Superior Unobstructed Vision (SUV) Camera

Version III

16.621

Author: Darlene Utter

Advisor: Karen Willcox **Partner:** Kathleen McCoy

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*Graphic on this page from National Highway Traffic Safety Administration, http://www.nhtsa.dot.gov/cars/problems/studies/LTV/

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List of Acronyms

CC	Compact Car
CTS	Camera and Tripod System
IVT	In-Vehicle Technology
LTV	Light Trucks, sport utility vehicles, and Vans
MIT	Massachusetts Institute of Technology
NADS	National Advanced Driving Simulator
NHTSA	National Highway Traffic Safety Administration
SUV	Sport Utility Vehicle

Executive Summary

The Superior Unobstructed Vision Camera project is the feasibility study of a solution to the geometric incompatibility problem that exists between compact cars and sport utility vehicles. This geometric incompatibility is due to the higher ride profile of sport utility vehicles, vans, and light trucks, and causes obstructed vision of the roadway for the drivers of smaller vehicles. This project hypothesizes that an external camera mounted on a compact car can provide useful information to the compact car drivers, such that it reduces the reaction time of the drivers in situations where their vision may have been blocked by a sport utility vehicle.

In order to evaluate the proposed solution, the project is split into three phases. The first phase consists of constructing an external camera system that can be mounted on a compact car to display and record real-time images of traffic situations from an elevated perspective. These images are displayed inside the car via a laptop. The second phase will entail creating and recording traffic scenarios where blocked vision is considered to be a problem. Recordings will be made of the same scenarios from the perspective of a compact car driver and from the external camera perspective. The third phase is the evaluation of these recorded perspectives in the MIT Age Lab Driving Simulator by test drivers. The test drivers will test all of the driving scenarios and perspectives, and will give written feedback as to their ease of driving with the external camera perspective, the compact car driver perspective, and to the combination of these perspectives. Their response times to obstructions on the roadway will be measured and analyzed to determine if having a higher perspective available while driving is useful.

This project will use several pieces of equipment already available from MIT at no expense. Thus, the project can be completed within 15 weeks at a cost of no more than $165. If successful, this project can provide an effective means to overcome the problem of blocked vision for the drivers of small cars. It can also reduce the reaction time of the driver, thus reducing the likelihood of an accident.

1.0 Introduction

1.1 Project Motivation and Significance

Over the last ten years, the number of light trucks and vans (LTV's) has soared, now totaling more than 35 percent of all registered motor vehicles in the United States.[1] The category of LTV's consists of sport utility vehicles(SUV's), vans, and light trucks. Even though LTV's only comprise about one-third of all motor vehicles, over 60 percent of occupant fatalities in two-vehicle crashes can be attributed to them.[2] As a result, several incompatibilities between LTVs and passenger cars have been researched and revealed, including mass incompatibilities, stiffness incompatibilities, and geometric incompatibilities.[3] Accordingly, the third priority in the *National Highway Traffic Safety Administration (NHTSA) Vehicle Safety Rulemaking Priorities: 2002-2005* is to "Address the Incompatibility Between Passenger Cars and Light Trucks."[1] The priority states that there exists "problems of blocked vision of passenger car and motorcycle drivers due to the higher [ride] profile of LTVs…"[1]

This project proposes to investigate an immediate solution to the geometric incompatibility problem between compact cars (CC's) and SUV's. The proposed solution is an external camera system that can be mounted to a CC to obtain live images of traffic situations in scenarios where the driver's vision is blocked by an SUV. The system will display the images in real time to the driver of the CC via an internal dashboard display.

In order to assess the usefulness of this information to the driver, blocked vision scenarios will be recorded from the perspective of the driver and from the external camera. Using the Driving Simulator in the Massachusetts Institute of Technology (MIT) Age Lab, drivers can review the two perspectives and evaluate the usefulness of the external camera images. Inherent in the results obtained from the evaluation of these images is whether or not the test drivers are distracted by the addition of a display in the vehicle.

1.2 Overview of Previous Work

The research of LTV and passenger car incompatibility has begun only recently, its beginning dating back only to 1998. As stated in the *NHTSA Vehicle Safety Rulemaking Priorities*,[1] current research is being conducted to study these vehicle incompatibilities and to propose solutions for dealing with them. Most of the research conducted thus far has been crash testing and statistical analysis to determine the relationships between vehicle design and collision fatalities. We could find no research conducted previously that studies the solution proposed by this project.

The studies of driver distraction and vehicle technology usefulness are also current research questions. There is research information available from past experiments that describes how to best measure driver distraction. Several proposed methods to determine the distraction level of the driver include measured response time to a given scenario, lane position deviation, eye tracking devices, and subjective questioning of the driver. However, this project is not concerned with measuring the level of distraction of the driver, but rather the driver's performance in the test situations as result of the driver's distraction.

1.3 Value to Drivers

This project is a feasibility study of a proposed solution to one of the CC-LTV incompatibility issues. If successful, it can provide an immediate solution for drivers of compact cars. Also, with the ever-increasing concern for driver and passenger safety, this project can provide another perspective on the current issue of driver distraction from new vehicle technologies.

2.0 Project Statement

2.1 Hypothesis

The project hypothesis is that an externally mounted camera on a CC can provide useful information to the driver in situations where SUVs normally block his/her vision.

2.2 Objective

The main objective of this project is to evaluate in the MIT Age Lab Driving Simulator whether images from an externally mounted camera on a CC can provide sufficient information to reduce the response time of a driver in situations where blocked vision from an SUV would be a problem.

2.3 Success Criteria

The success criteria for this project is the evaluation of whether external camera system images provide sufficient information to reduce the response time of a driver in situations where blocked vision from an SUV is a problem.

3.0 Literature Review

Although there are several articles and reports written about the incompatibility of LTVs and CCs, there does not appear to be any literature regarding proposed solutions to the incompatibility problem. Most of the information found by the author provides the motivation for the solution proposed by this project. In addition, there is a good deal of research available about driver safety; however, much of this information does not pertain to the new innovation of internal video displays.

