1)=[[0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                    [1 1   1   1
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,3,3,1,1)=[[1 1   1   1
1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                                    [1 1    1    1
1    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                    [1 1    1    1
1    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                    [1 1    1    1
1    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                    [1 1    1    1
1    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                    [1 1    1    1
1    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                    [1 1    1    1
1    1    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                    [0.5    0.5 0.5
0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                    [0.5    0.5 0.5
0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                    [0.5    0.5 0.5
0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                    [0.5    0.5 0.5
0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                    [0.5    0.5 0.5
0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                    [0.5    0.5 0.5
0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0];
                                                                    [0.5    0.5 0.5
0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                    [0.5    0.5 0.5
0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                    [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(5,:,:,2,2,3,1)=[[0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                    [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                    [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                    [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
```

```
                                                                        [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [0.5   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [1 1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(5,:,:,2,2,1,1)=[[1 1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [1 1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [1 1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [1 1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [1 1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                        [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(5,:,:,2,3,3,1)=[[0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                            [0 0    0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0    0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(5,:,:,2,3,1,1)=[[1 1    1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1    1   1
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0.5    0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                            [0.5    0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                            [0 0    0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0];
                                                            [0 0    0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0    0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(5,:,:,3,2,3,1)=[[0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                  [1 1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
```

```
PBackingInitiationAutomaticBrakingOTProxGrid(5,:,:,3,2,1,1)=[[1 1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0.5 0.5 0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                                            [1 1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1 1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(5,:,:,3,3,3,1)=[[0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                                                    [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [0 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    1    0.5  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    1    0.5  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    1    0.5  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    1    0.5  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    1    0.5  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    1    0.5  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    1    0.5  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    1    0.5  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]]'; 
PBackingInitiationAutomaticBrakingOTProxGrid(5,:,:,3,3,1,1)=[[1 1    1    1
1    1    0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
                                                                                    [1 1    1    1
1    1    0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]; 
```

```
                                                                      [1 1   1   1
1   1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                      [1 1   1   1
1   1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                      [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                      [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                      [0.5   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                      [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                      [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                      [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                      [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                      [0 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
    % Information from Grid Test, Dynamic Longitudinal (Test #107)
NoPBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,2,2,3,1)=[[0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                        [0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                              [0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,2,2,1,1)=[[0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                                                   [0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0];
                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,2,3,3,1)=[[0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                   [0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
```

```
                                                               [0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,2,3,1,1)=[[1   1   1
1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [1   1   1
1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [1   1   1
1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [1   1   1
1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [1   1   1
1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0.5 0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0.5 0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                               [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,3,2,3,1)=[[0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,3,2,1,1)=[[1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                                    [1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                              [1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,3,3,3,1)=[[0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [1    1    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [1    1    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [1    1    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [1    1    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [1    1    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [1    1    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(1,:,:,3,3,1,1)=[[1    1    1
1    1    0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [1    1    1
1    1    0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [1    1    1
1    1    0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [1    1    1
1    1    0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [1    1    1
1    1    0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [1    1    1
1    1    0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                                   [0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
```

```
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(2,:,:,:,:,:,:)=NoPBackingIniti
ationAutomaticBrakingOTProxGrid(1,:,:,:,:,:,:);
NoPBackingInitiationAutomaticBrakingOTProxGrid(3,:,:,:,:,:,:)=NoPBackingIniti
ationAutomaticBrakingOTProxGrid(1,:,:,:,:,:,:);
NoPBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,2,2,3,1)=[[0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                       [1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                                      [1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [1   0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,2,2,1,1)=[[1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [1   1   0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [0.5 0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [0.5 0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                      [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
```

```
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,2,3,3,1)=[[0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                              [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,2,3,1,1)=[[1   1   1
1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
```

```
                                                                                           [1   1   1
1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [1   1   1
1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [1   1   1
1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [1   1   1
1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [1   1   1
1   1   1   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,3,2,3,1)=[[0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                           [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
```

```
                                                                            [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,3,2,1,1)=[[1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                            [1   1   1
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
```

```
                                                                [0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,3,3,3,1)=[[0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [1   1   1
1   1   0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                [1   1   1
1   1   0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
```

```
                                                                                                        [1   1   1   1
  1   0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                        [1   1   1
1   1   0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0    0   0   0   0
  0   0   0   0   0   0];
                                                                                                        [1   1   1
1   1   0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [1   1   1
1   1   0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [1   1   1
1   1   0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [1   1   1
1   1   0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0]]';
NoPBackingInitiationAutomaticBrakingOTProxGrid(4,:,:,3,3,1,1)=[[1   1   1
1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [1   1   1
1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [1   1   1
1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [1   1   1
1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [1   1   1
1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
                                                                                                        [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0
0   0   0   0   0   0   0];
```

```
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                                [0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0]]';
PBackingInitiationAutomaticBrakingOTProxGrid(6,:,:,:,:,:,:)=PBackingInitiatio
nAutomaticBrakingOTProxGrid(5,:,:,:,:,:,:);
NoPBackingInitiationAutomaticBrakingOTProxGrid(6,:,:,:,:,:,:)=NoPBackingIniti
ationAutomaticBrakingOTProxGrid(5,:,:,:,:,:,:);

PBackingInitiationAutomaticBrakingOTProxGrid(:,:,:,:,4,:,:)=PBackingInitiatio
nAutomaticBrakingOTProxGrid(:,:,:,:,3,:,:);
NoPBackingInitiationAutomaticBrakingOTProxGrid(:,:,:,:,4,:,:)=NoPBackingIniti
ationAutomaticBrakingOTProxGrid(:,:,:,:,3,:,:);
    % Information from Grid Test, Full Lock (Test #105)
BackingInitiationAutomaticBrakingOTProxGrid(1,:,:,1,1,2,2)=[[0  0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0  0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0  0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0  0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0  0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0  0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0  0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [1  1   0.75
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                            [0  0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0  0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0];
                                                            [0  0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                            [0  0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
BackingInitiationAutomaticBrakingOTProxGrid(2,:,:,1,1,2,2)=[[0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0.5    0.25
0.25    0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                              [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
BackingInitiationAutomaticBrakingOTProxGrid(3,:,:,1,1,2,2)=[[0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0]]';
BackingInitiationAutomaticBrakingOTProxGrid(4,:,:,1,1,2,2)=[[0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                                                                                    [0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
```

```
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [1   0.75      0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]]';
BackingInitiationAutomaticBrakingOTProxGrid(5,:,:,1,1,2,2)=[[0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                                [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
```

```
                                                                      [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                      [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                      [1   1    0.25
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                                                      [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                      [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                      [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                      [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                      [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                      [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                      [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                                      [0   0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0]]';
BackingInitiationAutomaticBrakingOTProxGrid(6,:,:,:,:,:,:)=BackingInitiationA
utomaticBrakingOTProxGrid(5,:,:,:,:,:,:);

BackingInitiationAutomaticBrakingOTProxGrid(:,:,:,2,1,2,2)=BackingInitiationA
utomaticBrakingOTProxGrid(:,:,:,1,1,2,2);
BackingInitiationAutomaticBrakingOTProxGrid(:,:,:,2,2,2,2)=BackingInitiationA
utomaticBrakingOTProxGrid(:,:,:,1,1,2,2);
BackingInitiationAutomaticBrakingOTProxGrid(:,:,:,2,3,2,2)=BackingInitiationA
utomaticBrakingOTProxGrid(:,:,:,1,1,2,2);
BackingInitiationAutomaticBrakingOTProxGrid(:,:,:,2,4,2,2)=BackingInitiationA
utomaticBrakingOTProxGrid(:,:,:,1,1,2,2);

BackingInitiationAutomaticBrakingOTProxGrid(:,:,:,3,1,2,2)=BackingInitiationA
utomaticBrakingOTProxGrid(:,:,:,1,1,2,2);
BackingInitiationAutomaticBrakingOTProxGrid(:,:,:,3,2,2,2)=BackingInitiationA
utomaticBrakingOTProxGrid(:,:,:,1,1,2,2);
BackingInitiationAutomaticBrakingOTProxGrid(:,:,:,3,3,2,2)=BackingInitiationA
utomaticBrakingOTProxGrid(:,:,:,1,1,2,2);
BackingInitiationAutomaticBrakingOTProxGrid(:,:,:,3,4,2,2)=BackingInitiationA
utomaticBrakingOTProxGrid(:,:,:,1,1,2,2);

BackingInitiationAutomaticBrakingOTProxGrid(:,:,:,:,:,1,2)=BackingInitiationA
utomaticBrakingOTProxGrid(:,:,:,:,:,2,2);
```

```
BackingInitiationAutomaticBrakingOTProxGrid(:,:,:,:,:,3,2)=BackingInitiationA
utomaticBrakingOTProxGrid(:,:,:,:,:,2,2);
%%% ACTIVE BACKING BACKING WARNING STAGE 1
ActiveBackingBWStage1OTProxGrid=reshape(zeros(6,29,16,3,4,3,2),6,29,16,3,4,3,
2);
PActiveBackingBWStage1OTProxGrid=reshape(zeros(6,29,16,3,4,3,2),6,29,16,3,4,3
,2);
NoPActiveBackingBWStage1OTProxGrid=reshape(zeros(6,29,16,3,4,3,2),6,29,16,3,4
,3,2);
    % Information from Grid Test, Dynamic Longitudinal (Test #104)
    % The following is the matrix derived from the vehicle dynamic / static
    % obstacle test.  The following assumptions are made: 1) the warning
    % location is substracted from the obstacle location and half a square
    % is added, and 2)the detection area is assumed to be as wide
    % as the vehicle (since the obstacle is not moving and steering input
    % is minimal, only an obstacle in the vehicle track can be hit)
ActiveBackingBWStage1OTProxGrid(1,1:7,3:13,1,2,2,1)=[[1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage1OTProxGrid(1,1:19,3:13,1,3,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
```

```
                                                      [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                      [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                      [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage1OTProxGrid(1,1:11,3:13,1,4,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1
1];
                                                      [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                      [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                      [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                      [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                      [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                      [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                      [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage1OTProxGrid(2,1:6,3:13,1,2,2,1)=[[1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1
1]];
ActiveBackingBWStage1OTProxGrid(2,1:21,3:13,1,3,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [1 1 1 1 1 1 1 1 1 1 1];
                                                     [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
```

```
                                                   [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                   [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage1OTProxGrid(2,1:14,3:13,1,4,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                   [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67]];
ActiveBackingBWStage1OTProxGrid(3,1:7,3:13,1,2,2,1)=[[1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage1OTProxGrid(3,1:26,3:13,1,3,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [1 1 1 1 1 1 1 1 1 1 1];
                                                   [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                   [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                   [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
```

```
                                                  [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                  [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                  [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage1OTProxGrid(3,1:28,3:13,1,4,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                  [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                  [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                  [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                  [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                  [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                  [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                  [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                  [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67
0.67];
                                                  [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                  [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                  [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage1OTProxGrid(4,1:6,3:13,1,2,2,1)=[[1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                  [1 1 1 1 1 1 1 1 1 1
1]];
ActiveBackingBWStage1OTProxGrid(4,1:22,3:13,1,3,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
```

```
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [0.80 0.80 0.80 0.80
0.80 0.80 0.80 0.80 0.80 0.80 0.80];
                                             [0.80 0.80 0.80 0.80
0.80 0.80 0.80 0.80 0.80 0.80 0.80];
                                             [0.60 0.60 0.60 0.60
0.60 0.60 0.60 0.60 0.60 0.60 0.60];
                                             [0.60 0.60 0.60 0.60
0.60 0.60 0.60 0.60 0.60 0.60 0.60];
                                             [0.60 0.60 0.60 0.60
0.60 0.60 0.60 0.60 0.60 0.60 0.60];
                                             [0.60 0.60 0.60 0.60
0.60 0.60 0.60 0.60 0.60 0.60 0.60];
                                             [0.40 0.40 0.40 0.40
0.40 0.40 0.40 0.40 0.40 0.40 0.40];
                                             [0.20 0.20 0.20 0.20
0.20 0.20 0.20 0.20 0.20 0.20 0.20]];
ActiveBackingBWStage1OTProxGrid(4,1:18,3:13,1,4,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [1 1 1 1 1 1 1 1 1 1 1];
                                             [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                             [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                             [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                             [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                             [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                             [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                             [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                             [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                             [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                             [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
```

```
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage1OTProxGrid(5,1:6,3:13,1,2,2,1)=[[1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1
1]];
ActiveBackingBWStage1OTProxGrid(5,1:24,3:13,1,3,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage1OTProxGrid(5,1:21,3:13,1,4,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
```

```
                                                                  [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                                  [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage1OTProxGrid(6,:,:,:,:,:,:)=ActiveBackingBWStage1OTProxGri
d(5,:,:,:,:,:,:);
    % Information from Grid Test, Dynamic Longitudinal (Test #106)
PActiveBackingBWStage1OTProxGrid(1,:,:,2,2,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                             [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
```

