Team 7 – Rear View

Final Report

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Executive Summary

Semi trucks make up only 4% of vehicles on the road, but they consume roughly 20% of the fuel used in the US (Union of Concerned Scientists, 2010). In 2008, nearly 2,250,000 heavy duty trucks traveled over 140 billion miles in the United States. In 2008 there were also 380,000 reported accidents involving semi trucks, resulting in millions in damages and lawsuits. These heavy duty trucks, also known as semi trucks, traveled over 140 billion miles and consumed over 26 billion gallons of fuel.

The project seeks to implement rear view camera technology and its possible applications for the heavy-duty trucking industry with respect to fuel savings and increased safety. The project studied the effects of replacing the existing conventional convex blind spot safety mirrors on semi trucks, with a camera and monitor system. In an attempt to increase safety and fuel economy, a system for semi trucks was developed. This system will reduce the drag force produced by semi-truck blind spot mirrors, while increasing the visibility and reducing the blind spots size. A prototype was also developed and tested with Equity Transportation Inc. which received positive feedback from the driver who tested the system.

If implemented the system could reduce fuel consumption in semi trucks by up to 0.48%. Although this may not seem to be a significant increase in fuel efficiency, considering the number of trucks on the roads in the US and the amount of fuel these trucks consume annually, this 0.48% increase in fuel efficiency could lead to a savings of millions of gallons of diesel fuel annually. In addition to the increase in fuel efficiency, by providing a wider field of vision for truck drivers and reducing the blind spots produced by conventional mirrors, the system increases the safety of not only the drivers of semi trucks but also everyone else on the roads.
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1. Introduction

1.1. Context and Motivation
As the push for greater fuel economy and fewer CO\textsubscript{2} emissions continues to expand at a remarkable rate we are beginning to see great improvements in the area of small vehicle efficiencies. But how much are we gaining as a country when we are focusing so intently on increasing the efficiency of our most efficient means of transportation? There is another area of transportation that must be considered when looking to decrease dependence on foreign oil. The heavy duty trucking industry is an integral part of our nation’s economy and is also one of the least efficient means of product transportation in use today. Semi trucks today make up only 4% of vehicles on the road, but they consume roughly 20% of the fuel used in the US (Union of Concerned Scientists, 2010). In 2008, nearly 2,250,000 heavy duty trucks traveled over 140 billion miles in the United States. In 2008 there were also 380,000 reported accidents involving semi trucks, resulting in millions in damages and lawsuits. These heavy duty trucks, also known as semi trucks, traveled the 140 billion miles and consumed over 26 billion gallons of fuel. As the USDOT and EPA push for greater fuel economy in the transportation sector, great increases in efficiency will need to be made in the trucking industry. This report is a look at one solution that could help propel fuel efficiency in heavy-duty trucks toward the goal of 10 mpg by the year 2017, compared to the current estimated 6.5 mpg today.

The purpose of this project is to analyze new rear view camera technology and its possible applications for the heavy-duty trucking industry with respect to fuel savings and increased safety. Rear view camera monitoring systems are starting to become standard safety features on most new luxury vehicles. These same rear view camera monitoring systems can be applied to the trucking industry and provide a means of fuel savings as well as an increase in driver safety. The main goal of our project is to study the effects of replacing existing conventional convex blind spot safety mirrors on semi trucks, with a camera and monitor system. In an attempt to increase safety and fuel economy, a system for semi trucks was developed. This system will reduce the drag force produced by semi-truck blind spot mirrors, while increasing the visibility and reducing the size of blind spots created by standard mirrors.

1.2. Team Members
Team 7, Rear View, consists of 3 members in the mechanical engineering concentration at Calvin College. The members are Jason Busscher, Yakubu Gang, and Jaesung Lee. The team members have diverse backgrounds but share a common interest in engineering.
1.2.1. Jason Busscher
   I was born and raised in Holland, MI and hope to remain in the area after graduation in May of 2011. I have been interested in the auto industry since childhood, so working on this project is particularly interesting for me. I enjoy building things and working with my hands in any number of project situations. In my spare time I enjoy watching movies and spending time with my friends and family.