3.1 Project Significance

The motivation for this project is supplied in several articles and government reports. An article entitled "Civilizing the Sport Utility Vehicle," written by John D. Graham[2], addresses several of the key issues that stem from the increasing popularity of SUV's. Although some of Graham's article discusses information, not relevant to this investigation, such as SUV roll-over rates, pollution concerns and tire issues, he provides detailed information about the SUV-CC incompatibility problems. Graham substantiates this information with crash test and accident analysis that clearly indicates that the incompatibility issue is dangerous to the drivers of compact cars. Graham further states that one of the major concerns voiced by the motorists he surveyed was that "large SUVs make it impossible for drivers in smaller vehicles to see the traffic ahead of them or to see the traffic flow when a driver is pulling out of a side street onto a major thruway."[2] This information provides the motivation for some of the scenarios being tested in this project. Graham concludes his article by proposing that in order to combat these incompatibility issues, the federal government needs to begin researching and imposing regulations on SUV design and construction that take into account the differences in vehicle mass, stiffness and geometry. Although Graham proposes a solution to this problem, this federal process will take several years to complete and thus an immediate solution is still not available.

Two government reports also reflect the need for a solution to the incompatibility problem. In fact, one of the reports "NHTSA Vehicle Safety Rulemaking Priorities: 2002-2005"[1] lists the incompatibility between passenger cars and light trucks as the third matter they must address in the upcoming years. The report also addresses how the mass, stiffness and geometry differences between the two classes of motor vehicles must be studied, including the problem of decreased visibility for small cars due to blocked vision. The Priorities state that no specific rulemaking plans have been made, and that further research into the problems will be undertaken by more crash testing and developing system models. The second NHTSA report, "The Aggressivity of Light Trucks and Vans in Traffic Crashes," written by Gabler and Hollowell, [3] proves the case of incompatibility between SUVs and CCs, and demonstrates with this data the dangers presented to CC drivers. Gabler and Hollowell numerically summarize the increase in LVTs on the road and the correlation to fatal accidents (defined by the term "aggressivity"). They further stipulate that in side impact collisions by an LTV into a CC, the fatality rates are significantly greater than in other types of accidents. Although Gabler and Hollowell do not directly state the relationship this may have to blocked vision, it seems that blocked vision may be one of the greatest contributors to this type of fatal collision. They also describe in greater detail what is meant by mass incompatibility, stiffness incompatibility, and geometric incompatibility between SUVs and CCs. They propose no other solution than further research of these problems.

3.2 Video Camera Technology on Cars

There is a great deal of information available about camera technology and video recording. However there is very little information available about the use of video cameras on cars, or video displays within cars. All references to video cameras mounted on cars concerns their use on police vehicles for surveillance purposes. The systems described for police use are very complex, multi-featured, and very expensive. In an article entitled "Mercer Island Police Find Video Cameras Useful" Atienza and Ronningen, state that the Mercer Island Police force is asking for $56,000 for only 6 new camera systems. That figure estimates each camera system at about $9,000. That is more expensive than most of today's CCs! These camera systems are definitely not a feasible purchase for the average consumer. Although most of the article is concerned with the legal issues involved with camera recording, it stresses how useful the police force has found the cameras in catching suspects due to the details captured on video. Thus, although the technology does exist for operating camera systems on cars, it is unreasonably expensive.

3.3 Driver Safety and Distractions

With the increasing use of in-vehicle technologies (IVTs), driver safety and distraction research has become another prominent issue. There is a vast amount of research and analysis available, most of it sponsored by the NHTSA. The NHTSA has prepared a summary of distraction research, entitled "Driver Distraction Research: Past, Present and Future," by Ranney, Mazzae, Garrot, and Goodman.[5] The authors explain that driver distraction is characterized as "any activity that takes a driver's attention away from the task of driving." [6] Furthermore, they classify driving distraction into four distinct categories: "visual distraction (e.g., looking away from the roadway), auditory distraction (e.g., responding to a ringing cell phone), biomechanical distraction (e.g., manually adjusting the radio volume), and cognitive distraction (e.g., being lost in thought)."[6] The article explains the factors that influence distraction, such as the workload of the driver and the driver's willingness to engage in a task. It also provides the motivation behind researching driver distraction: it is one of the biggest contributors to accidents and roadway fatalities. The authors summarize past research done by the NHTSA, for example the workload study of Truck Drivers with new communications equipment, research into wireless phone use and distraction, and analyzing navigation systems and destination entry technology.

Future research the NHTSA has planned is in the new National Advanced Driving Simulator (NADS), and will focus on IVT. Since the Superior Unobstructed Vision Camera could become a new IVT, the distraction results obtained from the project will be important for comparison with the new leading edge technology in the NADS. Another future project involves the use of infra-red night vision displays. This project is very similar to the Superior Unobstructed Vision Camera project proposed. The Night Vision system will allow drivers the ability to see objects otherwise unrecognizable at night by performing a thermal scan down the road and displaying an enhanced map on the windshield. The article states that like the proposed Superior Unobstructed Vision project, the Night Vision project, "involves a tradeoff between increased object recognition and driver distraction. If drivers look down at the display, they may see the enhanced objects more clearly than with direct vision. However, looking at the display may distract driver's attention to some degree from other objects and roadway features not visible on the display…"[6] This is precisely an issue that will be studied in the proposed project, and will be analyzed from the driver's performance.

4.0 Technical Approach

4.1 Experiment Overview

There are three main phases of the experiment. Each phase is based on the product of the previous phase and all phases must be completed in entirety before completing the next phase.

4.1.1 *Phase I: Camera and Mount System*

The first phase consists of the construction of the external camera system to record driving scenarios in Phase II. Using the camera resources available at MIT, a small inexpensive camera will be selected for the external camera. Next, a camera mount will be designed and constructed so that the camera can be attached to a standard adjustable camera tripod that will be placed on a compact car. The correct height of the tripod will need to be determined based on the height of the SUV and CC being used during recording. The camera system will need to be connected to a laptop inside the vehicle that will record the images.

4.1.2 *Phase II: Traffic Image Recording*

The second phase consists of recording traffic scenarios where blocked vision may be a problem, from the perspective of both the driver and the external camera. The current plan is to record three similar, but different, scenarios. The scenarios will be planned and rehearsed before actual image recording takes place. The external camera images will be recorded onto a laptop. At the same time, a handheld video camera will record what the driver of the CC sees.