```
PActiveBackingBWStage1OTProxGrid(1,:,:,2,2,1,1)=[[1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0];
                                                  [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(1,:,:,2,3,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                            [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
  1    1    1    1    0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0
0    0    0]]';
PActiveBackingBWStage1OTProxGrid(1,:,:,2,3,1,1)=[[1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [1 1    1    1    1    1    1
1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
```

```
                                                            [1 1   1   1   1   1   1
1   1   1   1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(1,:,:,3,2,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0];
                                                            [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                          [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(1,:,:,3,2,1,1)=[[1 1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0.5   0.5 0.5 0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [0.5   0.5 0.5 0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(1,:,:,3,3,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [1 1   1   1   1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                          [1 1   1   1   1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                  [1 1   1   1   1   0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(1,:,:,3,3,1,1)=[[0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(2,:,:,:,:,:,:)=PActiveBackingBWStage1OTProxG
rid(1,:,:,:,:,:,:);
PActiveBackingBWStage1OTProxGrid(3,:,:,:,:,:,:)=PActiveBackingBWStage1OTProxG
rid(1,:,:,:,:,:,:);
```

```
PActiveBackingBWStage1OTProxGrid(4,:,:,2,2,3,1)=[[0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [0.5    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                 [1 1    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0]]';
PActiveBackingBWStage1OTProxGrid(4,:,:,2,2,1,1)=[[1 1    1    1    0.5 0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    1    1    0.5 0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                 [1 1    1    1    0.5 0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
```

```
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0.5   0.5 0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0];
                                                      [0.5   0.5 0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                      [0.5   0.5 0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(4,:,:,2,3,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                      [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0];
                                      [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(4,:,:,2,3,1,1)=[[1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0];
                                      [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                            [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(4,:,:,3,2,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5 0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                               [1 1    1    1    1    0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [1 1    1    1    1    0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [1 1    1    1    1    0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [1 1    1    1    1    0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0]]';
PActiveBackingBWStage1OTProxGrid(4,:,:,3,2,1,1)=[[1 1    1    1    1    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [1 1    1    1    1    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [1 1    1    1    1    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [1 1    1    1    1    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [1 1    1    1    1    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [1 1    1    1    1    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [1 1    1    1    1    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [1 1    1    1    1    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [0.5    0.5 0.5 0.5 0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0.5    0.5 0.5 0.5 0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0.5    0.5 0.5 0.5 0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                               [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
```

```
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(4,:,:,3,3,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [1 1   1   1   1   1   0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(4,:,:,3,3,1,1)=[[1 1   1   1   1   1   1
1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
  1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                            [1 1   1   1   1   1   1
1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(5,:,:,2,2,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0    0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0    0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0    0];
                                                            [1 1    1    1    1    1    0.5
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0.5
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0.5
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0.5
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0.5
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0.5
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0.5
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0.5
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0]]';
PActiveBackingBWStage1OTProxGrid(5,:,:,2,2,1,1)=[[1 1    1    1    1    1    0
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [1 1    1    1    1    1    0
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
                                                            [0 0    0    0    0    0    0
0   0    0    0    0    0    0    0    0    0    0    0    0   0    0    0    0    0    0
0   0    0];
```

```
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(5,:,:,2,3,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0   0   0   0   0
0   0   0];
```

```
                                                            [1 1   1   1   1   1   1
  1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(5,:,:,2,3,1,1)=[[1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                        [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(5,:,:,3,2,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [1 1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [1 1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [1 1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [1 1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [1 1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [1 1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [1 1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [1 1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [1 1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(5,:,:,3,2,1,1)=[[1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage1OTProxGrid(5,:,:,3,3,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0];
```

```
                                                          [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [0 0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0];
                                                          [0 0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                          [1 1    1    1    1    1    1
1    1    0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
1    1    0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
1    1    0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
1    1    0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
1    1    0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
1    1    0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
1    1    0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
1    1    0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0]]';
PActiveBackingBWStage1OTProxGrid(5,:,:,3,3,1,1)=[[1 1    1    1    1    1    1
0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  0    0    0];
                                                          [1 1    1    1    1    1    1
0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                          [1 1    1    1    1    1    1
0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
```

```
                                                      [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [1 1   1   1   1   1   1
0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                      [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
    % Information from Grid Test, Dynamic Longitudinal (Test #107)
NoPActiveBackingBWStage1OTProxGrid(1,:,:,2,2,3,1)=[[0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0.5 0.5 0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0.5 0.5 0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                                  [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(1,:,:,2,2,1,1)=[[1   1   0.5 0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   0.5 0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   0.5 0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   0.5 0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   0.5 0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   0.5 0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [1   1   0.5 0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [0.5 0.5 0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                  [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                                 [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(1,:,:,2,3,3,1)=[[0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   1   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   1   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   1   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   1   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   1   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   1   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   1   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   1   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   1   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   1   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                               [1   1   1   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(1,:,:,2,3,1,1)=[[1   1   1   1   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0];
                                                               [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0];
                                                               [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0];
                                                               [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(1,:,:,3,2,3,1)=[[0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                        [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [0.5 0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [0.5 0.5 0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    0.5 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    0.5 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    0.5 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    0.5 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    0.5 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    0.5 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    0.5 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    0.5 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    0.5 0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0]]';
NoPActiveBackingBWStage1OTProxGrid(1,:,:,3,2,1,1)=[[1    1    1    0.5 0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    1    0.5 0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    1    0.5 0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    1    0.5 0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                        [1    1    1    0.5 0.5 0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
```

```
                                                            [1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(1,:,:,3,3,3,1)=[[0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(1,:,:,3,3,1,1)=[[1   1   1   1   1   1
1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   1   1   1   1
1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   1   1   1   1
1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   1   1   1   1
1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   1   1   1   1
1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   1   1   1   1
1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   1   1   1   1
1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0]]';
NoPActiveBackingBWStage1OTProxGrid(2,:,:,:,:,:,:)=NoPActiveBackingBWStage1OTP
roxGrid(1,:,:,:,:,:,:);
NoPActiveBackingBWStage1OTProxGrid(3,:,:,:,:,:,:)=NoPActiveBackingBWStage1OTP
roxGrid(1,:,:,:,:,:,:);
NoPActiveBackingBWStage1OTProxGrid(4,:,:,2,2,3,1)=[[0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
```

```
                                                             [1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(4,:,:,2,2,1,1)=[[1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   0];
                                                             [1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [1   1   1   1   1   0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                             [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0]]';
NoPActiveBackingBWStage1OTProxGrid(4,:,:,2,3,3,1)=[[0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5  0.5  0.5  0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5  0.5  0.5  0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5  0.5  0.5  0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5  0.5  0.5  0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5  0.5  0.5  0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5  0.5  0.5  0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5  0.5  0.5  0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5  0.5  0.5  0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5  0.5  0.5  0.5  0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0]]';
NoPActiveBackingBWStage1OTProxGrid(4,:,:,2,3,1,1)=[[1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    0.5  0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    0.5  0    0    0    0    0    0    0    0
0    0    0    0];
```

```
                                                            [1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    0.5 0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    0.5 0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    0.5 0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    0.5 0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    0.5 0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    0.5 0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [0.5  0.5  0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [0.5  0.5  0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [0.5  0.5  0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0
  0    0    0    0];
                                                            [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0]]';
NoPActiveBackingBWStage1OTProxGrid(4,:,:,3,2,3,1)=[[0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                            [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
```

```
                                                                [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(4,:,:,3,2,1,1)=[[1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
  0   0   0   0];
                                                                [1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                                [1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
```

```
                                                              [1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   1   1   1   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0.5 0.5 0.5 0.5 0.5 0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(4,:,:,3,3,3,1)=[[0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   1   1   1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   1   1   1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   1   1   1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                              [1   1   1   1   1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                            [1   1   1   1   1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   0.5 0.5 0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(4,:,:,3,3,1,1)=[[1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0    0   0   0   0   0   0
0   0   0   0];
```

```
                                                                    [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(5,:,:,2,2,3,1)=[[0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [0.5 0.5 0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [0.5 0.5 0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                    [1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(5,:,:,2,2,1,1)=[[1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                               [1    1    1    1    0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    1    0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    1    0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    1    0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    1    0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    1    0.5  0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0.5  0.5  0.5  0.5  0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0.5  0.5  0.5  0.5  0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0.5  0.5  0.5  0.5  0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0.5  0.5  0.5  0.5  0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0.5  0.5  0.5  0.5  0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0]]';
NoPActiveBackingBWStage1OTProxGrid(5,:,:,2,3,3,1)=[[0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
```

```
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(5,:,:,2,3,1,1)=[[1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0];
```

```
                                                            [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0];
                                                            [1   1   1   1   1   1
1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(5,:,:,3,2,3,1)=[[0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                                 [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage1OTProxGrid(5,:,:,3,2,1,1)=[[1   1   0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [1   1   0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                 [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0]]';
NoPActiveBackingBWStage1OTProxGrid(5,:,:,3,3,3,1)=[[0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                               [1    1    1    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0]]';
```

```
NoPActiveBackingBWStage1OTProxGrid(5,:,:,3,3,1,1)=[[1   1   1   1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [1   1   1   1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [1   1   1   1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0];
                                                          [1   1   1   1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [1   1   1   1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [1   1   1   1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [1   1   1   1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [1   1   1   1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                          [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
PActiveBackingBWStage1OTProxGrid(6,:,:,:,:,:,:)=PActiveBackingBWStage1OTProxG
rid(5,:,:,:,:,:,:);
NoPActiveBackingBWStage1OTProxGrid(6,:,:,:,:,:,:)=NoPActiveBackingBWStage1OTP
roxGrid(5,:,:,:,:,:,:);

PActiveBackingBWStage1OTProxGrid(:,:,:,:,4,:,:)=PActiveBackingBWStage1OTProxG
rid(:,:,:,:,3,:,:);
NoPActiveBackingBWStage1OTProxGrid(:,:,:,:,4,:,:)=NoPActiveBackingBWStage1OTP
roxGrid(:,:,:,:,3,:,:);
```

```
    % Information from Grid Test, Full Lock (Test #105)
ActiveBackingBWStage1OTProxGrid(1,:,:,1,1,2,2)=[[0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                [1  1   1   1   0.75    0.5
0.5 0.25    0.25    0.25    0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
ActiveBackingBWStage1OTProxGrid(2,:,:,1,1,2,2)=[[0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [1  1   1   0.5 0.5 0.25
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                    [1  1   1   1   1   0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
ActiveBackingBWStage1OTProxGrid(3,:,:,1,1,2,2)=[[0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
ActiveBackingBWStage1OTProxGrid(4,:,:,1,1,2,2)=[[0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [1  1   0.75    0.5 0.25
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
```

```
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
ActiveBackingBWStage1OTProxGrid(5,:,:,1,1,2,2)=[[0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [1   1   0.5 0.5 0.5 0.25
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0];
                                                    [0.5     0.5 0.5 0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                        [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
ActiveBackingBWStage1OTProxGrid(6,:,:,:,:,:,:)=ActiveBackingBWStage1OTProxGri
d(5,:,:,:,:,:,:);

ActiveBackingBWStage1OTProxGrid(:,:,:,2,1,2,2)=ActiveBackingBWStage1OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage1OTProxGrid(:,:,:,2,2,2,2)=ActiveBackingBWStage1OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage1OTProxGrid(:,:,:,2,3,2,2)=ActiveBackingBWStage1OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage1OTProxGrid(:,:,:,2,4,2,2)=ActiveBackingBWStage1OTProxGri
d(:,:,:,1,1,2,2);

ActiveBackingBWStage1OTProxGrid(:,:,:,3,1,2,2)=ActiveBackingBWStage1OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage1OTProxGrid(:,:,:,3,2,2,2)=ActiveBackingBWStage1OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage1OTProxGrid(:,:,:,3,3,2,2)=ActiveBackingBWStage1OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage1OTProxGrid(:,:,:,3,4,2,2)=ActiveBackingBWStage1OTProxGri
d(:,:,:,1,1,2,2);

ActiveBackingBWStage1OTProxGrid(:,:,:,:,:,1,2)=ActiveBackingBWStage1OTProxGri
d(:,:,:,:,:,2,2);
ActiveBackingBWStage1OTProxGrid(:,:,:,:,:,3,2)=ActiveBackingBWStage1OTProxGri
d(:,:,:,:,:,2,2);
%%% ACTIVE BACKING BACKING WARNING STAGE 2
ActiveBackingBWStage2OTProxGrid=reshape(zeros(6,29,16,3,4,3,2),6,29,16,3,4,3,
2);
PActiveBackingBWStage2OTProxGrid=reshape(zeros(6,29,16,3,4,3,2),6,29,16,3,4,3
,2);
NoPActiveBackingBWStage2OTProxGrid=reshape(zeros(6,29,16,3,4,3,2),6,29,16,3,4
,3,2);
    % Information from Grid Test, Dynamic Longitudinal (Test #104)
    % The following is the matrix derived from the vehicle dynamic / static
    % obstacle test.  The following assumptions are made: 1) the warning
    % location is substracted from the obstacle location and half a square
    % is added, and 2)the detection area is assumed to be as wide
    % as the vehicle (since the obstacle is not moving and steering input
    % is minimal, only an obstacle in the vehicle track can be hit)
ActiveBackingBWStage2OTProxGrid(1,1:14,3:13,1,3,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
```