1.2.2. Yakubu Gang
   I transferred from the University of Jos in Nigeria where I was a second year computer science major. When I started my engineering program, I was leaning towards the electrical concentration but after a few classes I decided to apply for the mechanical program instead. I am also involved in some extracurricular activities. I am currently an active member of Engineers Without Borders (EWB), National Association of Black Engineers (NSBE) and the president of the International Student Association Committee. In my free time I like to play basketball and soccer. Along with the sports, I also make sure I am in touch with my family and friends at home.

1.2.3. Jaesung Lee
   I was born in South Korea and came to the US when I was 3 years old. I returned to Korea when I was 12 years old. After high school and 2 years in the ROK Army I came to Calvin to study engineering. I enjoy sports and music in my free time and plan to return to Korea after graduation.

1.3. Sponsors

1.3.1. Equity Transport Inc.
   “Equity Transportation Inc. is a Midwest trucking company engaged as a contract carrier, for hire, doing business in the contiguous 48 states with most of our freight moving east of the Mississippi River. Equity Transportation has been fortunate to attain solid and sustained growth in our dealings with our freight clientele, who for the most part, are recession proof. The clients enable us to get our associate drivers to their home terminals on a regular and consistent basis.
Equity Transportation Inc., a Midwest trucking company based out of Grand Rapids, MI is an industry leader in the transportation, warehousing and logistics industry combining the resources of over 250 professionals, decades of experience and industry leadership, and the financial stability of a privately held (family) business to create competitive advantage for our customers.” Website: www.equityinc.com

1.3.2. Gentex Corporation

“Gentex is a global, high technology electronics company that is managed by engineers and others who understand the freedom and discipline that’s required to run an entrepreneurial company. We are a unique, profitable company that is vertically integrated in highly automated electronics, CMOS camera development and manufacturing, vacuum coatings, and glass bending and fabrication. We specialize in a broad spectrum of technologies and processes to deliver high quality products to the automotive, aerospace and fire protection industries.” Website: www.gentex.com
2. **Project Definition**

2.1. **Objectives**

The 3 main objectives of this project are: increase fuel economy of a semi-truck by 2%, increase driver safety, and provide a product that is economically advantageous for trucking companies by providing an acceptable payback period.

2.1.1. **Increase Fuel Economy**

By replacing blind spot mirrors with a system of cameras and monitors, it will be possible to eliminate, or greatly decrease, the drag caused by these mirrors. A system of cameras and monitors would help to reduce the drag applied to produce a percentage in fuel savings. This is accounted for by the reduction in energy used up by the engine and less fuel burned. With a reduction in the wind resistance, there will also be a reduction in fuel usage.

2.1.2. **Increase Safety**

A system of cameras and monitors can be used to increase the driver’s angle of vision. The placement of conventional mirrors is limited to the driver’s line of sight. However, cameras are not restricted to this limitation and thus, can be placed in the optimal locations that maximized the driver’s field of vision. In talking with Equity and looking at many different trucks on the road, it was discovered that the blind spot mirrors are neither required nor uniformly located. Measuring the increase in safety will then be defined on a general basis determined by the typical viewing angle and blind spot size.

2.1.3. **Payback Period**

Using the cost savings in fuel and the reduction in losses due to accidents, potential customers will be able to pay-off the cost of the system. The goal for this project is to design a system such that this payback period is under 5 years. This payback will take into account the cost of all of the parts for the system and the cost to install it. This will represent the direct cost to the consumer for complete installation of the new system.

2.2. **Design Norms**

2.2.1. **Transparency**

As Christian engineers, we are called to be honest and care for the need of others. We want our product to reflect our care for people especially truck drivers by producing a camera and monitoring system that is reliable for the long turn. It should reflect our work as engineers to produce a product that our customers are very pleased with. We desire to have open communication with the drivers about our design and to assist them in adjusting to the new system. We will leave no stone unturned in order to produce a reliable camera and monitoring system to replace the existing blind spot mirrors. Our product must also be easily understandable, very consistent and predictable. The camera and monitoring system must be easy to understand for any driver. It should not be complicated and require any particular skill to view the mirrors. The monitoring system must also be applied in a comfortable position in order to make the driver view the system with the most ease possible. We have to be responsible through our placement of the monitoring system. Our product must also be safer for the drivers especially during their long drives on the highway at the late hours of the night.