4.1.3 *Phase III: Driving Simulator Evaluation*

Phase III will involve the MIT Age Lab Driving Simulator for evaluation of the usefulness of the images recorded in Phase II. The simulator is configured to play the perspective of the driver on a wide screen projector in front of the car. A laptop will be used in the car's interior to play back the images recorded from the externally mounted camera. Three different combinations of perspectives are needed to obtain the best results from the test drivers. The first is the scenarios from the perspective of the CC driver, which will be displayed on the wide screen viewer. This perspective is the "Normal CC View," and will be used for comparison with the second perspective. The second perspective will be the view from the external camera, or "Unobstucted View," and will also be shown on the widescreen to simulate what the view from another SUV is like. Last, the third perspective will be the "Normal CC View" displayed on the wide screen, and the "Unobstructed View" displayed on the laptop internal display. In every Driving Simulator set-up, the response time of the driver to an obstruction on the road will be to evaluate the images. In addition, a questionnaire will be given to evaluate the test driver's thoughts on the usefulness of the external camera images and the distraction caused by an internal display.

4.2 Description of Apparatus

4.2.1 Phase I: Camera and Mount System Description

This phase focuses on one apparatus – the camera and tripod system (CTS) A small camera has been selected from several inexpensive cameras available at MIT. The camera will be mounted to a standard camera tripod via a machined mount detailed in Section 5.1. The CTS will be mounted to a compact car via powerful suction cups. The CTS is shown in Figure 1 – Camera and Tripod System.

Figure 1 – Camera and Tripod System

The camera will be placed above the driver of the compact car, as show in Figure 2 – Camera and Tripod Placement.

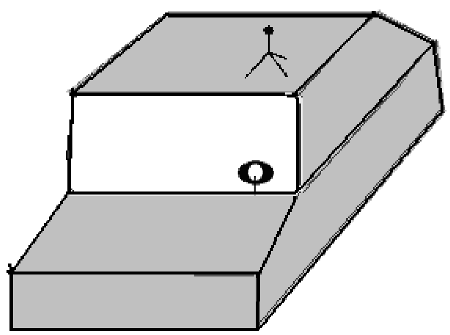

Figure 2 – Camera and Tripod Placement

One video line will need to be connected from the external camera to the laptop inside the vehicle. A battery pack will supply power to the camera.

4.2.2 *Phase II: Traffic Image Recording Description*

For Phase II, there are several items required for successful image recording. First, the finished product from Phase I must be mounted on a CC, (Refer to Figure 2) and configured for laptop recording. Second, a handheld video recorder is needed to record the scenarios from the perspective of the CC driver. Any standard available video camera can be used for this phase. Also, one CC and an SUV with drivers must be obtained to perform the driving situations. These will be provided by the project authors and advisors. Next, the situations for the driving scenarios will need to be rehearsed to get precise synchronization for recording with the external and internal camera, the timing of vehicle maneuvers, and to choose the optimum speeds and distances for the three driving scenarios. The three scenarios are depicted in greater detail in section 5.2. In addition to the items mentioned above, this phase will require some stop watches and the construction of various props (such as 2 cardboard pedestrians, a cardboard animal, a stop sign, and some cones.)

4.2.3 Phase III: Driving Simulator Evaluation Apparatus

All of the image evaluation will take place in the MIT Age Lab Driving Simulator. The Simulator is a red Volkswagen Beetle that is fitted with instruments to record the movements and responses of drivers. In front of the driver is a wide screen, displaying the images from an overhead projector. A picture of the Age Lab Driving Simulator is shown in Figure 3 – Age Lab Driving Simulator.

Figure 3 – Age Lab Driving Simulator [6]

The inside of the Simulator is very similar to an average. A picture of the inside of the Driving Simulator is shown in Figure 4 – Driving Simulator Interior. From Figure 4, please note that the dashboard of the simulator is wide and flat, making the addition of an internal video display via a laptop easy to implement. The laptop will be placed as close to the driver as possible, without interfering with the driver's view out the windshield. A probable location for the laptop display is marked in Figure 4.

Possible laptop placement

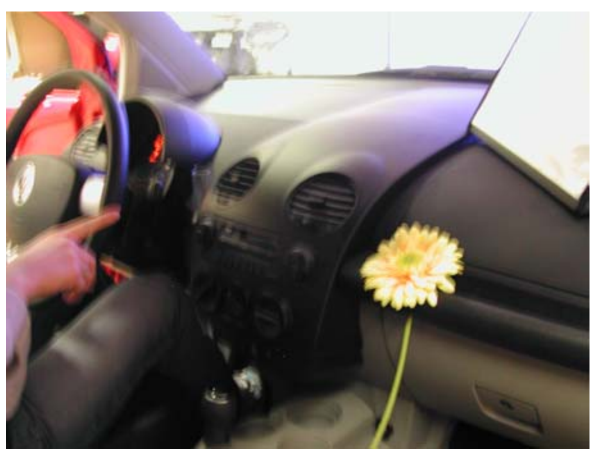

Figure 4 – Driving Simulator Interior

4.3 Description of Test Subjects

4.3.1 Phase I: Camera and Mount Test Descriptions

Phase I is a construction phase, so no formal testing is planned. However, for this phase, a few things will need to be checked prior to the start of Phase II. The video and power connections need to be tested to ensure that they are working properly while the external camera is attached to the vehicle. In addition, the tripod height will need to be determined. Because the camera is mounted to a tripod, its height will be easily adjustable. For each of the scenarios being tested, the height of the camera will be determined and adjusted to give the best view of the roadway at a set distance behind an SUV.

4.3.2 Phase II: Traffic Image Recording Test Scenarios

Three scenarios are going to be recorded by the CC externally mounted camera and the internal driver perspective camera for evaluation in the Age Lab. The scenarios are all testing the reaction of the CC driver to a situation where their vision is obstructed by an SUV. All three of these scenarios will be used in Phase III to determine the reaction time of the CC driver from when the obstruction on the road is first visible from the CC perspective. Scenario A is depicted in Figure 5 – Driving Scenario A.