```
                                                           [1 1 1 1 1 1 1 1 1 1
1];
                                                           [1 1 1 1 1 1 1 1 1 1
1];
                                                           [1 1 1 1 1 1 1 1 1 1
1];
                                                           [1 1 1 1 1 1 1 1 1 1
1];
                                                           [1 1 1 1 1 1 1 1 1 1
1];
                                                           [1 1 1 1 1 1 1 1 1 1
1];
                                                           [1 1 1 1 1 1 1 1 1 1
1];
                                                           [1 1 1 1 1 1 1 1 1 1
1];
                                                           [1 1 1 1 1 1 1 1 1 1
1];
                                                           [1 1 1 1 1 1 1 1 1 1
1];
                                                           [1 1 1 1 1 1 1 1 1 1
1];
                                                           [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]
                                                           [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage2OTProxGrid(2,1:12,3:13,1,3,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                          [1 1 1 1 1 1 1 1 1 1 1];
                                                          [1 1 1 1 1 1 1 1 1 1 1];
                                                          [1 1 1 1 1 1 1 1 1 1 1];
                                                          [1 1 1 1 1 1 1 1 1 1 1];
                                                          [1 1 1 1 1 1 1 1 1 1 1];
                                                          [1 1 1 1 1 1 1 1 1 1 1];
                                                          [1 1 1 1 1 1 1 1 1 1 1];
                                                          [1 1 1 1 1 1 1 1 1 1 1];
                                                          [1 1 1 1 1 1 1 1 1 1 1];
                                                          [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                          [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage2OTProxGrid(2,1:12,3:13,1,4,2,1)=[[0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                          [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                          [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                          [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                          [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                          [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                          [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                          [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
```

```
                                                      [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                      [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                      [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                      [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage2OTProxGrid(3,1:13,3:13,1,3,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1
1]];
ActiveBackingBWStage2OTProxGrid(3,1:22,3:13,1,4,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                      [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                      [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                      [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                      [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                      [0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67 0.67 0.67 0.67];
                                                      [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage2OTProxGrid(4,1:11,3:13,1,3,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
                                                      [1 1 1 1 1 1 1 1 1 1 1];
```

```
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [0.20 0.20 0.20 0.20
0.20 0.20 0.20 0.20 0.20 0.20 0.20]];
ActiveBackingBWStage2OTProxGrid(4,1:14,3:13,1,4,2,1)=[[0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage2OTProxGrid(5,1:13,3:13,1,3,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage2OTProxGrid(5,1:18,3:13,1,4,2,1)=[[1 1 1 1 1 1 1 1 1 1
1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
                                                    [1 1 1 1 1 1 1 1 1 1 1];
```

```
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [1 1 1 1 1 1 1 1 1 1 1];
                                                                  [0.33 0.33 0.33 0.33
0.33 0.33 0.33 0.33 0.33 0.33 0.33]];
ActiveBackingBWStage2OTProxGrid(6,:,:,:,:,:,:)=ActiveBackingBWStage2OTProxGri
d(5,:,:,:,:,:,:);
    % Information from Grid Test, Dynamic Longitudinal (Test #106)
PActiveBackingBWStage2OTProxGrid(1,:,:,2,3,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                            [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
PActiveBackingBWStage2OTProxGrid(1,:,:,2,3,1,1)=[[1 1   1   1   1   1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1    1   1   1   1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1    1   1   1   1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1    1   1   1   1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1    1   1   1   1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [1 1    1   1   1   1   1
1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0 0    0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0    0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0    0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0    0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0    0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0    0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
```

```
PActiveBackingBWStage2OTProxGrid(2,:,:,:,:,:,:)=PActiveBackingBWStage2OTProxG
rid(1,:,:,:,:,:,:);
PActiveBackingBWStage2OTProxGrid(3,:,:,:,:,:,:)=PActiveBackingBWStage2OTProxG
rid(1,:,:,:,:,:,:);
PActiveBackingBWStage2OTProxGrid(4,:,:,2,3,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage2OTProxGrid(4,:,:,2,3,1,1)=[[0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                            [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage2OTProxGrid(4,:,:,3,3,1,1)=[[0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                            [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                                [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage2OTProxGrid(5,:,:,2,3,3,1)=[[0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                                [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [1 1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
PActiveBackingBWStage2OTProxGrid(5,:,:,3,3,3,1)=[[0 0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                  [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                      [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                      [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                      [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                      [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                      [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                      [0.5   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
    % Information from Grid Test, Dynamic Longitudinal (Test #107)
NoPActiveBackingBWStage2OTProxGrid(1,:,:,2,3,1,1)=[[0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                        [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
```

```
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0]]';
NoPActiveBackingBWStage2OTProxGrid(2,:,:,:,:,:,:)=NoPActiveBackingBWStage2OTP
roxGrid(1,:,:,:,:,:,:);
NoPActiveBackingBWStage2OTProxGrid(3,:,:,:,:,:,:)=NoPActiveBackingBWStage2OTP
roxGrid(1,:,:,:,:,:,:);
NoPActiveBackingBWStage2OTProxGrid(4,:,:,2,3,1,1)=[[1    1    1    1    1    1
1    1    1    1    1    1    1    1    0.5  0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    1    1    1    0.5  0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    1    1    1    0.5  0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    1    1    1    0.5  0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    1    1    1    0.5  0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    1    1    1    0.5  0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    1    1    1    0.5  0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    1    1    1    0.5  0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5  0.5  0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5  0.5  0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
```

```
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
NoPActiveBackingBWStage2OTProxGrid(4,:,:,3,3,1,1)=[[1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [1   1   1   1   1   1
1   1   1   1   1   0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                               [0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0]]';
```

```
NoPActiveBackingBWStage2OTProxGrid(5,:,:,2,3,1,1)=[[1    1    1    1    1    1
1    1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [1    1    1    1    1    1
1    1    1    1    1    0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0];
                                                                [0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0]]';
PActiveBackingBWStage2OTProxGrid(6,:,:,:,:,:,:)=PActiveBackingBWStage2OTProxG
rid(5,:,:,:,:,:,:);
NoPActiveBackingBWStage2OTProxGrid(6,:,:,:,:,:,:)=NoPActiveBackingBWStage2OTP
roxGrid(5,:,:,:,:,:,:);

PActiveBackingBWStage2OTProxGrid(:,:,:,:,4,:,:)=PActiveBackingBWStage2OTProxG
rid(:,:,:,:,3,:,:);
NoPActiveBackingBWStage2OTProxGrid(:,:,:,:,4,:,:)=NoPActiveBackingBWStage2OTP
roxGrid(:,:,:,:,3,:,:);
```

```
    % Information from Grid Test, Full Lock (Test #105)
ActiveBackingBWStage2OTProxGrid(1,:,:,1,1,2,2)=[[0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0.5    0.5 0.5 0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                [0.5    0.5 0.5 0.5 0.5 0.5
0.25    0.25    0.25    0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                                [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                [0.5    0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
ActiveBackingBWStage2OTProxGrid(2,:,:,1,1,2,2)=[[0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                [0  0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0]]';
ActiveBackingBWStage2OTProxGrid(3,:,:,1,1,2,2)=[[0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                        [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
```

```
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0]]';
ActiveBackingBWStage2OTProxGrid(4,:,:,1,1,2,2)=[[0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
                                                    [0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0];
```

```
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0]]';
ActiveBackingBWStage2OTProxGrid(5,:,:,1,1,2,2)=[[0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
                                                            [0   0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0];
```

```
                                                        [0   0    0    0    0    0    0
0   0   0   0   0   0   0   0   0   0   0   0   0   0    0    0    0    0    0
0   0   0];
                                                        [0   0    0    0    0    0    0
0   0   0   0   0   0   0   0   0   0   0   0   0   0    0    0    0    0    0
0   0   0];
                                                        [0   0    0    0    0    0    0
0   0   0   0   0   0   0   0   0   0   0   0   0   0    0    0    0    0    0
0   0   0];
                                                        [0   0    0    0    0    0    0
0   0   0   0   0   0   0   0   0   0   0   0   0   0    0    0    0    0    0
0   0   0];
                                                        [0   0    0    0    0    0    0
0   0   0   0   0   0   0   0   0   0   0   0   0   0    0    0    0    0    0
0   0   0]]';
ActiveBackingBWStage2OTProxGrid(6,:,:,:,:,:,:)=ActiveBackingBWStage2OTProxGri
d(5,:,:,:,:,:,:);

ActiveBackingBWStage2OTProxGrid(:,:,:,2,1,2,2)=ActiveBackingBWStage2OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage2OTProxGrid(:,:,:,2,2,2,2)=ActiveBackingBWStage2OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage2OTProxGrid(:,:,:,2,3,2,2)=ActiveBackingBWStage2OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage2OTProxGrid(:,:,:,2,4,2,2)=ActiveBackingBWStage2OTProxGri
d(:,:,:,1,1,2,2);

ActiveBackingBWStage2OTProxGrid(:,:,:,3,1,2,2)=ActiveBackingBWStage2OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage2OTProxGrid(:,:,:,3,2,2,2)=ActiveBackingBWStage2OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage2OTProxGrid(:,:,:,3,3,2,2)=ActiveBackingBWStage2OTProxGri
d(:,:,:,1,1,2,2);
ActiveBackingBWStage2OTProxGrid(:,:,:,3,4,2,2)=ActiveBackingBWStage2OTProxGri
d(:,:,:,1,1,2,2);

ActiveBackingBWStage2OTProxGrid(:,:,:,:,:,1,2)=ActiveBackingBWStage2OTProxGri
d(:,:,:,:,:,2,2);
ActiveBackingBWStage2OTProxGrid(:,:,:,:,:,3,2)=ActiveBackingBWStage2OTProxGri
d(:,:,:,:,:,2,2);
%%% ACTIVE BACKING REAR EMERGENCY BRAKING
ActiveBackingAutomaticBrakingOTProxGrid=BackingInitiationAutomaticBrakingOTPr
oxGrid;
PActiveBackingAutomaticBrakingOTProxGrid=PBackingInitiationAutomaticBrakingOT
ProxGrid;
NoPActiveBackingAutomaticBrakingOTProxGrid=NoPBackingInitiationAutomaticBraki
ngOTProxGrid;

%%% This section puts into the SIM the results of the false alarm tests.
FalseAlarmOT=reshape(zeros(3,4,2),3,4,2);
FalseAlarmOT(1,:,:)=[[0.165 0 0 0];
                     [0.023 0.326 0.023 0.279]]';
FalseAlarmOT(2,:,1)=[[0.403 0 0 0]];
FalseAlarmOT(3,:,:)=[[0.36 0 0 0];
                     [0 0.124 0.083 0.083]]';

% Eyeglance Transition Times from Driver in the Loop Tests
```

```
% Column 1 - No DVI, Column 2 - Proximity Information, Column 3 - Visual
% and Warning Auditory, Column 4 - Visual, Warning Auditory, and Haptic,
% Column 5 - Automatic Braking.  Parameters are for a Weibull Distribution
TransitionScale=[0,1.06081,1.06081,1.06081,1.19432];
TransitionShape=[0,1.67034,1.67034,1.67034,2.01109];

%%%% This section introduces the trust values from driver-in-the-loop tests
ProximityInformationTrustValue=[[0 0 0 0 0 0 0 0 0 0 0 0];
                                [0 0 0 0 0 0 0 0 0 0 0 0];
                                [0 0 0 0 0 0 0 0 0 0 0 0];
                                [0 0 0 0 0 0 0 0 0 0 0 0];
                                [0 0 0 0 0 0 0 0 0 0 0 0];
                                [0 0 0 0 0 0 0 0 0 0 0 0];
                                [0 0 0 0 0 0 0 0 0 0 0 0];
                                [0 0 0 0 0 0 0 0 0 0 0 0];
                                [0 0 0 0 0 0 0 0 0 0 0 0];
                                [0 0 0 0 0 0 0 0 0 0 0 0]];
CautionaryBackingWarningTrustValue=[[0 0 0 0 0 0 0 0 0 0 0 0];
                                    [0 0 0 0 0 0 0 0 0 0 0 0];
                                    [0 0 0 0 0 0 0 0 0 0 0 0];
                                    [0 0 0 0 0 0 0 0 0 0 0 0];
                                    [0 0 0 0 0 0 0 0 0 0 0 0];
                                    [0 0 0 0 0 0 0 0 0 0 0 0];
                                    [0 0 0 0 0 0 0 0 0 0 0 0];
                                    [0 0 0 0 0 0 0 0 0 0 0 0];
                                    [0 0 0 0 0 0 0 0 0 0 0 0];
                                    [0 0 0 0 0 0 0 0 0 0 0 0]];
ImminentBackingWarningTrustValue=[[0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67];
                                  [0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67];
                                  [0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67];
                                  [0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67];
                                  [0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67];
                                  [0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67];
                                  [0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67];
                                  [0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67];
                                  [0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67];
                                  [0.67 0.67 0.67 0.67 0.67 0.67 0.67 0.67
0.67 0.67 0.67 0.67]];
AutomaticBrakingTrustValue=[[1 1 1 1 1 1 1 1 1 1 1 1];
                            [1 1 1 1 1 1 1 1 1 1 1 1];
                            [1 1 1 1 1 1 1 1 1 1 1 1];
                            [1 1 1 1 1 1 1 1 1 1 1 1];
                            [1 1 1 1 1 1 1 1 1 1 1 1];
                            [1 1 1 1 1 1 1 1 1 1 1 1];
                            [0.77 0.77 0.77 0.77 0.77 0.77 0.77 0.77 0.77
0.77 0.77 0.77];
                            [1 1 1 1 1 1 1 1 1 1 1 1];
                            [1 1 1 1 1 1 1 1 1 1 1 1];
```