2.2.2. **Stewardship**

As stewards of the earth, we desire our product to reflect our position as Christian engineers. As engineers, we have certain codes of ethics that we choose to abide by. From these codes of ethics, we have to produce a product that is good for our environment. Scripture gives some direction in
Numbers 35:33-34 with the following words, “You shall not pollute the land in which you live.... You shall not defile the land in which you live, in which I also dwell; for I the LORD dwell among the Israelites.” Also in Leviticus 18:16 and 18 the Bible tells us this, “You must keep my decrees and my laws.... And if you defile the land, it will vomit you out as it vomited out the nations that were before you.”

Our team plans to be true messenger of God by making a product that is environmentally friendly. Our environment is being destroyed by the level of CO₂ emission coming from our automobiles and as Christian engineers we desire to help our environment. Our product if successful would greatly reduce the amount of CO₂ emission to our environment. We hope to reduce the amount of fuel consumed on a semi-truck by 2%. The percentage reduction would result in a similar percentage of reduction in CO₂ emissions to the environment. Our product would not only be better for our environment but it would also preserve some of our natural resources for future generations. The American government is beginning to push really hard on fuel reduction in trucks. Hopefully our product will be a beginning of that change that is needed. At the end of the day, we want our product to reflect our stewardship towards our environment.

2.2.3. Caring

Our product should also show our care for the drivers. As engineers, we should not only focus on the profitable part but also the care and attention to detail required to produce a functioning product. As a team, we would also make sure to take care of the equipment that we use. Through the engineering department, we are going to be in contact with a lot of equipment both from Calvin and company sponsors. We have to make sure that we take good care of the tools that we use. We have to follow the examples of our predecessors who cared for the equipment and allowed us to use them to produce our system.

Most importantly, we also have to care for the opinion of the drivers. Our team plans to talk to truck drivers to understand how they view the mirrors and the challenges they face. Our team would then try to make our product according to the needs of the drivers. We plan to care for the opinion of the drivers before we produce our system and also after we have installed the final version of our camera and monitoring system. At the end of the day, the drivers are our biggest consumers. We must care for their responses.
3. Research

3.1. Aerodynamics
   Aerodynamics is the study of the motion of fluids moving past a body. Aerodynamics in trucks and other high sided vehicles is of significant interest when it comes to reducing accidents due to wind loading and also in improving the fuel economy. We will study the drag implications on the truck side mirrors.

   In recent years, millions of semi and combination trucks have traveled over 100,000 miles per year. These trucks operate at an average of 6.2 mpg and consume about 36.7 billion gallons of fuel annually. Due to recent shortages of cruel oil, and our overdependence of oil imports, the government has imposed several regulations on fuel usage for semi trucks. The regulation states that all trucking companies must reduce their fuel usage by 18% before 2018. These regulations have caused truck producing companies to reconsider and redesign many of their products and processes to begin to prepare for the new millage requirements.

   Until recently, the aerodynamics of large transport trucks has been ignored. In order to reduce the total fuel consumption on semi trucks, the effect of the drag on the vehicle needs to be addressed and better solutions must be developed. Reductions in fuel usage are possible both by aerodynamic improvements to the underbody, and by attention to the various contributions of parts from the wheels, wheel wells, drip-rails, window recesses, and external mirrors. Other features of the trailers pulled by semi trucks must also be considered and addressed.

   Our project focuses on the effect of replacing the external side mirrors, blind spot mirrors, with a more aerodynamic camera and monitor system. Based on the surface area of an extruding mirror compared to a small camera, the drag force on the two should be significantly different. With a reduction in drag force of our new system in place of the monitor, the total fuel usage of the truck could be reduced by roughly 2%.

   The reduction in the drag produced by the trucks is due to a reduction in the coefficient of drag ($C_d$). In an effort to increase fuel economy, and support the newly issued government regulations, more aerodynamic side view mirrors have also begun to be developed. Reshaping the mirrors with a more aerodynamic shape can improve the fuel economy of the trucks while still maintaining the visibility.

3.2. Regulations
   The US Department of Transportation –Federal Motor Carrier Safety Administration has set regulations for rear view mirrors on trucks. In compliance with the regulations, the design of camera/monitor system will focus on replacing the two front blind spot mirrors and the two side blind spots mirrors. All relevant regulations are included in the appendix.