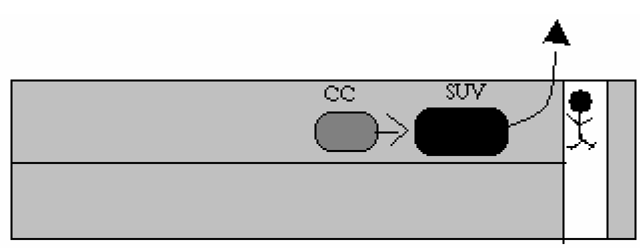

Figure 5 – Driving Scenario A

Scenario A is when a CC is traveling behind an SUV, and the vision of the driver in the CC is obstructed by the SUV, such that the CC driver can not see what lies ahead of the SUV. In the road is a stationary pedestrian. The SUV veers left to avoid the pedestrian, allowing the CC driver to see the obstacle for the first time.

Scenario B will test for the same things, but the set-up is slightly different. As show in Figure 6 – Driving Scenario B, an SUV and a CC are approaching an intersection, where an obstruction is stationary in the road. (This obstruction will most likely be a ball or a cone.) The driver of the CC cannot see the obstruction until the SUV makes a left turn.

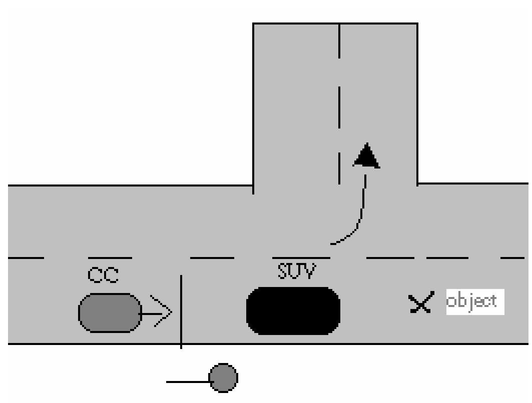

Figure 6 – Driving Scenario B

The last scenario is more is shown in Figure 7 – Driving Scenario C. A CC is driving straight down a side street when a pedestrian walks out from behind a parked SUV and enters a crosswalk. The pedestrian proceeds into the crosswalk where s/he stops.

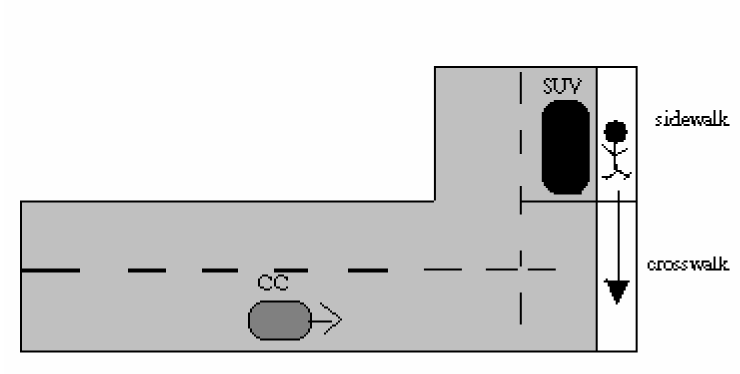

Figure 7 – Driving Scenario C

4.3.3 Phase III: Driving Simulator Evaluation Test Configurations

As stated in section 4.1.3, there are 3 possible perspectives that need to be shown to drivers for best results. The "Normal CC View" will be referred to as 1, the "Unobstructed View" will be referred to as 2, and the combination of these 2 views will be referred to as 3. Therefore, there are 3 possible perspectives (1,2,3), and 3 possible scenarios (A,B,C). Based on these two parameters, there are nine possible test configurations that need to be evaluated (A1, B1, C1, A2, B2, C2, A3, B3, C3). The problem in phase three is to choose the best configurations to get the most accurate, unbiased results. There are 3 different types of testing configurations possible to best evaluate the images recorded by the video cameras. These possibilities and their positive and negative features are outlined in Table 1 – Possible Evaluation Configurations.[∀]

[∀] Results portrayed in this table are the result of a meeting with Professor Kuchar on 4/2/2003.

Table 1 – Possible Test Configurations

Possibility	**Description**	**Example**	**Positives**	**Negatives**
Within Subject	Every test driver tests every possible scenario/perspective	Test Driver 1 tests same as test driver 2… same as….They test A1, B1, C1, A2, B2,C2, A3, B3, C3	-Every possible situation is exhausted. -There is no problem comparing driver 1's A1 with results from driver 2's A2. -Do not need to worry about skills varying between drivers.	-Learning curve when same scenario is played at a different perspective- driver already knows what to expect and driver response times are very biased.
Between Subject	Between every test driver, all scenarios are tested	-Driver 1: A1, B1, C1 -Driver 2: A2, B2, C2 -Driver 3: A3, B3, C3	The learning curve problem is eliminated. Each driver only sees each scenario once.	The results are incomplete- cannot decipher if perspective 2 is more useful than perspective 1 due to more information, or because driver's skills are better.
Block Counter Balance	Information in each scenario is slightly different: (ie, ball rolls from right, pedestrian crosses on left…) and grouped into blocks so that each driver sees every scenario in different orders, but the blocks remain the same.	Block 1: A1, B1, C1 Block 2: B2, C2, A2 Block 3: C3, B3, A3 -Driver 1 sees: Block 1, Block 2, Block 3 -Driver 2 sees: Block 2, Block 3, Block 1 -Driver 3 sees: Block 3, Block 1, Block 2.	-Every subject tests every scenario- so the skills of driver do not need to be considered from scenario A to B. - Situations will be slightly different, so the learning curve will be smaller. - Have enough test subjects (ie, 6, 9, 12…) so that each block in each order is given in that order 2x to assess the learning curve. (ex: both drivers 2 and 6 see block 2 first)	- Video clips must be continuous for each block: difficult to do given the shortness of resources. -Each scenario needs to be repeated differently enough so that the driver does not expect the main event. - More complex to analyze.

All configurations, as shown, have good characteristics and bad characteristics. After consulting with two MIT Human Factor's Professors, a decision was made to use a scaled-down Block Counter Balance experiment. The scaled-down version consists of each driver testing each of the perspectives, and each of the scenarios. For example, Test Driver 1 tests A1, B2, and C3. This reduction in the number of tests can be made by assuming that each of the scenarios is similar enough that the response to them is comparable. The exact details of the Driving Simulator test design can be found in Section 5.3 Human Experiment Protocol.