```
                            [1 1 1 1 1 1 1 1 1 1 1 1]];

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%END OF OBJECTIVE TEST INPUTS%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Parameters.m

```
% Vehicle half-width (in m) - based on a spec width of 79 in (2.01 m)
VehicleWidth=[0,1.01];

% Reaction Time Distribution Parameters (in sec)
RTAlertedScale=[0,0.9279];
RTAlertedShape=[0,2.5733];
RTNonAlertedScale=[0,1.2360];
RTNonAlertedShape=[0,3.3846];

% Driver Braking Performance Distribution Parameters (in g)
BrakeDataPeak=zeros(10,2,2);
BrakeDataAverage=zeros(10,2,2);

    % Scenarios 1, 5, and 9, non-alerted
BrakeDataPeak(1,1,:)=[0.1125,5.6094];
BrakeDataAverage(1,1,:)=[0.3404,5.2445];
BrakeDataPeak(5,1,:)=BrakeDataPeak(1,1,:);
BrakeDataAverage(5,1,:)=BrakeDataAverage(1,1,:);
BrakeDataPeak(9,1,:)=BrakeDataPeak(1,1,:);
BrakeDataAverage(9,1,:)=BrakeDataAverage(1,1,:);
    % Scenario 2, non-alerted
BrakeDataPeak(2,1,:)=[0.0932,8.839];
BrakeDataAverage(2,1,:)=[0.3404,5.2445];
```

```
    % Scenarios 3, 4, 6, 7, 8, 10, non-alerted
BrakeDataPeak(3,1,:)=[0.1263,4.2134];
BrakeDataAverage(3,1,:)=[0.3404,5.2445];
BrakeDataPeak(4,1,:)=BrakeDataPeak(3,1,:);
BrakeDataAverage(4,1,:)=BrakeDataAverage(3,1,:);
BrakeDataPeak(6,1,:)=BrakeDataPeak(3,1,:);
BrakeDataAverage(6,1,:)=BrakeDataAverage(3,1,:);
BrakeDataPeak(7,1,:)=BrakeDataPeak(3,1,:);
BrakeDataAverage(7,1,:)=BrakeDataAverage(3,1,:);
BrakeDataPeak(8,1,:)=BrakeDataPeak(3,1,:);
BrakeDataAverage(8,1,:)=BrakeDataAverage(3,1,:);
BrakeDataPeak(10,1,:)=BrakeDataPeak(3,1,:);
BrakeDataAverage(10,1,:)=BrakeDataAverage(3,1,:);

    % All scenarios, alerted
BrakeDataPeak(:,2,:)=[[0.3572,5.7115];
                      [0.3572,5.7115];
                      [0.3572,5.7115];
                      [0.3572,5.7115];
                      [0.3572,5.7115];
                      [0.3572,5.7115];
                      [0.3572,5.7115];
                      [0.3572,5.7115];
                      [0.3572,5.7115];
                      [0.3572,5.7115]];
BrakeDataAverage(:,2,:)=[[0.2336,7.704];
                         [0.2336,7.704];
                         [0.2336,7.704];
                         [0.2336,7.704];
                         [0.2336,7.704];
                         [0.2336,7.704];
                         [0.2336,7.704];
                         [0.2336,7.704];
                         [0.2336,7.704];
                         [0.2336,7.704]];

% Automatic Braking Parameters
AutoBrakeMaximum=[0,0.95]; % in g
AutoBrakeSlope=[0,2]; % in g/sec

% Parameters for glance durations (in sec), provided by Mazzae, et al.
% (ORDURVS study).  Values in comments represent fits to DIL data, not used
% since the ORDURVS data were believed more accurate given the much larger
% sample
OverLeftShoulderLocation=[0,0.07];
OverLeftShoulderScale=[0,4.325];
OverLeftShoulderShape=[0,0.911];
ForwardLocation=[0,0.07];
ForwardScale=[0,1.12]; %[0,0.74786];
ForwardShape=[0,0.58208]; %[0,0.943617];
InstrumentPanelLocation=[0,0.07];
InstrumentPanelScale=[0,1.519]; %[0,1.85309];
InstrumentPanelShape=[0,0.62594]; %[0,2.3326];
LeftMirrorLocation=[0,0.07];
LeftMirrorScale=[0,1.339]; %[0,1.03816];
LeftMirrorShape=[0,0.61548]; %[0,1.52278];
CenterMirrorLocation=[0,0.07];
```

```
CenterMirrorScale=[0,0.98]; %[0,0.953941];
CenterMirrorShape=[0,0.60099]; %[0,1.25346];
OtherLocation=[0,0.05];
OtherScale=[0,1.39]; %[0,0.249696];
OtherShape=[0,0.6048]; %[0,0.157944];
OverRightShoulderLocation=[0,0.08];
OverRightShoulderScale=[0,2.487]; %[0,2.28886];
OverRightShoulderShape=[0,0.68652];  %[0,1.66394];
ProxDisplayLocation=[0,0];
ProxDisplayScale=[0,2.28886];
ProxDisplayShape=[0,1.66394];
RightMirrorLocation=[0,0.05];
RightMirrorScale=[0,1.13]; %[0,1.16378];
RightMirrorShape=[0,0.56802]; %[0,1.56866];
EnhancedVideoLocation=[0,0.08];
EnhancedVideoScale=[0,1.58]; %[0,1.38038];
EnhancedVideoShape=[0,0.61213]; %[0,1.41641];

% This section contains the eyeglance model.  Dimensions of
% "EyeglanceSequence" are: 1) Enhanced Vision Present, 2) DVI Active,
% 3) Input probability, 4) Glance duration breakdowns, 5) Previous glance
EyeglanceSequence=reshape(zeros(2,4,40,4,11),2,4,40,4,11);

     % No DVI Present
EyeglanceSequence(1,1,:,1,:)=[[1    1    1    1    2    2    2    2    3    3    3
3    3    3    3    3    4    4    4    5    5    5    5    5    5    6    7    7    7    7
7    7    8    8    8    8    8    9    10   10];
                              [2    2    2    2    2    2    2    2    2    2    2
2    2    2    2    3    3    3    3    3    3    3    3    3    3    3    3    4    4    4
4    5    6    7    7    8    8    9    9    10];
                              [1    1    1    1    1    1    1    1    1    1    1
1    1    3    3    3    3    3    3    3    3    4    4    5    6    7    8    8    8    8
8    8    8    8    8    8    8    8    9    10];
                              [1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    2    2    2    2    2    2    2    4    4    4    5    5    5    5    5
6    7    7    7    7    7    8    9    9    10];
                              [1    1    1    1    1    1    1    1    1    1    1
1    1    2    2    2    2    2    2    2    2    3    3    3    3    3    3    3    3    3
3    3    5    6    7    7    8    9    9    10];
                              [1    1    1    1    1    1    1    1    1    1    1
2    2    2    2    3    3    3    3    3    3    3    3    3    3    3    3    3    3    3
3    3    3    3    3    4    7    8    9    10];
                              [1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    2    2    3    3    3    3    3    3    3    3    3    3    3    4    4
5    5    7    8    8    9    9    9    10   10];
                              [1    1    1    1    1    1    1    1    1    1    1
2    2    2    2    3    3    3    3    3    3    3    3    3    3    3    3    3    3    3
3    3    3    3    3    4    7    8    9    10];
                              [1    1    1    1    1    1    1    1    1    1    2
2    2    2    2    2    2    2    2    2    2    2    2    2    3    3    3    3    3    3
3    3    3    3    4    4    6    7    9    10];
                              [1    1    1    1    1    1    1    1    1    1    1
1    2    2    2    2    2    3    3    3    3    3    3    3    3    3    3    3    3    3    3
  3    4    5    6    7    7    8    10   10];
                              [1    1    1    1    1    1    1    1    1    1    1
2    2    2    2    2    3    3    3    3    3    3    3    3    3    4    4    4    4
4    4    5    6    6    7    8    8    9    9]]';
```

```
EyeglanceSequence(1,1,:,2,:)=[[1    1   1   1   2   2   2   2   3   3   3
3   3   3   3   3   4   4   4   5   5   5   5   5   5   6   7   7   7   7
7   7   8   8   8   8   8   9   10  10];
                                        [2   2   2   2   2   2   2   2   2   2   3
3   3   3   3   3   3   3   3   4   4   5   5   5   5   5   7   7   7   7
7   8   8   8   8   8   8   9   9   10];
                                        [1   1   1   1   1   1   1   3   3   3   3
3   3   3   3   3   3   4   5   5   6   7   7   7   8   8   8   8   8   8
8   8   8   8   8   8   8   8   9   9];
                                        [1   1   1   1   1   1   1   1   1   2   2
2   2   2   2   2   2   4   4   5   5   5   5   5   5   5   6   7   7   7
7   7   7   7   7   8   8   8   9   10];
                                        [1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   2   2   2   2   2   2   3   3   3   3   3   5   5   7
7   7   8   8   9   9   9   10  10  10];
                                        [1   1   1   1   1   1   1   2   2   2   2
2   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3
3   3   4   8   8   8   8   9   9   10];
                                        [1   1   1   1   1   1   1   1   1   1   1
1   1   2   2   2   2   2   2   2   2   2   2   2   2   2   8   9   9   9
9   9   9   10  10  10  10  10  10  10];
                                        [1   1   1   1   1   1   1   2   2   2   2
2   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3
3   3   4   8   8   8   8   9   9   10];
                                        [1   1   1   2   2   2   2   2   2   2   2
2   2   2   2   3   3   3   3   3   3   3   3   4   4   4   5   5   5   5
5   5   6   7   7   7   7   7   9   9];
                                        [1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   2   2   2   2   2
2   3   3   3   3   3   4   4   8   8];
                                        [1   1   1   1   1   1   1   2   2   2   2
2   2   2   2   3   3   3   3   3   3   3   3   3   3   5   5   5   5   7
7   7   7   9   9   9   9   9   9   9]]';
EyeglanceSequence(1,1,:,3,:)=EyeglanceSequence(1,1,:,2,:);
EyeglanceSequence(1,1,:,4,:)=[[1    1   1   1   2   2   2   2   3   3   3
3   3   3   3   3   4   4   4   5   5   5   5   5   5   6   7   7   7   7
7   7   8   8   8   8   8   9   10  10];
                                        [2   2   2   2   2   3   3   3   3   3   3
3   3   3   3   5   5   5   5   5   5   5   7   7   7   7   7   7   7   8
8   8   8   8   8   8   8   9   9   9];
                                        [1   1   1   1   1   1   3   3   3   3   3
3   3   5   5   5   6   7   7   7   8   8   8   8   8   8   8   8   8   8
8   8   8   8   8   9   9   9   9   10];
                                        [1   1   1   2   2   2   2   2   2   4   5
5   5   5   5   5   5   5   5   5   5   6   7   7   7   7   7   7   7   7
7   7   7   8   8   8   9   9   9   10];
                                        [1   1   1   1   1   1   1   1   2   2   3
3   3   3   3   5   5   5   5   5   5   5   5   5   5   7   7   7   7   7
7   7   7   7   7   8   8   8   10  10];
                                        [1   1   2   2   2   3   3   3   3   3   3
3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   4
7   8   8   8   8   8   8   8   9   9];
                                        [1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1];
```

```
                                  [1    1   2   2   2   3   3   3   3   3   3
3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   4
7   8   8   8   8   8   8   8   9   9];
                                  [1    1   1   2   2   2   2   3   3   3   3
3   3   3   3   3   3   3   3   3   3   3   3   4   4   4   4   5   5   5
5   5   5   7   7   7   7   7   7   7];
                                  [1    1   1   1   1   1   1   1   1   1   2
2   2   2   2   2   2   3   3   3   3   3   3   3   3   3   3   3   3   3
5   5   5   6   6   6   6   7   7   7];
                                  [2    2   2   2   3   3   3   3   3   3   3
3   4   4   4   4   5   5   5   5   5   5   5   5   7   7   7   7   7   7
7   7   8   8   8   8   8   8   8   8]]';
%EyeglanceSequence(1,2,:,:,:)=EyeglanceSequence(1,1,:,:,:);
%EyeglanceSequence(1,3,:,:,:)=EyeglanceSequence(1,1,:,:,:);
%EyeglanceSequence(1,4,:,:,:)=EyeglanceSequence(1,1,:,:,:);
%EyeglanceSequence(1,5,:,:,:)=EyeglanceSequence(1,1,:,:,:);
     % Enhanced Vision Only
EyeglanceSequence(2,1,:,1,:)=[[1    1   1   1   2   2   2   2   2   2   3
3   3   3   3   3   3   4   4   4   5   5   5   5   6   6   6   6   6   7
7   7   7   8   8   9   9   9   10  10];
                                  [2    2   2   2   2   2   2   2   2   2   2
2   2   3   3   3   3   3   3   3   3   3   4   4   4   4   4   5   6   6
6   6   6   7   8   9   9   9   9   10];
                                  [1    1   1   1   1   1   1   1   1   1   1
3   3   3   3   3   3   3   3   3   4   4   5   6   6   6   6   6   6   7
8   8   8   8   8   8   8   8   9   10];
                                  [1    1   1   1   1   1   1   1   1   1   1
2   2   2   2   2   4   4   4   4   5   5   5   5   5   6   6   6   6   6
6   7   7   7   7   7   8   9   9   10];
                                  [1    1   1   1   1   1   1   1   2   2   2
2   2   2   3   3   3   3   3   3   3   3   3   3   3   3   3   3   5   6
6   6   6   6   6   7   8   9   9   10];
                                  [1    1   1   1   1   1   2   2   2   2   3
3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3
3   3   3   6   6   6   6   6   6   10];
                                  [1    1   1   1   1   1   1   2   2   2   2
2   2   2   3   3   3   3   3   3   3   3   3   3   3   3   3   3   4   4
4   5   5   7   8   9   9   9   10  10];
                                  [1    1   1   1   1   1   2   2   2   2   3
3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3
3   3   3   6   6   6   6   6   6   10];
                                  [1    1   1   1   1   1   1   2   2   2   2
2   2   3   3   3   3   3   3   3   3   3   3   3   3   3   3   4   4   4
5   5   5   6   6   6   7   7   7   9];
                                  [1    1   1   1   1   1   1   1   1   1   1
1   1   1   1   2   2   2   2   3   3   3   3   3   3   3   3   3   3   4
4   5   6   6   6   7   8   10  10  10];
                                  [1    1   1   1   1   1   1   1   1   1   1
1   2   2   2   2   2   2   2   2   2   3   3   4   4   4   4   4   5   6
6   6   6   6   6   6   8   9   9   9]]';
EyeglanceSequence(2,1,:,2,:)=[[1    1   1   1   2   2   2   2   2   2   3
3   3   3   3   3   3   4   4   4   5   5   5   5   6   6   6   6   6   7
7   7   7   8   8   9   9   9   10  10];
                                  [2    2   2   2   2   2   2   2   2   2   2
2   2   2   2   3   3   3   3   3   3   3   3   3   4   5   5   5   6   6
7   7   8   8   8   8   9   9   9   10];
```

```
                                            [1    1    1    1    3    3    3    3    3    3    3
3    3    3    3    3    3    3    4    4    5    5    5    5    6    6    6    6    7    7
7    8    8    8    8    8    8    8    8    10];
                                            [1    1    1    1    1    1    2    2    2    2    2
2    2    4    5    5    5    5    5    5    5    5    5    6    6    6    6    7    7    7
7    7    7    7    7    8    8    9    9    10];
                                            [1    1    1    1    1    1    1    2    2    2    2
2    2    3    3    3    3    3    3    3    3    3    3    5    5    5    6    6    6    6
6    6    6    7    7    7    7    8    8    9];
                                            [1    1    1    1    2    2    2    2    2    3    3
3    3    3    3    3    3    3    3    3    3    3    3    3    6    6    6    6    6    6
6    6    6    6    7    8    8    9    9    9];
                                            [1    1    1    1    2    2    2    2    2    2    2
2    2    2    3    3    3    3    3    3    3    3    5    5    5    5    5    5    5    7
7    7    7    7    7    8    9    9    9    10];
                                            [1    1    1    1    2    2    2    2    2    3    3
3    3    3    3    3    3    3    3    3    3    3    3    3    6    6    6    6    6    6
6    6    6    6    7    8    8    9    9    9];
                                            [1    1    1    1    1    1    1    2    2    2    2
2    2    3    3    3    3    3    3    3    3    3    3    3    3    3    3    4    4    4
5    5    5    6    6    6    7    7    7    9];
                                            [1    1    1    1    1    1    1    1    1    1    1
1    1    2    2    2    2    3    3    3    3    3    3    3    3    3    3    3    3    5
5    5    6    6    6    6    6    7    7    7];
                                            [1    1    1    1    1    1    1    1    1    1    2
2    2    2    2    2    2    2    2    2    2    3    4    4    5    5    6    6    6    6
6    6    6    7    7    9    9    9    9    9]]';
EyeglanceSequence(2,1,:,3,:)=EyeglanceSequence(2,1,:,2,:);
EyeglanceSequence(2,1,:,4,:)=[[1    1    1    1    2    2    2    2    2    2    3
3    3    3    3    3    3    4    4    4    5    5    5    5    6    6    6    6    6    7
7    7    7    8    8    9    9    9    10   10];
                                            [2    2    2    2    2    2    2    2    2    2    3
3    3    3    3    3    3    4    5    5    5    5    5    5    6    6    6    6    6    7
7    7    7    7    7    8    8    8    9    9];
                                            [1    1    1    1    3    3    3    3    3    3    3
3    3    3    3    3    3    4    5    5    5    6    6    7    7    8    8    8    8    8
8    8    8    8    8    8    8    8    9    9];
                                            [1    1    1    1    2    2    2    2    2    4    5
5    5    5    5    5    5    5    5    5    6    6    7    7    7    7    7    7    7    7
7    7    8    8    8    8    8    9    9    9];
                                            [2    2    2    2    2    2    2    2    2    2    3
3    3    3    5    5    5    5    5    5    5    6    6    6    6    6    6    6    6    7
7    7    7    7    7    7    9    9    10   10];
                                            [1    1    2    2    2    2    2    2    2    3    3
3    3    3    3    3    3    3    3    3    3    3    3    3    6    6    6    6    6    6
6    6    6    8    8    8    9    9    9    9];
                                            [1    1    1    2    2    2    2    2    2    2    2
2    2    2    2    3    3    3    3    3    3    4    5    5    5    5    5    5    5    5
7    7    7    7    7    7    7    7    8    9];
                                            [1    1    2    2    2    2    2    2    2    3    3
3    3    3    3    3    3    3    3    3    3    3    3    3    6    6    6    6    6    6
6    6    6    8    8    8    9    9    9    9];
                                            [1    1    1    1    1    1    1    2    2    2    2
2    2    2    2    2    2    2    2    2    3    3    3    3    3    3    4    5    7    7
9    9    9    9    9    9    9    9    9    9];
```

```
                                       [1    1  1  1  1  1  1  1  1  1  1
1  1  1  2  3  3  3  3  3  3  5  5  5  5  5  5  6  6  6
6  6  6  6  7  7  7  7  7  7];
                                       [2    2  2  2  2  2  2  2  2  2  2
2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
5  5  5  6  6  6  6  6  7  7]]';

      % Enhanced Vision and Proximity Information with Advisory Auditory
EyeglanceSequence(2,2,:,1,:)=[[1    1  2  2  2  2  2  2  3  3  3
3  3  3  3  4  4  5  5  5  5  5  5  6  6  6  6  6  7  7
7  7  7  8  8  8  9  9  10  10];
                                       [2    2  2  2  2  2  2  2  2  2  2
2  2  2  3  3  3  3  3  3  3  4  4  4  4  4  5  5  6  6
6  7  7  8  8  9  9  9  10  10];
                                       [1    1  1  1  1  1  1  1  1  1  1
1  3  3  3  3  3  3  3  4  4  4  4  5  6  6  6  7  8  8
8  8  8  8  8  8  8  8  9  10];
                                       [1    1  1  1  1  1  1  1  1  2  2
2  2  2  2  2  2  2  2  4  4  4  4  4  4  5  5  5  5  6
6  6  7  7  7  7  7  8  9  10];
                                       [1    1  1  1  1  1  1  1  2  2  2
2  2  2  2  2  3  3  3  3  3  3  3  3  3  3  3  3  3  3
3  5  6  6  6  7  8  9  9  10];
                                       [1    1  1  1  1  1  1  1  1  2  2
2  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3
3  3  4  6  6  6  7  8  9  10];
                                       [1    1  1  1  1  1  1  1  2  2  2
2  2  2  2  3  3  3  3  3  3  3  3  3  4  4  4  4  4  5
5  5  7  7  8  9  9  9  10  10];
                                       [1    1  1  1  1  1  1  1  1  2  2
2  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3  3
3  3  4  6  6  6  7  8  9  10];
                                       [1    1  1  2  2  2  2  2  2  2  2
2  2  2  3  3  3  3  3  3  3  3  4  5  5  5  5  5  5  5
6  7  7  7  7  7  7  7  9  9];
                                       [1    1  1  1  1  1  1  1  1  1  1
1  1  1  1  2  2  2  2  2  3  3  3  3  3  3  3  3  4  4
5  5  6  6  6  6  7  8  10  10];
                                       [1    1  1  1  1  1  1  1  1  2  2
2  2  2  2  2  2  2  3  4  4  4  4  4  4  4  5  6  6  6
6  6  7  7  9  9  9  9  9  9]]';
EyeglanceSequence(2,2,:,2,:)=[[1    1  2  2  2  2  2  2  3  3  3
3  3  3  3  4  4  5  5  5  5  5  5  6  6  6  6  6  7  7
7  7  7  8  8  8  9  9  10  10];
                                       [2    2  2  2  2  2  2  2  2  2  2
2  2  2  2  2  2  2  3  3  3  3  4  4  5  5  5  6  7  7
7  8  8  8  8  8  8  8  9  10];
                                       [1    1  1  1  1  1  3  3  3  3  3
3  3  4  4  5  5  5  6  6  7  7  7  8  8  8  8  8  8  8
8  8  8  8  8  8  8  8  8  10];
                                       [1    1  1  1  1  1  1  2  2  2  2
2  2  2  2  2  2  4  4  4  4  5  5  5  5  5  6  7  7  7