   “Every bus, truck, and truck tractor shall be equipped with two rear-vision mirrors, one at each side, firmly attached to the outside of the motor vehicle, and so located as to reflect to the driver a view of the highway to the rear, along both sides of the vehicle.” (US DOT – Federal Motor Carrier Safety Administration Regulations)

3.3. Intellectual Properties (Patents)
   James Secor currently has a patent that describes a product that is similar to ours. Secor’s idea was a rear viewing arrangement provided for a motor vehicle to permit the operator to view traffic conditions to rearward from left and right sides of the vehicle, as well as directly behind the vehicle. The only discrepancy was the fact that his design was not based on saving fuel but to only improve safety. There are also several other patents out with similar technology that have built a viewing display to replace the extruding side view mirror and references can be viewed in the Appendix D.
Due to some government regulations, most of these patents have not brought into production thus far. There have been numerous inventions for better, more aerodynamic, viewing systems to replace the extruding mirrors. Due to the rigorous regulations, most of these inventions are not in existence. In fact, the only backup viewing system implemented currently is in automobiles. With the recent push by the government to reduce fuel usage, there is no better time to research, and implement, more aerodynamic viewing systems than now.

These intellectual properties are protected by patents, trademarks, and copyrights to keep the production in the sole ownership of the inventor of the production avoiding any lawsuits or scams.

3.4. Human Factors

For our project to be successful, we must determine how to account for certain human factors that exist in a truck driver’s environment. The brain reacts to certain images that it sees and a response is put forward. Researching these responses and the factors that humans bring into the design process is important for our project because the effectiveness for the user is the greatest concern. A question that was posed with respect to the design of a rear view camera monitoring systems like this one is, “Why hasn’t it been done before?” After considering this question, one area of possibility and possible solution to the posed question was the way that a system would affect the drivers. In order to better understand the human interaction features of this project research was conducted in several human reaction and behavioral response areas. The following sections are summaries of the research conducted in the specific areas, like reaction time.

According to Adler’s *Physiology of the Eye*, the term accommodation is the dynamic change in the dioptric power of the eye following point of focus of the eye, to be changed from distant to near objects. When the eye accommodates an image, there is an increase in the lens thickness, increase in the anterior surface curvature and anterior movement of the anterior lens surface. When light enters the eye, it is focused on the retina. It’s that focus on the retina that allows all semi truck drivers to be able to see clearly.

Adler also mentions the depth of field of the eye. The pupil of the drivers helps him to have a larger or smaller depth of field. With a large pupil there is a small depth of field, and with a small pupil, a person has a larger depth of field. Therefore, a bright image produces a decrease in pupil size and an increase in the depth of field. As a target is brought closer, the driver must decide at what point the object is no longer in acceptable focus. (Adler, 40-70)

3.4.1. Reaction Time (Focal Length Focus)

Each individual’s focal length is different. In many cases, the speed with which a person can respond, i.e. “reaction time,” can directly affect the number of accidents and the liability for that driver. The faster a driver’s reaction time, the more likely he is to avoid an accident. In fact, reaction time is a complicated behavior and is affected by a large number of variables. All drivers respond to things that they hear, see, and feel as the drive their vehicles. There are three main components that affect a driver’s reaction time according to Marc Green in *Driver Reaction Time*.

3.4.1.1. Mental Processing Time

This is the time that it takes a responder to perceive a signal, and decide on a response. For instance, if a pedestrian is walking across the street, it is the time it takes for the driver to detect the person before he or she is able to take action. It takes time for drivers to see a visual and to react to that visual. With our camera and monitor in place of a mirror, the mental processing time is subject to change. The main issue with the new system is the mental capability of the brain to detect a moving body on the monitor and to then react in time before the driver reaches the person. With the implementation of any new system, it takes time for the eyes to adjust or get used to looking at a
monitor instead of a screen. Although the focal length of the eye might change as it focuses on images from the mirror, the eye is capable of adjusting its focus to a monitor when the driver eyes have become accustomed to this new setup. (Driver reaction time)

3.4.1.2. Movement Time
This is the time it takes a driver to notice a moving object and the time it takes for him or her to react. The process of the driver removing his leg from the gas pedal and applying his brakes is the movement time. This factor depends on the reaction of the driver to the circumstance. Some drivers have a faster reaction time than other due to their reflex action. (Driver reaction time)