4.4 Measurements

4.4.1 Phase I: Camera and Mount Measurements

As stated, Phase I consists primarily of the construction of the CTS. Only one numerical measurement will be taken during Phase I - the best camera operating height. This will most likely be a subjective evaluation based on the range of visibility at a given distance from an SUV.

4.4.2 Phase II: Traffic Image Recording Measurements

Many numerical measurements will need to be taken during Phase II. Not all measurements have been determined yet, as they are scenario dependent. These measurements will need to be decided on based on the size of the vehicles being used and the environment the recordings will be taken in. These decisions will take place in Week 2 of the Project Experiment. (See Section 7.1.) The measurements that need to be taken include the speed of the CC and SUV in each scenario; the distance between vehicles whiles traveling and while stopped; and the times at which the obstruction enters the roadway or field of view of CC driver (if necessary). These measurements are described in more detail in Section 5.2.

4.4.3 *Phase III: Driving Simulator Evaluation Measurements*

Before evaluation in the simulator can be done, the “time zero” of each scenario will need to be determined from video recording playback. “Time zero” refers to the time in each scenario when the obstruction first enters the view of the driver from the driver’s perspective. All of the quantitative measurements taken in this phase will be compared to “time zero.” One quantitative measurement will need to be taken for ever scenario/perspective combination driven by the driver – the response time of the driver to an obstruction on the road. Essentially, the drivers will be instructed to step on the brake as soon as they see something dangerous, potentially dangerous, or that may cause an accident. The Driving Simulator is set-up to record the braking times in relation to the video feed at a set .2 second interval, and can be analyzed using Matlab.

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In addition to the objective measurements described above, several questions will be asked of each driver to obtain their subjective opinion of the images produced by the cameras and their levels of distraction and comfort. A possible questionnaire is shown in Appendix A – Driver Test Survey. The survey will most likely be given to the test drivers after completing all of the scenarios and perspectives. The results from each survey will be compared to the driver’s response data and, and to the surveys of other test drivers.

4.5 Error Discussion

4.5.1 *Phase I: Camera and Mount System Errors*

In Phase I, the only possible errors may be biased errors due to the incorrect height or placement of the CTS.

4.5.2 *Phase II: Traffic Image Recording Errors*

There are several possible errors in Phase II. Most of the error is biased and concerns modeling real world driving with simple situations. The image recording is taking place in a tightly controlled environment, not very similar to daily driving. This negligence may be overlooking key details such as effects on the external camera from passing cars and weather effects. The images recorded from the perspective of the driver are also biased. The driver will not be taking these images; a second person will be recording the images from inside the car, near the driver.

An important random error issue will be timing. Since the scenarios should be as realistic as possible, timing is very important; however it is very difficult to coordinate the timing of the external camera with the internal camera. Synchronization equipment, like a camera coupler, will be used to try to avoid this error.

4.5.3 *Phase III: Driving Simulator Evaluation Errors*

Many errors are possible in Phase III. Several of these errors are biased, including the assumption mentioned previously that the scenarios being tested are similar enough to be comparable. There may also be a learning curve when viewing the similar situations. Also, apparent in any simulated experience is the biased error of trying to model real world, real time occurrences in a simulator. Some of these simulation errors include the braking time to a simulated environment, as compared to in the real world, the use of images on a screen (as opposed to in 3-D on the actual roadway), and the fact that the driver is not actually controlling the vehicle in the simulator. In addition, being unfamiliar with the Driving Simulator, or a driver who processes the images more slowly, can cause a delay in braking time.

A big part of the evaluation of the images is based on the biased opinions of the driver in the Driver Test Survey (See Appendix A.). These opinions are entirely subjective and may not accurately reflect what the driver was feeling at a given time. They may not even correlate to the objective results obtained by the driver's response times. Thus, these opinions need to be analyzed and compared with the recorded data carefully.

In addition to the biased errors, several probable random errors can be noted at this time. First, and most critical to the experiment, is the time synchronization of the widescreen images and the internal display images. All possible measures will be taken to ensure that the time synchronization is as exact as possible, or it will be quantified and accounted for in the response time analysis. (See sections 5.3 and 6.2) Another possible random error may be the correlation between the braking response time of the driver and its synchronization with the images being shown on the displays.

5.0 Experiment Design

5.1 Design and Construction of Apparatus-Phase I

For this experiment, only one apparatus needs to be constructed. This is Phase I of the experiment. The apparatus being constructed is the CTS. As mentioned, the camera tripod will be a readily available standard camera tripod. It will be affixed to the car using large suction cups, like those shown in Figure 8.

Figure 8 – Suction Cups

The small camera being used to record the external images, shown in Figure 9, will be mounted on the tripod with an adaptor designed by the project authors.

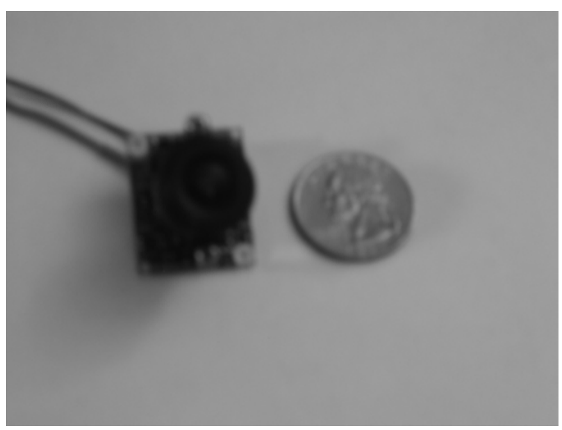

Figure 9 – External Camera

The adaptor, shown in Appendix B – Camera Mount Design, will be made of 60/61 aluminum and will be constructed during Week 1 (See Section 7.2) of the

Project Execution. The camera screws directly into the adaptor and the adaptor screws directly into the tripod. This will provide the necessary stability for the camera while recording.

To complete the system, the camera will be powered by 4 AAA batteries that will be taped to the roof of the CC. A video line will be run along the roof of the car and into the passenger window for recording by the laptop.