7  7  7  8  8  8  8  8  8  9];
                                       [1    1  1  2  2  2  2  2  2  2  2
2  2  2  2  2  2  2  2  2  3  3  3  3  3  3  3  3  5  5  5
  6  7  7  7  7  8  9  10  10];
```

```
                                        [1    1   1   1   1   1   2   2   2   2   2
2   2   2   2   2   2   2   2   2    2   3   3   3   3   3   3   3   6   8
8   8   8   8   8   8   8   8   9    9];
                                        [1    1   1   2   2   2   2   2   2   2   2
2   2   2   4   5   5   5   5   5    5   5   5   7   7   7   7   7   7   7
7   7   8   8   8   8   8   8   9    10];
                                        [1    1   1   1   1   1   2   2   2   2   2
2   2   2   2   2   2   2   2   2    2   3   3   3   3   3   3   3   6   8
8   8   8   8   8   8   8   8   9    9];
                                        [1    1   1   2   2   2   2   2   2   2   2
2   2   2   3   3   3   3   3   3    3   3   4   5   5   5   5   5   5   5
6   7   7   7   7   7   7   7   9    9];
                                        [1    1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1    2   2   2   2   2   2   2   3   3   3
3   3   3   3   5   5   6   7   7    10];
                                        [1    1   1   2   2   2   2   2   2   2   2
2   2   2   2   2   2   2   2   3    4   5   5   6   6   6   6   6   6   6
7   7   7   9   9   9   9   9   9    9]]';
EyeglanceSequence(2,2,:,3,:)=EyeglanceSequence(2,2,:,2,:);
EyeglanceSequence(2,2,:,4,:)=[[1    1   2   2   2   2   2   2   3   3   3
3   3   3   3   4   4   5   5   5    5   5   5   6   6   6   6   6   7   7
7   7   7   8   8   8   9   9   10   10];
                                        [2    2   2   2   2   2   2   2   2   2   2
2   2   2   3   3   3   4   4   4    5   5   5   6   7   7   7   8   8   8
8   8   8   8   8   9   9   9   10   10];
                                        [1    1   1   3   3   3   3   4   5   5   5
6   7   7   7   8   8   8   8   8    8   8   8   8   8   8   8   8   8   8
8   8   8   8   8   8   8   9   9    9];
                                        [1    1   1   2   2   2   2   2   2   2   2
2   2   2   2   2   2   5   5   5    5   5   5   5   5   6   7   7   7   7
7   7   7   7   7   8   8   9   9    9];
                                        [1    1   2   2   2   2   2   2   2   2   2
2   2   2   2   2   2   2   2   2    2   2   3   3   5   5   5   7   7   7
8   8   9   9   9   9   9   9   10   10];
                                        [1    1   1   1   1   1   1   1   2   2   2
2   3   3   3   3   3   3   3   3    3   3   3   3   8   8   8   8   8   8
8   8   8   8   8   8   8   8   8    8];
                                        [2    2   2   2   2   2   2   2   2   2   2
2   2   2   3   4   4   5   5   5    5   5   5   5   7   7   7   7   7   7
 7   8   8   8   9   9   9   9   9    9];
                                        [1    1   1   1   1   1   1   1   2   2   2
2   3   3   3   3   3   3   3   3    3   3   3   3   8   8   8   8   8   8
8   8   8   8   8   8   8   8   8    8];
                                        [1    1   1   2   2   2   2   2   2   2   2
2   2   2   2   2   2   2   2   2    2   2   2   2   2   2   2   2   4   4
4   5   5   5   6   6   6   7   7    7];
                                        [1    1   1   1   1   1   1   1   1   1   2
2   2   2   2   2   2   2   2   2    2   2   2   2   2   3   3   3   3   3
5   5   5   5   6   6   7   7   7    7];
                                        [1    1   1   1   2   2   2   2   2   2   2
2   2   2   2   2   2   2   2   2    2   2   2   2   4   4   4   4   6   6
6   6   9   9   9   9   9   9   9    9]]';

      % Enhanced Vision and Visual and Warning Auditory
EyeglanceSequence(2,3,:,1,:)=[[2    2   2   2   2   3   3   3   3   3   3
3   3   6   6   6   6   6   6   6    6   6   6   6   6   6   6   6   6   6
6   8   9   9   9   9   9   9   10   10];
```

```
                                            [2    2   2   2   2   2   2   2   3   3   3
3   3   3   3   4   4   4   4   4   4   4   4   4   5   6   6   6   6   6
8   9   10  10  10  10  10  10  10  10];
                                            [1    1   1   1   1   1   1   3   3   3   3
3   3   3   3   3   4   4   4   4   4   4   4   4   4   5   6   6   6   6
6   6   6   6   9   9   10  10  10  10];
                                            [1    1   1   1   1   2   2   2   2   2   4
4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   5   5
7   7   7   9   9   10  10  10  10  10];
                                            [1    1   1   2   2   2   2   2   2   2   2
2   2   2   2   3   3   3   3   3   3   3   3   3   3   3   3   5   6   6
6   6   6   6   8   9   10  10  10  10];
                                            [1    1   1   1   1   1   2   2   2   2   2
3   3   3   3   3   3   3   3   3   3   3   3   4   4   4   4   4   4   9
9   9   9   9   10  10  10  10  10  10];
                                            [1    1   1   1   1   1   2   2   2   2   2
2   2   2   3   3   3   4   4   4   4   4   4   4   4   8   9   9   9   9
9   10  10  10  10  10  10  10  10  10];
                                            [1    1   1   1   1   1   2   2   2   2   2
3   3   3   3   3   3   3   3   3   3   3   3   4   4   4   4   4   4   9
9   9   9   9   10  10  10  10  10  10];
                                            [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                            [1    1   1   1   1   1   1   1   1   1   2
2   2   2   2   3   3   3   3   3   5   5   5   6   6   6   6   6   6   6
6   6   6   6   6   6   6   6   7   7];
                                            [1    1   1   1   1   1   1   1   1   1   1
2   2   2   2   2   3   3   3   4   4   4   4   4   4   4   4   4   4   5
5   6   6   6   6   6   7   9   9   9]]';
EyeglanceSequence(2,3,:,2,:)=[[2    2   2   2   2   3   3   3   3   3   3
3   3   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6
6   8   9   9   9   9   9   9   10  10];
                                            [2    2   2   2   2   2   2   2   2   2   3
3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3   3
5   5   5   5   5   7   7   7   7   7];
                                            [1    1   1   1   3   3   3   3   3   3   3
3   3   3   3   3   3   3   4   4   4   4   6   6   6   6   6   6   6   6
6   9   9   9   9   9   10  10  10  10];
                                            [2    2   2   2   2   2   2   2   2   2   2
2   2   2   2   2   2   2   2   2   4   4   4   4   4   4   4   4   4   4
4   4   4   4   4   4   4   4   4   4];
                                            [1    1   1   1   1   1   1   1   2   2   2
2   2   2   2   2   3   3   3   3   3   3   3   3   6   6   6   6   6   6
6   6   9   9   9   9   9   9   9   9];
                                            [1    1   1   1   1   1   1   3   3   3   3
3   3   3   3   3   3   3   3   3   4   4   4   4   4   4   4   6   6   6
6   6   6   6   6   6   6   6   6   6];
                                            [1    1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   5   5   5   5   5   5   5   5   5   5
7   7   7   7   7   7   7   7   7   7];
                                            [1    1   1   1   1   1   1   3   3   3   3
3   3   3   3   3   3   3   3   3   4   4   4   4   4   4   4   6   6   6
6   6   6   6   6   6   6   6   6   6];
                                            [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
```

```
                                        [1    1   1   1   1   1   1   1   1   1   3
3   3   3   3   3   3   3   3   3   6   6   6   6   6   6   6   6   6   6
10  10  10  10  10  10  10  10  10  10];
                                        [1    1   1   1   1   1   2   2   2   2   2
2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   2   4
4   4   4   4   4   4   4   4   4   4]]';
EyeglanceSequence(2,3,:,3,:)=EyeglanceSequence(2,3,:,2,:);
EyeglanceSequence(2,3,:,4,:)=[[2    2   2   2   2   3   3   3   3   3   3
3   3   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6
6   8   9   9   9   9   9   9   10  10];
                                        [3    3   3   3   3   3   3   3   3   3   3
3   3   3   3   3   3   3   3   3   6   6   6   6   6   6   6   6   6   6
6   6   6   6   6   6   6   6   6   6];
                                        [1    1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   4   4   4   4   4   4   4   4   4   4
4   4   4   4   4   4   4   4   4   4];
                                        [1    1   1   1   1   1   1   1   1   1   4
4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4
5   5   5   5   5   7   7   7   7   7];
                                        [1    1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   9   9   9   9   9   9   9   9   9   9
9   9   9   9   9   9   9   9   9   9];
                                        [1    1   1   1   1   1   1   1   4   4   4
4   4   4   4   4   6   6   6   6   6   6   6   6   6   6   6   6   6   6
6   6   10  10  10  10  10  10  10  10];
                                        [9    9   9   9   9   9   9   9   9   9   9
9   9   9   9   9   9   9   9   9   9   9   9   9   9   9   9   9   9   9
9   9   9   9   9   9   9   9   9   9];
                                        [1    1   1   1   1   1   1   1   4   4   4
4   4   4   4   4   6   6   6   6   6   6   6   6   6   6   6   6   6   6
6   6   10  10  10  10  10  10  10  10];
                                        [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                        [2    2   2   2   2   2   2   2   2   2   2
2   2   2   2   2   2   2   2   2   6   6   6   6   6   6   6   6   6   6
6   6   6   6   6   6   6   6   6   6];
                                        [9    9   9   9   9   9   9   9   9   9   9
9   9   9   9   9   9   9   9   9   9   9   9   9   9   9   9   9   9   9
9   9   9   9   9   9   9   9   9   9]]';

     % Enhanced Vision,Visual and Warning Auditory, and Haptic Pulse
EyeglanceSequence(2,4,:,1,:)=[[2    2   2   2   2   3   3   3   3   3   3
3   3   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6
6   8   9   9   9   9   9   9   10  10];
                                        [3    3   3   3   3   3   3   3   3   3   3
3   3   4   4   4   4   4   4   4   4   4   4   4   4   4   4   5   5   5
5   5   5   7   7   7   7   7   7   10];
                                        [3    3   3   3   3   3   3   3   3   3   3
3   3   5   5   5   5   5   5   5   6   6   6   6   6   6   6   6   6   6
6   6   6   7   7   7   7   7   7   10];
                                        [4    4   4   4   4   4   4   4   4   4   4
4   4   4   4   4   5   5   5   5   5   5   5   5   7   7   7   7   7   7
7   7   10  10  10  10  10  10  10  10];
                                        [2    2   2   2   2   2   2   2   2   2   2
2   2   2   2   2   2   2   2   2   2   2   2   2   3   3   3   3   3   3
3   3   3   3   3   3   3   3   3   3];
```

```
                                        [2     2   2   2   2   2   2   2   2   2   2
2   2   2   2   2   2   2   2   2   3   3   3   3   3   3   3   3   3   3
3   3   3   3   3   3   3   3   3   3];
                                        [1     1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                        [2     2   2   2   2   2   2   2   2   2   2
2   2   2   2   2   2   2   2   2   3   3   3   3   3   3   3   3   3   3
3   3   3   3   3   3   3   3   3   3];
                                        [1     1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                        [1     1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                        [1     1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   2   2   2
2   2   2   2   2   2   2   2   2   2]]';
EyeglanceSequence(2,4,:,2,:)=[[2     2   2   2   2   3   3   3   3   3   3
3   3   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6
6   8   9   9   9   9   9   9   10  10];
                                        [1     1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                        [10    10  10  10  10  10  10  10  10  10  10
10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
10  10  10  10  10  10  10  10  10  10];
                                        [1     1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                        [1     1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                        [4     4   4   4   4   4   4   4   4   4   4
4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4
4   4   4   4   4   4   4   4   4   4];
                                        [1     1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                        [4     4   4   4   4   4   4   4   4   4   4
4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4
4   4   4   4   4   4   4   4   4   4];
                                        [1     1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                        [10    10  10  10  10  10  10  10  10  10  10
10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10  10
10  10  10  10  10  10  10  10  10  10];
                                        [1     1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10]]';
EyeglanceSequence(2,4,:,3,:)=EyeglanceSequence(2,4,:,2,:);
EyeglanceSequence(2,4,:,4,:)=[[2     2   2   2   2   3   3   3   3   3   3
3   3   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6
6   8   9   9   9   9   9   9   10  10];
```

```
                                  [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                  [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                  [5    5   5   5   5   5   5   5   5   5   5
5   5   5   5   5   5   5   5   5   7   7   7   7   7   7   7   7   7   7
7   7   7   7   7   7   7   7   7   7];
                                  [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                  [1    1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1];
                                  [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                  [1    1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1];
                                  [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                  [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                                  [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10]]';

    % Enhanced Vision and Autobraking
EyeglanceSequence(2,5,:,1,:)=[[2    2   2   2   2   3   3   3   3   3   3
3   3   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6
6   8   9   9   9   9   9   9   10  10];
                                  [2    2   2   2   2   3   3   3   3   3   3
3   4   4   4   4   4   4   4   4   4   5   5   6   6   6   7   7   9   9
9   9   10  10  10  10  10  10  10  10];
                                  [1    1   1   1   1   1   1   1   1   1   1
1   3   3   3   3   3   3   4   4   4   4   4   4   4   6   6   6   6   6
9   9   9   9   9   10  10  10  10  10];
                                  [1    1   1   1   1   2   2   4   4   4   4
4   4   4   4   4   4   4   4   4   4   4   4   5   5   5   5   5   7   7
7   7   7   9   9   9   9   10  10  10];
                                  [1    1   1   2   2   2   2   2   2   2   2
2   2   3   3   3   3   3   3   5   5   6   6   6   6   6   6   7   9   9
9   9   9   9   9   9   9   10  10  10];
                                  [1    1   1   2   2   2   2   2   3   3   3
3   3   3   3   4   4   4   6   6   6   6   6   6   6   9   9   9   9   9
9   9   9   10  10  10  10  10  10  10];
                                  [1    1   1   1   1   1   1   1   1   1   1
1   1   1   4   4   4   9   9   9   9   9   9   9   9   9   9   9   9   9
9   10  10  10  10  10  10  10  10  10];
                                  [1    1   1   2   2   2   2   2   3   3   3
3   3   3   3   4   4   4   6   6   6   6   6   6   6   9   9   9   9   9
9   9   9   10  10  10  10  10  10  10];
```

```
                             [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                             [1    1   1   1   1   1   1   2   3   3   3
3   5   5   5   5   5   6   6   6   6   6   6   6   6   6   6   6   7   7
7   7   7   10  10  10  10  10  10  10];
                             [1    1   1   1   1   1   1   1   2   2   2
2   3   4   4   4   4   4   4   4   4   4   4   4   4   5   5   6   6   6
6   6   6   6   7   8   9   9   9   9]]';
EyeglanceSequence(2,5,:,2,:)=[[2    2   2   2   2   3   3   3   3   3   3
3   3   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6
6   8   9   9   9   9   9   9   10  10];
                             [2    2   2   2   2   2   2   2   2   2   2
2   2   2   2   2   2   2   2   2   5   5   5   5   5   5   5   5   5   5
7   7   7   7   7   7   7   7   7   7];
                             [1    1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   3   3   3   3   3   3   3
3   3   3   3   10  10  10  10  10  10];
                             [1    1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   9   9   9   9   9   9   9   9   9   9
9   9   9   9   9   9   9   9   9   9];
                             [1    1   1   1   1   1   1   1   1   1   1
1   1   6   6   6   6   6   6   6   6   6   6   6   6   6   8   9   9   9
9   9   9   9   9   9   9   9   9   10];
                             [1    1   1   1   1   1   1   1   1   1   3
3   3   3   3   3   3   3   3   3   6   6   6   6   6   6   6   6   6   6
10  10  10  10  10  10  10  10  10  10];
                             [4    4   4   4   4   4   4   4   4   4   4
4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4   4
4   4   4   4   4   4   4   4   4   4];
                             [1    1   1   1   1   1   1   1   1   1   3
3   3   3   3   3   3   3   3   3   6   6   6   6   6   6   6   6   6   6
10  10  10  10  10  10  10  10  10  10];
                             [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5   6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10  10];
                             [1    1   1   1   1   1   2   2   2   2   2
3   3   3   3   3   3   5   5   5   5   5   5   6   6   6   6   6   6   7
7   7   7   7   10  10  10  10  10  10];
                             [1    1   1   1   1   1   2   2   2   2   2
2   2   2   2   2   2   4   4   4   4   4   4   4   4   4   4   4   4   4
4   4   4   4   9   9   9   9   9   9]]';
EyeglanceSequence(2,5,:,3,:)=EyeglanceSequence(2,5,:,2,:);
EyeglanceSequence(2,5,:,4,:)=[[2    2   2   2   2   3   3   3   3   3   3
3   3   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6   6
6   8   9   9   9   9   9   9   10  10];
                             [3    3   3   3   3   3   3   3   3   3   3
3   3   6   6   6   6   6   6   6   6   6   6   6   6   6   9   10  10  10
10  10  10  10  10  10  10  10  10  10];
                             [1    1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   6   6   6   6   6   6   6   6   6   6
6   6   6   6   6   6   6   6   6   6];
                             [5    5   5   5   5   5   5   5   5   5   5
5   5   5   5   5   5   5   5   5   7   7   7   7   7   7   7   7   7   7
7   7   7   7   7   7   7   7   7   7];
```

```
                                   [2    2   2   2   2   2   2   2   2   2   2
2   2   2   2   2   2   2   2   2    9   9   9   9   9   9   9   9   9   9
9   9   9   9   9   9   9   9   9    9];
                                   [1    1   1   1   1   1   1   1   1   1   3
3   3   3   3   3   3   4   4   4    4   4   4   9   9   9   9   9   9   9
10  10  10  10  10  10  10  10  10   10];
                                   [10   10  10  10  10  10  10  10  10  10  10
10  10  10  10  10  10  10  10  10   10  10  10  10  10  10  10  10  10  10
10  10  10  10  10  10  10  10  10   10];
                                   [1    1   1   1   1   1   1   1   1   1   3
3   3   3   3   3   3   4   4   4    4   4   4   9   9   9   9   9   9   9
10  10  10  10  10  10  10  10  10   10];
                                   [1    1   1   1   2   2   2   2   3   3   3
3   4   4   4   4   5   5   5   5    6   6   6   6   7   7   7   7   8   8
8   8   9   9   9   9   10  10  10   10];
                                   [1    1   1   1   1   1   1   2   2   2   2
2   2   4   4   4   4   4   4   4    4   4   4   4   4   4   5   6   6   6
6   6   6   10  10  10  10  10  10   10];
                                   [1    1   1   1   1   1   1   1   4   4   4
4   4   4   4   4   4   4   4   4    4   4   4   4   6   6   6   6   6   6
6   6   9   9   9   9   9   9   9    9]]';

% Simulation end time (in seconds) - assumed, sufficiently large to resolve
% all cases
MaxTime=[0,90];
```