3.4.1.3. Mechanical Device Response Time
Mechanical devices have begun to take most of our mental attention when we drive these days. Devices like GPS, stereos, phones are all being controlled and adjusted as we drive. With these distractions, the reaction time becomes slower for drivers on the road. Implementing a camera instead of a mirror will improve the safety for truck drivers, as well as for all other drivers on the road. By reducing the distance that the image is from the driver, their reaction time should also improve and therefore reduce the number of accidents per year. With the camera and monitor, drivers also get a larger viewing angle, which improves their focal length focus. Once truck drivers get used to the newer system instead of conventional blind spot mirrors, their reaction time will also improve, and that means that the trucks will be safer on the roads. (Driver reaction time)
4. Testing

4.1. Camera & Mirror Viewing Angles

In order to ensure that the camera is in fact a suitable option for increasing safety and increasing viewing angle, a measurement of the camera viewing angle was performed. The camera that was used for this application is a Sony rearview camera, model and serial numbers: VCB-G301, 625-0446-000, and 101976. The test conducted to measure the angle was as follows. The camera and conventional mirror we both mounted in a location to represent actual mounting on a truck. The camera and mirror were aimed so the right side of the mirror and monitor were along an edge representing the edge of the semi truck trailer. Due to the convex shape of the mirror and the similar bulging effect of the camera lenses, the angles were measured ten feet perpendicularly away from the mounting location. The perpendicular distance where the angle was measured was chosen at be ten feet because that distance is roughly the width of one lane of traffic. A diagram of the test situation can be seen below.

From this figure you can see the direct comparison between the viewing angles of the camera and the convex mirror. The red lines here represent the rough outline of the viewing angle by the camera, and the blue are the same for the conventional mirror. This comparison is only based on the camera and mirror used for this project. The mirror was purchased from a trucking supply company where the sales person suggested it as a mirror used by many semi truck drivers. The camera was supplied by Gentex and similar to the model used in their camera backing system. Both the camera and mirrors for these applications have different possible specifications and viewing angles.

Once the viewing angles were determined for the camera and the mirror we were able to look at the system as a whole and compare the covered area surrounding a semi-truck. The next two figures are approximate comparisons of viewing angles on the horizontal plane and the vertical plane.
The top image in this figure represents a truck with four blind spot mirrors and two standard side rear view mirrors. The mirror angles are 60° as measured in the viewing angle test and the mirrors were aimed to gain the best viewing angles possible for the driver. The viewing area was also restrained to ten feet from the side of the truck like the test. Since these blind spot mirrors are located in different places on many different trucks and because of driver preference, the area covered is only a rough estimation at what most truck divers actually are able to see when they drive. This estimation is based on information gathered from our Equity Transport contact and where their drivers locate their mirrors.

When first arriving at Equity, there was one interesting difference in the location the blind spot mirrors were mounted on the trucks. Driving down the high way, you often see trucks with these mirrors mounted on the front quarter panel and fender, one foot or so back from the front of the truck. Equity mounts their mirrors much closer to the front of the truck, as seen in Figure 4. This difference is again attributed to driver and owner preference. With the blind spot mirrors located closer to the front of the truck, the driver is able to see around the front of the truck by each of the fenders. This capability is not taken advantage of by many drivers on the roads but we believe that this capability is something that we want to work into the final design for the camera monitoring system.
When comparing the conventional mirror viewing angle to the viewing angle for a possible camera system, it is interesting to note that the majority of the improvement occurred at the front of the semi-truck. In Figure 5, there is a picture of a standard side view mirror on top and a second blind spot mirror mounted below. The top mirror is regulated and must remain for the insured rearward visibility for the driver.

After constructing and testing our camera and monitor system on a truck at equity there was a rather unexpected result. The driver, Roger, really liked the wider viewing angle for backing up. The wider angle camera lenses allowed Roger to see the end of the truck with the truck was completely jack-knifed.

4.2. Drag Force

The amount of drag force on trucks depends on their aerodynamic shape. More aerodynamic trucks consume less fuel overall. Rear view mirrors account 3% to 6% of the total vehicle drag (Cresswell, 29-34). The following equation determines the force that is applied on the mirror at a particular speed. On the fleet of trucks that haul our highways, the amount of mirrors determine the value of the drag force applied on each mirror.
Equation 1: Theoretical Force

\[ F_D = \frac{C_D \cdot A \cdot \rho \cdot V^2}{2} \]

\( F_D \) = Drag force of truck
\( C_D \) = Drag coefficient of the mirror
\( A \) = Frontal area of mirror
\( \rho \) = Density of air at outside temperature
\( V \) = Fluid velocity (or speed of the truck)

4.2.1. Preliminary Testing

A preliminary test was conducted to determine the drag force produced by a blind spot mirror for fuel usage calculations. In order to measure the force produced by a conventional blind spot mirror going down the freeway at 60 miles per hour, several pieces of equipment were required. First, a standard conventional blind spot mirror was required to ensure accuracy of wind displacement and force production. A force gauge was then mounted to the mirror by using brackets and clips. Once the force gauge is connected to the mirror, data can then be gathered by recording the force measured by the gauge with the mirror out the window of a vehicle traveling at various speeds. Force measurements were then taken at several different speeds, allowing for cost savings calculations at several different speeds. Results from the test are shown below.