5.2 Design and Construction of Test Specimens – Phase II

The test specimens for this experiment are the different driving scenarios for recording in Phase II. As explained in Section 4.3.2, there are 3 scenarios that need to be recorded from two different perspectives. A major design concern is how to synchronize the two different perspectives. As of right now, the best option we have found is to use a camera coupler, available from the Wright Brothers Wind Tunnel at MIT. Both the images from the handheld internal camera, and the external camera, will feed into the coupler, which will be recorded by a VCR. The external camera, in addition to being connected to the coupler, will also be split off and wired into the laptop, where an additional recording will be made. This is because once coupled, the two images are impossible to uncouple. By using the splitting technique, we can be assured that the external images can also be displayed on the laptop in the driving simulator. In addition to the coupler, an USB-video converter is needed for the images to be recorded by the laptop. A schematic of this recording set-up is depicted in Figure 10 – Phase II Recording Schematic.

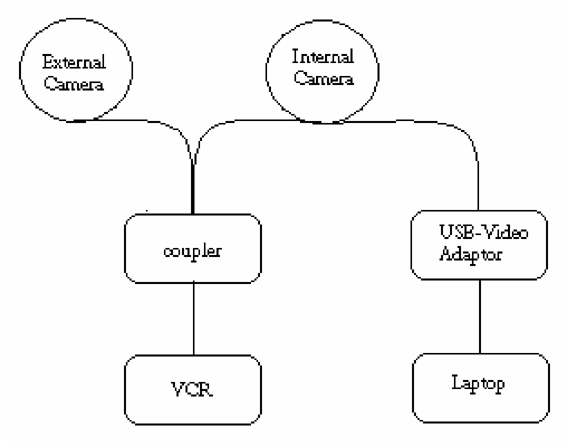

Figure 10 – Phase II Recording Schematic

In addition to the recording set-up, the individual scenarios need to be designed. As mentioned, the exact parameters will not be decided on until the driving environment and exact vehicles are chosen in Week 2. (See Section 7.2.) However the parameters that will need to be measured are known. In Scenario A, shown in Figure 11, there is the distance between the CC and SUV, Ssuv, the distance between the SUV and pedestrian when the SUV turns, Sobject, and the speed of the CC, Vcc.

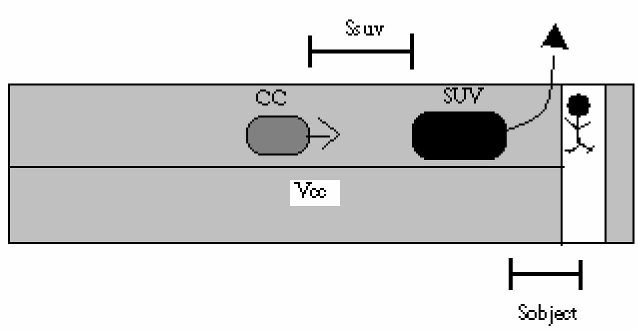

Figure 11 – Scenario A Measurements

In Scenario 2, there are also three measurements that will need to be taken. As shown in Figure 12, the necessary measurements are the speed of the SUV, Vsuv, the distance from the object when the SUV turns, Ssuv, and the time the CC waits at the stop sign before moving again, Twait.

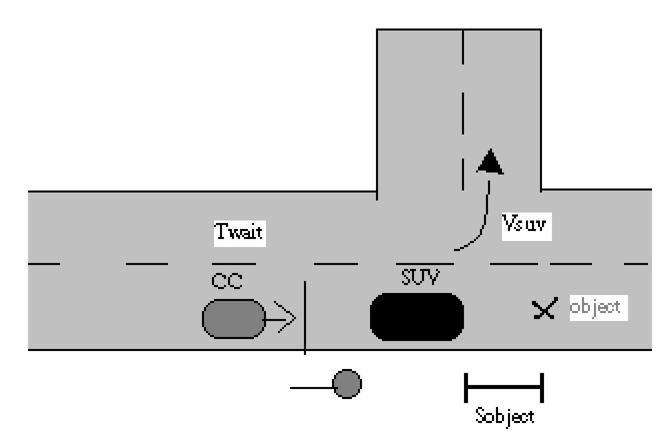

Figure 12 – Scenario B Measurements

Last, for Scenario C, another 3 measurements need to be taken. Needed are the CC's distance from the crosswalk when the pedestrian begins to walk, Scrosswalk; the distance from the other side of the road the pedestrian stops, Sstop; and the speed of the CC, Vcc. These measurements are depicted in Figure 13.

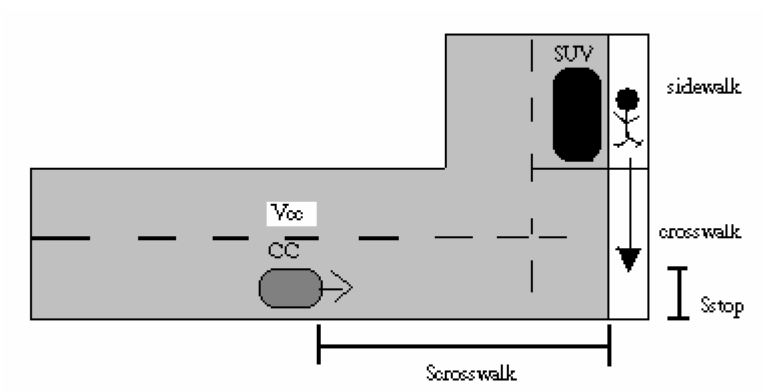

Figure 13 – Scenario C Measurements

5.3 Design of Human Protocol – Phase III

5.3.1 Human Factors Experiment Method Selection

The method for Human Subject testing will be a scaled-down Block Counter Balance test. In studying the positive and negative effects in Table 1, it is evident that the Block Counter Balance method offered the best way to deal with driver skill differences and the learning curve issue. However, it required several combinations of scenarios and was difficult to record and analyze. By making the assumption that every scenario is similar enough to warrant a similar response, but different enough that the driver does not expect what will happen, we can greatly reduce the number of perspective/scenario combinations that need to be tested. This will thus require less simulator time and less analysis.

Although this scaled-down method is the best that was found, it still has a few negative features. Some of these features are first, that the situations may indeed not be similar enough for comparison; second, that the scenarios may be too alike that the drivers anticipate what is going to happen; and third, that the driver learning curve and difference in abilities may still be a factor.