Visibility.m

```
%%% LEFT MIRROR
% The first and last row and column are all zeroed out to establish
% boundary conditions.
LeftMirrorOTProxGrid=reshape(ones(6,110,70),6,110,70);
LeftMirrorOTProxGrid(1,1:110,70:-1:1)=[[0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0];
									[0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0];
									[0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0];
									[0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0];
									[0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0];
									[0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0];
									[0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0];
```

```
                                                  [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                                  [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                                  [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                                  [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                                  [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                                  [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                                  [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                                  [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
```

```
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
```

```
[0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0];
[0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0];
[0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0];
[0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0];
[0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0];
[0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0];
[0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0];
[0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0];
```

```
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
```

```
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
```

```
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5
0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
```

```
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1
 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
```

```
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];]';
LeftMirrorOTProxGrid(2,:,:)=LeftMirrorOTProxGrid(1,:,:);
LeftMirrorOTProxGrid(3,:,:)=LeftMirrorOTProxGrid(1,:,:);
LeftMirrorOTProxGrid(4,:,:)=LeftMirrorOTProxGrid(1,:,:);
LeftMirrorOTProxGrid(5,:,:)=LeftMirrorOTProxGrid(1,:,:);
LeftMirrorOTProxGrid(6,:,:)=LeftMirrorOTProxGrid(1,:,:);
%%% RIGHT MIRROR
% The first and last row and column are all zeroed out to establish
% boundary conditions.
```

```
RightMirrorOTProxGrid=reshape(ones(6,110,70),6,110,70);
RightMirrorOTProxGrid(1,1:110,70:-1:1)=[[0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                            [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                            [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                            [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                            [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                            [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                            [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                            [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5
0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
```

```
                                                [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                                [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                                [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                                [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                                [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                                [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                                [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                                [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  1   1   1   0];
```

```
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  1   1   1   1   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0.5 0.5 1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
```

```
                                    [0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0.5 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 0];
                                    [0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 0];
                                    [0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 0];
                                    [0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0.5 0.5 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 0];
                                    [0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0.5 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 0];
                                    [0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0.5 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 0];
                                    [0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0.5 0.5 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 0];
                                    [0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0.5 0.5 0.5 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 0];
```

```
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5
0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   1
1   1   1   1   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                    [0  0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
```

```
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                    [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
```

```
                                        [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                        [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                        [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                        [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                        [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                        [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                        [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
                                        [0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0];
```

```
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
                                    [0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
0  0  0  0  0];
```

```
                                                            [0   0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0];
                                                            [0   0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0];
                                                            [0   0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0];
                                                            [0   0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0];
                                                            [0   0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0];
                                                            [0   0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0];]';
RightMirrorOTProxGrid(2,:,:)=RightMirrorOTProxGrid(1,:,:);
RightMirrorOTProxGrid(3,:,:)=RightMirrorOTProxGrid(1,:,:);
RightMirrorOTProxGrid(4,:,:)=RightMirrorOTProxGrid(1,:,:);
RightMirrorOTProxGrid(5,:,:)=RightMirrorOTProxGrid(1,:,:);
RightMirrorOTProxGrid(6,:,:)=RightMirrorOTProxGrid(1,:,:);

%%% REAR VIEW MIRROR
% The first and last row and column are all zeroed out to establish
% boundary conditions.
RearViewMirrorOTProxGrid=reshape(ones(6,110,70),6,110,70);
RearViewMirrorOTProxGrid(1,1:110,70:-1:1)=[[0   0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
```

```
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0];
                                        [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  1    1    1
1    1    1    1    1    0];
                                        [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  1    1    1    1    1
1    1    1    1    1    0];
                                        [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                        [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0.5
0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                        [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                        [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0.5  0.5  0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                        [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0.5  1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                        [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  1    1
```

```
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0.5  0.5  0.5  0.5  0.5  0.5  0.5  1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0.5  0.5  0.5  0.5  0.5  0.5  0.5  1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0.5
0.5  0.5  0.5  0.5  0.5  1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0.5  0.5  0.5  0.5
0.5  0.5  0.5  1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0.5  0.5  0.5  0.5  0.5  0.5
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0.5  0.5  0.5  0.5  0.5  1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
```

```
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5
0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5
0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5
0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
```

```
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
```

```
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0.5 1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1
1   1   1   1   1   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0.5 0.5 0.5 0.5 0.5 0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                                  [0   0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
```

```
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                        [0  0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];]';
RearViewMirrorOTProxGrid(2,:,:)=RearViewMirrorOTProxGrid(1,:,:);
RearViewMirrorOTProxGrid(3,:,:)=RearViewMirrorOTProxGrid(1,:,:);
RearViewMirrorOTProxGrid(4,:,:)=RearViewMirrorOTProxGrid(1,:,:);
RearViewMirrorOTProxGrid(5,:,:)=RearViewMirrorOTProxGrid(1,:,:);
RearViewMirrorOTProxGrid(6,:,:)=RearViewMirrorOTProxGrid(1,:,:);
%%% OVER THE SHOULDER GLANCES
OvertheShoulderOTProxGrid=reshape(ones(6,110,70),6,110,70);
OvertheShoulderOTProxGrid(1,1:110,70:-1:1)=[[0  0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0];
                                         [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5
0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 1   1   1
1   1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 1   1   1   1
1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 1   1   1   1   1
  1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 1   1   1   1   1
1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 1   1   1   1   1
1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1
```

```
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   0.5 0.5 0.5 1   1   1   1   1   1
1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 1   1   1   1   1   1
1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   0.5 0.5 0.5 1   1   1   1   1   1   1
1   1   1   1   1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   0.5 0.5 0.5 1   1   1   1   1   1   1
1   1   1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5
0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   0.5 0.5 0.5 0.5 1   1   1   1   1   1   1
1   1   0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5
0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   0.5 0.5 0.5 1   1   1   1   1   1   1   1   1
  1   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   0.5 0.5 0.5 1   1   1   1   1   1   1   1
1   0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   0.5
0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
```

```
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   0.5 0.5 0.5 1   1   1   1   1   1   1   0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5
0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0 0   0   0   0   0   0   0   0
0.5 0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5
0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0 0   0   0   0   0   0   0   0
0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5
0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                        [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
```

```
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
```

```
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0.5 1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0   0   0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
0    0    0    0    0    0    0    0    0.5  0.5  0.5  0.5  0.5  0.5  1    1    1    1    1
1    1    1    1    1    0];
                                          [0 0    0    0    0    0    0    0    0
0.5  0.5  1    1    1    1    1    1    1    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0
  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0.5  0.5  0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0];
                                          [0 0    0    0    0    0    0    0    0
0.5  0.5  1    1    1    1    1    1    1    1    0.5  0.5  0.5  1    1    1    1    1    1
1    1    1    1    1    1    1    0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0.5  0.5  0.5  0.5  0.5  0];
                                          [0 0    0    0    0    0    0    0    0
0.5  0.5  1    1    1    1    1    1    1    1    1    0.5  0.5  1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                          [0 0    0    0    0    0    0    0    0
0.5  0.5  1    1    1    1    1    1    1    1    1    1    0.5  0.5  1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    0.5  0.5  0.5  0.5
0.5  0.5  0.5  0    0    0    0    0    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                          [0 0    0    0    0    0    0    0    0
0.5  0.5  1    1    1    1    1    1    1    1    1    1    1    0.5  0.5  0.5  0.5  1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
0.5  1    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0.5  0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                          [0 0    0    0    0    0    0    0    0
0.5  0.5  1    1    1    1    1    1    1    1    1    1    1    1    1    1    0.5  0.5  1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                          [0 0    0    0    0    0    0    0    0
0.5  0.5  1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    0.5
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];
                                          [0 0    0    0    0    0    0    0    0
0.5  0.5  1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
0.5  0.5  1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    0.5  0.5  0.5  0.5  0.5  0.5  0.5
0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0.5  0    0    0
```

```
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   0.5 0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0   0   0   0   0   0
0   0   0   0   0   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0   0   0   0   0
0   0   0   0   0   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0   0   0   0   0   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0   0   0   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
  1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0.5 0.5 0.5 0.5 0.5 1   0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5
0.5 0.5 0.5 0.5 0.5 0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
```

```
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   0.5 0.5
0.5 0.5 0.5 0.5 0.5 0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   0.5 0.5 0.5 0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   0];
                                          [0 0   0   0   0   0   0   0   0
0.5 0.5 1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1   1
```

```
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                          [0 0    0    0    0    0    0    0    0
0.5 0.5 1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                          [0 0    0    0    0    0    0    0    0
0.5 0.5 1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                          [0 0    0    0    0    0    0    0    0
0.5 0.5 1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1    1
1    1    1    1    1    0];
                                          [0 0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
0    0    0    0    0    0];];';
OvertheShoulderOTProxGrid(2,:,:)=OvertheShoulderOTProxGrid(1,:,:);
OvertheShoulderOTProxGrid(3,:,:)=OvertheShoulderOTProxGrid(1,:,:);
OvertheShoulderOTProxGrid(4,:,:)=OvertheShoulderOTProxGrid(1,:,:);
OvertheShoulderOTProxGrid(5,:,:)=OvertheShoulderOTProxGrid(1,:,:);
OvertheShoulderOTProxGrid(6,:,:)=OvertheShoulderOTProxGrid(1,:,:);
```