Table 1: Preliminary Test Force Results

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Drag Force (N)</th>
<th>Drag Force (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>4</td>
<td>0.90</td>
</tr>
<tr>
<td>45</td>
<td>10</td>
<td>2.25</td>
</tr>
<tr>
<td>60</td>
<td>15.5*</td>
<td>3.66*</td>
</tr>
<tr>
<td>67</td>
<td>22</td>
<td>4.95</td>
</tr>
</tbody>
</table>

(* denotes averages)

A graph is shown below that compares the experimental force results, shown in the table above, with the experimental curve obtained from Equation 1. Figure 7 is an image of the mirror and the force gauge used in the test. The inputs and calculations for the theoretical force calculations can be seen in the equation and results pages in Figures 8 and 9.
Figure 6: Preliminary Testing Results

Figure 7: Force Gauge Used for Preliminary Testing
Assumptions:

\[ V_{mph} = 60 \text{ [mph]} \]
\[ hp_{truck} = 200 \text{ [hp]} \]
\[ mpg_{truck} = 10 \text{ [miles/gal]} \]
\[ TravelDistance = 500000 \text{ [miles]} \]
\[ MirrorNumber = 2 \]
\[ CostOfFuel = 3 \text{ [$/gal]} \]

Analysis done over the life of the truck. Assuming TravelDistance is total miles traveled by truck.

Calculations:

\[ V_{fts} = V_{mph} \cdot \frac{1.467 \text{ [ft/s]} \cdot \frac{ft}{s} \cdot \text{mph}}{mph} \]

\[ \text{TotalForce} = 0.0375 \text{ [lbf-ft/s]} \cdot V_{fts} \cdot \text{MirrorNumber} \quad \text{Assumes Linear Force to Velocity Relationship} \]

\[ hp_{Saved} = \frac{\text{TotalForce} \cdot V_{fts}}{550 \text{ [lbfs-hp]}} \]

\[ hp_{NowRequired} = hp_{truck} - hp_{Saved} \]

\[ hp_{Percent} = \frac{hp_{NowRequired}}{hp_{truck}} \]

\[ \text{TotalGallonsUsed} = \frac{\text{TravelDistance}}{mpg_{truck}} \]

\[ \text{FuelSaved} = \text{TotalGallonsUsed} \cdot (1 - hp_{Percent}) \]

\[ \text{MoneySaved} = \text{FuelSaved} \cdot \text{CostOfFuel} \]

---

Figure 8: Inputs and Equations for Theoretical Calculations

\[ \text{Unit Settings: SI C kPa kJ mass deg} \]

<table>
<thead>
<tr>
<th>CostOfFuel</th>
<th>hpNowRequired</th>
<th>hpSaved</th>
<th>MirrorNumber</th>
<th>mpg_{truck}</th>
<th>TotalGallonsUsed</th>
<th>V_{fts}</th>
<th>\text{FuelSaved}</th>
<th>\text{hpPercent}</th>
<th>hp_{truck}</th>
<th>MoneySaved</th>
</tr>
</thead>
</table>

TotalForce = 6.6 [lbf]

TravelDistance = 500000 [miles]

\[ V_{mph} = 60 \text{ [mph]} \]

Figure 9: Results of Theoretical Calculations
4.2.2. Strain Gage Testing

The second stage of aerodynamic testing was to conduct a similar test to that performed in the preliminary testing. The second test required the purchase of strain gauges and a mirror mounting bracket similar to the brackets used by Equity. The strain gauges were mounted to the base of the bracket and then connected to a Wheatstone Quarter bridge – Type 1. A diagram of the bridge can be seen below.