5.3.2 Set-Up and Pre-Testing in the Simulator

The Age Lab Driving Simulator is already equipped to display images on the widescreen projector, and record the braking time of the driver in relation to the simulation that is running. (See Figure 3.) In addition to getting familiar with the Age Lab equipment, a way to set up and synchronize the internal laptop display with the Age Lab simulator projector prior to testing needs to be found. Other tasks still need to be completed, such as obtaining consent to use Human test subjects from the Committee for Using Humans as Experimental Subjects, and determining how the recorded images can be played in conjunction with the Driving Simulator Program. These tasks will be completed during Week 3 and Week 6, respectively. (See section 7.2.)

Once all of the Driving Simulator details are determined and the scenarios are recorded and ready for evaluation, pre-testing is necessary. In order to ensure that the human factors' testing goes smoothly with the actual test subjects, unofficial rehearsals will be done. This pre-testing will include running the actual simulator tests and doing some preliminary analysis on the data to ensure that the expected results for the project are obtained. (See Section 6.) Pre-testing will take place during the first half of Week 7. (See Section 7.2.)

5.3.3 Age Lab Evaluation Tests

The experiments will be carried out according to Table 2 – Driving Simulator Test Scenarios. As a minimum, 9 test drivers are needed to ensure that the same number of test drives see a scenario and perspective first, as they do last. If time permits, a second cycle of the evaluation will be completed with 9 different subjects, and the results will be averaged.

Table 2 – Driving Simulator Test Scenarios

Test Subject	Test 1	Test 2	Test 3
1	A1	B2	C3
2	A2	B3	C1
3	A3	B1	C2
4	B1	C2	A3
5	B2	C3	A1
6	B3	C1	A2
7	C1	A2	B3
8	C2	A3	B1
9	C3	A1	B2

Each test driver will be told to brake when s/he sees an obstruction or potentially dangerous situation. In addition, it is vital to the experiment that the driver behaves like s/he is actually driving. Even though the drivers are not actually controlling the vehicle, they must still keep their eyes on the road, stay alert, check their mirrors, etc. They will be instructed to do so, or their responses will be thrown out.

After the test driver is seated in the driver's seat, has made the necessary height and mirror adjustments, and received the test instructions, the first test perspective/scenario combination will run. The simulator will begin to record any movement the driver makes. At the end of the first combination, the simulator will be reset for the second combination. The driver will get about a one minute break. The second combination will run just like the first and the same procedure for the changing of the scenario/perspective combination will occur. Finally, the third combination will run.

After completing all three combinations, the driver will be asked to step out of the vehicle and answer a survey about their comfort and level of distraction. A possible survey is shown in Appendix A.

5.4 Measurement Systems

The main measurement system being used in this project is the Driving Lab Simulator. The Simulator is equipped to record the movements of the driver, and the time that the movements occurred. Some examples of "movement" include turning the steering wheel or pressing on the accelerator or the brake pedal. For this project, when the test subject steps on the brake pedal is the time of interest. At the end of a simulation, the data obtained by the Simulator, is converted to Matlab matrix format by the simulator software for analysis.

In addition to the Simulator system, we will need to use a few other measurement systems. These include the vehicles' speedometers, a stopwatch, and a tape measurer to make the necessary measurements for recording the scenarios. (See Section 5.2.)

5.5 Equipment Decision

The decision was made to use standard, readily available camera equipment from MIT, rather than purchase newer technology. Although having the newer technology would be nicer and easier to use, it is not necessary to use anything better than the less expensive equipment available.

Furthermore, the decision was made to machine a new camera mount because the old mount did not adapt properly to a standard camera tripod. In addition, it was decided to use battery power for the camera, rather than the CC's car battery due to a difference in the amount of current needed for the camera.

A video-USB adaptor for the laptop has been ordered to change the images from the external camera into a format the computer can use. This will facilitate play back in Phase III of the project. The external camera images could have been recorded with a VCR, but it would be much more difficult to display those images in the driving lab using a small television, or to convert the VHS images to a laptop computer readable format later.

6.0 Data Analysis

6.1 Methods for Data Reduction

6.1.1 Primary Analysis

Phase III of this project yields the data that will be analyzed for testing the project hypothesis. This analysis will consist of comparing the mean driver response times for the three different perspectives. The method intended for data analysis will be follow a Constant System Analysis. ± For each of the different perspectives, a plot will be made of the response time for each driver. With that information, the mean response times and the standard deviation of the response times for each perspective will be calculated. Since the assumption that each of the trials is independent of any other trial can be made, the distribution of the responses will be Gaussian.

In addition to the overall analysis for each perspective, each driver's individual responses will be analyzed by plotting their individual response times in each perspective/scenario combination. In comparing each driver's performance, a comparison of every driver's skills can be made and a learning curve, if it exists, can be approximated and figured into the results.

Some data points may need to be excluded if the drivers do not behave like they are really driving. During each simulator test, the drivers will be monitored to ensure that they keep their eyes on the road ahead, stay alert, and check their mirrors. If they do not, this will be noted and their data may not count as part of the overall analysis.

Last, a study of the driver's Surveys will be made. The Surveys themselves will be analyzed and compared to find trends. Finally, a comparison of the survey

± Constant System Analysis method is outlined by Professor Deyst in a 16.621 lecture given on March 18, 2003 entitled "Data Reduction."

with each driver's individual response data will be done to see if there are any interesting correlations.

6.1.2 *Expected Results and Correlation to Hypothesis*

If testing and evaluation goes as planned, the overall data this project hopes to obtain will be similar to that in Figure 14 – Expected Average Results.

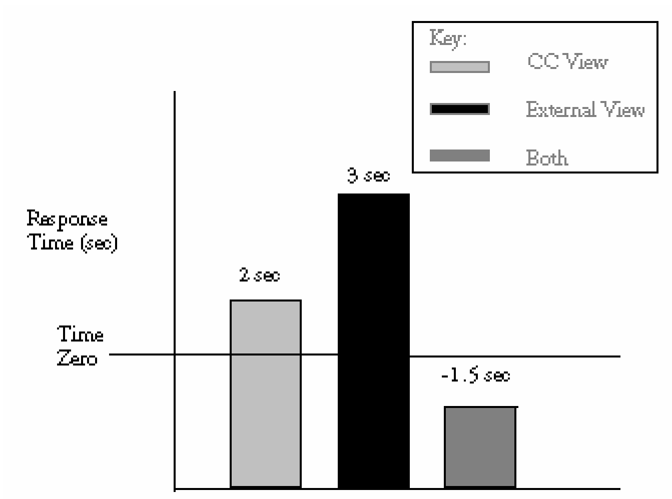

Figure 14 – Expected Average Results

It is expected that the CC/external camera view will allow for a decrease in response time from the Normal CC perspective. In addition, since the images taken from the external camera will be less focused and not what a driver is used to seeing, an increase in driver response time is expected for that perspective.