Generalized extreme value distribution

```
function r = gevrnd(k,sigma,mu,varargin)
%GEVRND Random arrays from the generalized extreme value distribution.
%   R = GEVRND(K,SIGMA,MU) returns an array of random numbers chosen from the
%   generalized extreme value (GEV) distribution with shape parameter K,
scale
%   parameter SIGMA, and location parameter MU.  The size of R is the common
%   size of K, SIGMA, and MU if all are arrays.  If any parameter is a
scalar,
%   the size of R is the size of the other parameters.
```

```
%
%   R = GEVRND(K,SIGMA,MU,M,N,...) or R = GEVRND(K,SIGMA,MU,[M,N,...])
returns
%   an M-by-N-by-... array.
%
%   When K < 0, the GEV is the type III extreme value distribution.  When K >
%   0, the GEV distribution is the type II, or Frechet, extreme value
%   distribution.  If W has a Weibull distribution as computed by the WBLRND
%   function, then -W has a type III extreme value distribution and 1/W has a
%   type II extreme value distribution.  In the limit as K approaches 0, the
%   GEV is the mirror image of the type I extreme value distribution as
%   computed by the EVRND function.
%
%   The mean of the GEV distribution is not finite when K >= 1, and the
%   variance is not finite when K >= 1/2.  The GEV distribution has positive
%   density only for values of X such that K*(X-MU)/SIGMA > -1.
%
%   See also EVRND, GEVCDF, GEVFIT, GEVINV, GEVLIKE, GEVPDF, GEVSTAT, RANDOM.

%   GEVRND uses the inversion method.

%   References:
%      [1] Embrechts, P., C. Klüppelberg, and T. Mikosch (1997) Modelling
%          Extremal Events for Insurance and Finance, Springer.
%      [2] Kotz, S. and S. Nadarajah (2001) Extreme Value Distributions:
%          Theory and Applications, World Scientific Publishing Company.

%   Copyright 1993-2005 The MathWorks, Inc.
%   $Revision: 1.1.6.1 $  $Date: 2005/05/31 16:44:34 $

if nargin < 3
    error('stats:gevrnd:TooFewInputs', ...
          'Requires at least three input arguments.');
end

[err,sizeOut] = statsizechk(3,k,sigma,mu,varargin{:});
if err > 0
    error('stats:gevrnd:InputSizeMismatch', ...
          'Size information is inconsistent.');
end
if isscalar(k), k = repmat(k,sizeOut); end

% Return NaN for elements corresponding to illegal parameter values.
sigma(sigma < 0) = NaN;

r = zeros(sizeOut,superiorfloat(k,sigma,mu));
u = rand(sizeOut);

% Find the k==0 cases and fill them in.
j = (abs(k) < eps);
r(j) = -log(-log(u(j)));

% Find the k~=0 cases and fill them in.
j = ~j;
r(j) = expm1(-k(j).*log(-log(u(j)))./k(j); % ((-log(u)).^(-k) - 1) ./ k

r = mu + sigma.*r;
```