![Wheatstone Quarter Bridge - Type 1](image)

The voltage difference created in the bridge ($V_{CH}$) was measured using a National Instruments DAQ device that was connected to a laptop. The laptop then recorded the voltage difference and converted it into strain. The mirror mounting bracket was mounted to the front of a vehicle using a wood support system and several straps to hold the support in place. The testing setup is pictured in the image below.

![Strain Gauge Testing Apparatus](image)

In order to collect and store the data collected by the strain gauges, a computer was used to process and store the data. A program called SignalExpress from National Instruments was used to convert the voltage into a strain value based on several inputs about the gauges and the initial voltage conditions. The setup used, including the pc, the Wheatstone bridges, and the power source, can be seen in the below image.
Strain measurements were taken at several different speeds, ranging from 10mph to 80mph. This data was then analyzed for statistical anomalies and it was discovered that one of three strain gauges installed wasn’t functioning properly and a second one was started to malfunction around the 75mph test point. The average strain for the different speeds can be seen below in table 2.

<table>
<thead>
<tr>
<th>Velocity (mph)</th>
<th>Average Strain (Mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top</td>
</tr>
<tr>
<td>10</td>
<td>0.00084931</td>
</tr>
<tr>
<td>20</td>
<td>0.00081342</td>
</tr>
<tr>
<td>40</td>
<td>0.00078823</td>
</tr>
<tr>
<td>50</td>
<td>0.00076961</td>
</tr>
<tr>
<td>50</td>
<td>0.00069933</td>
</tr>
<tr>
<td>55</td>
<td>0.00076633</td>
</tr>
<tr>
<td>55</td>
<td>0.00070773</td>
</tr>
<tr>
<td>60</td>
<td>0.00074297</td>
</tr>
<tr>
<td>60</td>
<td>0.00075424</td>
</tr>
<tr>
<td>65</td>
<td>0.00074348</td>
</tr>
<tr>
<td>65</td>
<td>0.00075392</td>
</tr>
<tr>
<td>70</td>
<td>0.00074981</td>
</tr>
<tr>
<td>70</td>
<td>0.00072349</td>
</tr>
<tr>
<td>75</td>
<td>0.00074757</td>
</tr>
<tr>
<td>75</td>
<td>0.00069858</td>
</tr>
<tr>
<td>80</td>
<td>0.00070042</td>
</tr>
<tr>
<td>80</td>
<td>0.00069710</td>
</tr>
</tbody>
</table>

The next step was to calculate the force from these strain values. This was done using the following equation.

\[
F_D = \frac{E \cdot \varepsilon \cdot I}{c \cdot L}
\]

*Equation 2: Strain to Force Calculation*

Where...

\[
F_D = \text{Drag force of mirror \\& assembly}
\]
\[ \varepsilon = \text{Strain} \]
\[ E = 28,000 \text{ ksi} \text{ (Modulus of elasticity of stainless steel)} \]
\[ I = 0.0148 \text{ in}^2 \text{ (Moment of inertia of the steel tubing)} \]
\[ c = 0.376 \text{ (Distance measurement was taken from neutral axis)} \]
\[ L = 15 \text{ in} \text{ (Length of bending arm)} \]

After the above equation was used to calculate strain and the data was adjusted to match the zero strain at zero mph, the following force data was observed by the middle and lower strain gauges.

<table>
<thead>
<tr>
<th>Velocity (mph)</th>
<th>Force (lb.) Middle</th>
<th>Force (lb.) Bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>1.36</td>
<td>1.99</td>
</tr>
<tr>
<td>50</td>
<td>3.58</td>
<td>6.40</td>
</tr>
<tr>
<td>55</td>
<td>3.59</td>
<td>6.05</td>
</tr>
<tr>
<td>60</td>
<td>4.04</td>
<td>7.77</td>
</tr>
<tr>
<td>65</td>
<td>9.48</td>
<td>7.35</td>
</tr>
<tr>
<td>70</td>
<td>9.72</td>
<td>7.96</td>
</tr>
<tr>
<td>75</td>
<td>5.30</td>
<td>9.09</td>
</tr>
<tr>
<td>80</td>
<td>6.16</td>
<td>12.43</td>
</tr>
</tbody>
</table>

4.2.3. Rolling Resistance

Rolling resistance is dependent on velocity, as a result of the rolling resistance coefficient’s dependence on velocity. However, the effect of velocity on the rolling resistance is negligible compared to the effect of velocity on the drag force. Equation 3 shows that the force of rolling resistance is not directly dependent on velocity. And in Figure 14 you can see the relation between the velocity and coefficient of rolling resistance.
\[ F = \frac{N_f \times b}{r} \]