With these results, a conclusion that the combined perspective is xx% better than the normal CC view is planned to be made. If the data does not turn out like the expected results, then similar conclusions based on the type of data obtained is planned to be made. For example, the Combined Perspective was actually xx% worse than the CC view, disproving the project hypothesis.

In addition, if the data turns out as expected, a conclusion about how reliably this external camera system is in decreasing the driver's reaction time can be made based on the number of tests,. If each driver's test result can be considered as a binomial response, than the results can be interpreted as either the external camera reduced the driver's reaction time or it did not. Using this principle, the number of tests conducted, and the method outlined in Appendix C – Reliability Engineering, a nomograph can be used to determine the reliability of the external system, and the confidence level in that reliability.

6.2 Error Analysis

A very large part of the evaluation of the data will be error analysis. As detailed in Section 4.5.3, there are several possible errors in Phase III. In addition to including an approximation of the learning curve mentioned in Section 6.1.1, there are a few other possible errors that may need to be included in the data analysis. These errors include the biased error of synchronization time, the random delay between a driver braking and the simulator registering the movement, and the random error of equipment start-up in relation to the start of the simulation (delay between pressing play and the projector playing). These errors can be approximated so that they may be included in the analysis of the response times. Since it can likely be assumed that all of these errors are independent and identically distributed random variables, their sum can be approximated as a Gaussian distribution using the Central Limit Theorem. Thus, the mean and variance of the error function can be found and added to the means and variances of the perspective analysis.

7.0 Project Planning

7.1 Project Budget

The Project budget is outlined in Table 3 – Expected Budget. All needed supplies are included in the budget, even if they are expected to cost nothing. The total budget expenses are approximated, conservatively, at $165.

Table 3 – Expected Budget

Item	**Expected Cost**	**Have/Need/Ordered**
Camera	$0	Have
Tripod	$20	Ordered
Scenario props (cardboard, cones, paint, tape)	$50	Need
USB-Video Adaptor	$60	Ordered
Battery pack/Batteries	$10	Have/May need more
Suction Cups	$5	Have
Driving Simulator	$0	Have permission to use
Recording Equipment (including AC/DC power converter, digital camera, laptop)	$0	Have some/ may need some
Wire Connectors	$5	Have
Test Subject Incentives (pizza?)	$15	Need
TOTAL	**$165.00**	

7.2 Project Schedule

The schedule for project execution is given in Table 4 – Project Execution Schedule. Three weeks are allotted for completing Phase I and making the necessary arrangements for smooth completion of Phases II and III. Two weeks are allotted for Phase II recording, even though only one week is likely to be needed. There is one week for driving Simulator preparation, and three weeks scheduled for Simulator Testing. A one week cushion time is given after the Simulator testing in case more time is needed in any of the other phases. Last, there are at least 2 weeks allotted for data reduction and error analysis. The project will be completed when final reports are submitted on December 9, 2003.

Table 4 – Project Execution Schedule

Week Number	Dates	Task	Milestone
1	September 3-9	Machine Parts/ Assemble Phase I	Team Meeting, 9th
2	10-16	Scenario Preparations (props/timing)	Team Meetings, 11th
3	17-23	Driving Simulator Preparation (Synchronization)	Notebook check, 23rd
4	24-30	Scenario Recording Week 1	Oral Progress Reports, 30th
5	October 1-7	Scenario Recording Week 2	Oral Progress Reports, 2nd
6	8-14	Simulator Final Preparations	
7	15-21	Simulator Testing Week 1	-Notebook Check, 16th -Team Meeting, 21st
8	22-28	Simulator Testing Week 2	Team Meeting, 23rd
9	29-4	Simulator Testing Week 3	*Finished Data Collection*
10	November 5-11	Cushion Time/Begin Analysis	
11	12-18	Analysis and Data Reduction -1	-Last Day to collect data, 13th -Notebook check, 13th -Outline Due for Report, 18th
12	19-25	Analysis and Data Reduction -2/ Prepare Final Presentation	Final Presentation, 25th
13	26-2	Prepare Final Report	
14	December 3-9	Prepare Final Report	Final Report Due, 9th

8.0 Conclusion

This project is a feasibility study of an immediate solution to the CC-LTV incompatibility issues that have become very important in evaluating the safety of CC drivers on the road today. Due to the high fatality rates of CC drivers in collisions with an SUV, the motivation for this project is very strong. The proposed solution, upon successful completion of this project, can provide an effective means to bypass the problem of blocked vision by an SUV and reduce the response time of a driver, thus reducing the likelihood of an accident. In addition, since driver safety is always a current issue, the results of this project may be very useful in assessing distraction to IVT.

9.0 References

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Appendix A – Test Driver Survey

Driver #___________ Test Configuration Driven:____________________

1. Rank your ease of driving when driving with Perspective 1:

   1 2 3 4 5

   Perspective 2:

   1 2 3 4 5

   Perspective 3:

   1 2 3 4 5

(1 = nervous, uncomfortable, 5= at ease)

2. Did you feel distracted by the addition of the internal camera?

   Y or N

3. Did you feel safer when viewing the road

   from Perspective 2? Y or N

   from Perspective 3? Y or N

4. Did you feel like you saw the obstructions/oncoming traffic earlier with

   Perspective 2? Y or N

   Perspective 3? Y or N

5. Did you feel like you were traveling faster in: (circle all that apply)

   Perspective 1 Perspective 2 Perspective 3 All same

6. How much are you willing to pay for the camera system that provided the internal images? _________

7. Did you feel that these external camera images are useful for avoiding collisions?

   Y or N

Appendix B – Camera Adaptor Design

Appendix C – Reliability Engineering