Norminv.m(Inverse of the normal cumulative distribution function)

```
function [x,xlo,xup] = norminv(p,mu,sigma,pcov,alpha)
%NORMINV Inverse of the normal cumulative distribution function (cdf).
%   X = NORMINV(P,MU,SIGMA) returns the inverse cdf for the normal
%   distribution with mean MU and standard deviation SIGMA, evaluated at
%   the values in P.  The size of X is the common size of the input
%   arguments.  A scalar input functions as a constant matrix of the same
%   size as the other inputs.
%
%   Default values for MU and SIGMA are 0 and 1, respectively.
%
%   [X,XLO,XUP] = NORMINV(P,MU,SIGMA,PCOV,ALPHA) produces confidence bounds
%   for X when the input parameters MU and SIGMA are estimates.  PCOV is a
%   2-by-2 matrix containing the covariance matrix of the estimated
parameters.
%   ALPHA has a default value of 0.05, and specifies 100*(1-ALPHA)%
confidence
%   bounds.  XLO and XUP are arrays of the same size as X containing the
lower
%   and upper confidence bounds.
%
%   See also ERFINV, ERFCINV, NORMCDF, NORMFIT, NORMLIKE, NORMPDF,
%            NORMRND, NORMSTAT.

%   References:
%      [1] Abramowitz, M. and Stegun, I.A. (1964) Handbook of Mathematical
%          Functions, Dover, New York, 1046pp., sections 7.1, 26.2.
%      [2] Evans, M., Hastings, N., and Peacock, B. (1993) Statistical
%          Distributions, 2nd ed., Wiley, 170pp.

%   Copyright 1993-2004 The MathWorks, Inc.
%   $Revision: 2.16.4.2 $  $Date: 2004/08/20 20:06:03 $

if nargin<1
    error('stats:norminv:TooFewInputs','Input argument P is undefined.');
end
if nargin < 2
    mu = 0;
end
if nargin < 3
    sigma = 1;
end

% More checking if we need to compute confidence bounds.
if nargout>2
   if nargin<4
      error('stats:norminv:TooFewInputs',...
            'Must provide covariance matrix to compute confidence bounds.');
   end
   if ~isequal(size(pcov),[2 2])
      error('stats:norminv:BadCovariance',...
```

```
            'Covariance matrix must have 2 rows and columns.');
   end
   if nargin<5
      alpha = 0.05;
   elseif ~isnumeric(alpha) || numel(alpha)~=1 || alpha<=0 || alpha>=1
      error('stats:norminv:BadAlpha',...
            'ALPHA must be a scalar between 0 and 1.');
   end
end

% Return NaN for out of range parameters or probabilities.
sigma(sigma <= 0) = NaN;
p(p < 0 | 1 < p) = NaN;

x0 = -sqrt(2).*erfcinv(2*p);
try
    x = sigma.*x0 + mu;
catch
    error('stats:norminv:InputSizeMismatch',...
          'Non-scalar arguments must match in size.');
end

% Compute confidence bounds if requested.
if nargout>=2
   xvar = pcov(1,1) + 2*pcov(1,2)*x0 + pcov(2,2)*x0.^2;
   if any(xvar<0)
      error('stats:norminv:BadCovariance',...
            'PCOV must be a positive semi-definite matrix.');
   end
   normz = -norminv(alpha/2);
   halfwidth = normz * sqrt(xvar);
   xlo = x - halfwidth;
   xup = x + halfwidth;
end
```

normpdf.m (Normal probability density function)

```
function y = normpdf(x,mu,sigma)
%NORMPDF Normal probability density function (pdf).
%   Y = NORMPDF(X,MU,SIGMA) returns the pdf of the normal distribution with
%   mean MU and standard deviation SIGMA, evaluated at the values in X.
%   The size of Y is the common size of the input arguments.  A scalar
%   input functions as a constant matrix of the same size as the other
%   inputs.
%
%   Default values for MU and SIGMA are 0 and 1 respectively.
%
%   See also NORMCDF, NORMFIT, NORMINV, NORMLIKE, NORMRND, NORMSTAT.

%   References:
%      [1] Evans, M., Hastings, N., and Peacock, B. (1993) Statistical
```

```
%          Distributions, 2nd ed., Wiley, 170pp.

%   Copyright 1993-2004 The MathWorks, Inc.
%   $Revision: 2.10.4.2 $  $Date: 2004/08/20 20:06:04 $

if nargin<1
    error('stats:normpdf:TooFewInputs','Input argument X is undefined.');
end
if nargin < 2
    mu = 0;
end
if nargin < 3
    sigma = 1;
end

% Return NaN for out of range parameters.
sigma(sigma <= 0) = NaN;

try
    y = exp(-0.5 * ((x - mu)./sigma).^2) ./ (sqrt(2*pi) .* sigma);
catch
    error('stats:normpdf:InputSizeMismatch',...
          'Non-scalar arguments must match in size.');
end
```

Normrnd.m (Random arrays from the normal distribution)

```
function r = normrnd(mu,sigma,varargin);
%NORMRND Random arrays from the normal distribution.
%   R = NORMRND(MU,SIGMA) returns an array of random numbers chosen from a
%   normal distribution with mean MU and standard deviation SIGMA.  The size
%   of R is the common size of MU and SIGMA if both are arrays.  If either
%   parameter is a scalar, the size of R is the size of the other
%   parameter.
%
%   R = NORMRND(MU,SIGMA,M,N,...) or R = NORMRND(MU,SIGMA,[M,N,...])
%   returns an M-by-N-by-... array.
%
%   See also NORMCDF, NORMFIT, NORMINV, NORMLIKE, NORMPDF, NORMSTAT,
%   RANDOM, RANDN.

%   NORMRND uses Marsaglia's ziggurat method.

%   References:
%      [1] Marsaglia, G. and Tsang, W.W. (1984) "A fast, easily implemented
%          method for sampling from decreasing or symmetric unimodal density
%          functions", SIAM J. Sci. Statist. Computing, 5:349-359.
```

```
%      [2] Evans, M., Hastings, N., and Peacock, B. (1993) Statistical
%          Distributions, 2nd ed., Wiley, 170pp.

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%   $Revision: 2.13.4.3 $  $Date: 2004/01/24 09:34:48 $

if nargin < 2
    error('stats:normrnd:TooFewInputs','Requires at least two input
arguments.');
end

[err, sizeOut] = statsizechk(2,mu,sigma,varargin{:});
if err > 0
    error('stats:normrnd:InputSizeMismatch','Size information is
inconsistent.');
end

% Return NaN for elements corresponding to illegal parameter values.
sigma(sigma < 0) = NaN;

r = randn(sizeOut) .* sigma + mu;
```

statsizechk.m (Check for compatible array sizes)

```
function [err, commonSize, numElements] = statsizechk(nparams,varargin)
%STATSIZECHK Check for compatible array sizes.
%   [ERR,COMMONSIZE,NUMELEMENTS] = STATSIZECHK(NPARAMS,A,B,...,M,N,...) or
%   [ERR,COMMONSIZE,NUMELEMENTS] = STATSIZECHK(NPARAMS,A,B,...,[M,N,...])
%   in effect computes size( A + B + ... + zeros(M,N,...) ), and catches
%   any size mismatches.  NPARAMS is the number of array input arguments.

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%   $Revision: 1.1.6.2 $  $Date: 2004/01/24 09:36:35 $
%
%   Mex file.

try
    tmp = 0;
    for argnum = 1:nparams
        tmp = tmp + varargin{argnum};
    end
    if nargin > nparams+1
        tmp = tmp + zeros(varargin{nparams+1:end});
    end
    err = 0;
    commonSize = size(tmp);
    numElements = numel(tmp);

catch
    err = 1;
    commonSize = [];
    numElements = 0;
```

```
end
```

WBLRND.m (Random arrays from the Weibull distribution)

```
function r = wblrnd(A,B,varargin)
%WBLRND Random arrays from the Weibull distribution.
%   R = WBLRND(A,B) returns an array of random numbers chosen from the
%   Weibull distribution with scale parameter A and shape parameter B.  The
%   size of R is the common size of A and B if both are arrays.  If either
%   parameter is a scalar, the size of R is the size of the other
%   parameter.
%
%   R = WBLRND(A,B,M,N,...) or  R = WBLRND(A,B,[M,N,...]) returns an
%   M-by-N-by-... array.
%
%   See also WBLCDF, WBLFIT, WBLINV, WBLLIKE, WBLPDF, WBLSTAT, RANDOM.

%   WBLRND uses the inversion method.

%   References:
%     [1] Lawless, J.F. (1982) Statistical Models and Methods for Lifetime
Data, Wiley,
%         New York.
%     [2} Meeker, W.Q. and L.A. Escobar (1998) Statistical Methods for
Reliability Data,
%         Wiley, New York.
%     [3] Crowder, M.J., A.C. Kimber, R.L. Smith, and T.J. Sweeting (1991)
Statistical
%         Analysis of Reliability Data, Chapman and Hall, London.

%   Copyright 1993-2004 The MathWorks, Inc.
%   $Revision: 1.4.4.2 $  $Date: 2003/11/01 04:29:42 $

if nargin < 2
    error('stats:wblrnd:TooFewInputs','Requires at least two input
arguments.');
end

[err, sizeOut] = statsizechk(2,A,B,varargin{:});
if err > 0
    error('stats:wblrnd:InputSizeMismatch','Size information is
inconsistent.');
end

% Return NaN for elements corresponding to illegal parameter values.  Both
% A or B equal to zero are allowed.
A(A < 0) = NaN;
B(B < 0) = NaN;
```

```
% Generate uniform random values, and apply the Weibull inverse CDF.
r = A .* (-log(rand(sizeOut))) .^ (1./B); % == wblinv(u, A, B)
```

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