Equation 3: Rolling Resistance

Where...
\( F \) = Force of rolling resistance
\( r \) = Wheel radius
\( b \) = Rolling resistance coefficient
\( N_f \) = Normal force

4.3. Prototype

One of the larger questions that this project tries to answer is, could this system, if implemented in a truck, be a suitable alternative for conventional blind spot mirrors? This question attempts to connect the theoretical angle calculations and functionality of the system to the actual use of the system. We plan to make this connection and answer the posed question by implementing this system on a truck for a week. Roger, a truck driver from Equity, has allowed us to install this system for a week and then provide feedback when the week is finished. In order to make this test a success, a prototype must be designed and built, and the feedback from Roger must be analyzed. The prototype is made up of an arm that attaches to the existing mirror mounting bracket and holds the camera, a monitor from Gentex, and an electronic system that runs off a DC 12V power outlet in the truck.
4.3.1. Camera Arm

For this prototype we will be focusing on the functionality and the adjustability of the system. In order to ensure the functionality of the camera that is held by the arm, a design was created to hold the camera. The design for the holder can be seen in Appendix E. The prototype arm needs to be adjustable as well. The arm has the camera holder attached to the end and then makes use of adjustment arms to allow for aiming of the camera. A picture of the installed system can be seen in the pictures below.

![Figure 15: Prototype Assembly Side View](image1)

![Figure 16: Prototype Assembly Front View](image2)

4.3.2. Monitor Mount

The monitor which is used for the visual display form the camera was placed above the dashboard. Originally, we planned to place the monitor at the left and right corners because the drivers were used to looking in that direction. An attempt was made to avoid the change in positioning of the viewing system to ease the transition from using the normal side mirrors to our camera and monitor. During our field test of our new system, we discovered that the positioning of the monitor is mainly based on the driver’s preference. The picture above shows the preference of our field test driver, Roger. Based on his use of our system, he preferred the monitor to be in the center of the windshield. This he said reduced the time it took for him to look into the monitor and back on the road. The power for the monitor was drawn from the DC 12V outlet in the cab. The video feed ran from the camera to the LCD monitor.
4.3.3. Electronics

Figure 18 shows the bread board that was built to hold all the connections in one place. All the connection coming from the monitor, camera and power source all ran from the bread board. Figure 19 shows how the voltage regulator and capacitors were connected to regulate the voltage going to the camera. The bread board was taped at the back of the passenger’s seat to prevent the wires from crossing the driver and also to avoid the overheating of the voltage regulator. The capacitors and voltage regulators were all soldered together to avoid the movement of the wires coming out of the bread board. Wires that ran out of the bread board were taped to the ground in a loop to avoid interference while driving.
4.3.4. Driver Feedback

After two weeks of using with camera and monitoring system, we asked Roger several questions. The following points summarize his response and overall interaction with the system.

- **Effectiveness of the system**: Based on Roger’s use of the system, he feels that the camera and monitor did a better job covering the blind spots overall. Roger described that the monitor eliminates the blind spot and notes the similarity to a convex mirror. In Roger’s opinion the systems rating was a 7 out of 10.

- **Adaptation**: The issue here was how long it would take Roger to get used to the system. The first day was kind of tough for him to adjust his angle of view from looking to the side and now focusing on the mirror, but on the second day he found himself using the system all the time and he began to rely on the monitor more.

- **Adjustment**: Roger seemed to have no difficulty adjusting to our system. The newer system takes away the time to look from the side mirror and back on the road. Looking at the monitor only requires a quick glance down and then Roger was able to refocus on the road. This quick glance down, compared to the longer time it takes to look at the conventional mirrors, and improves the safety for the driver.

- **Location of the monitor**: The positioning of the monitor is based on a personal preference of the driver. Roger preferred the monitor in the middle because it reduced the time it took for him to look to the side and back on the road, keeping his focus on the road.

- **Long term effect**: In Roger’s personal opinion, he could see the camera and monitor replacing the side and front blind spot mirrors to improve the safety of the trucks during long hours of travel.

- **Blind spots**: The system completely eliminated all the blind spots. This was important because it provided the driver with an additional view that the normal mirrors could not provide. This was beneficial in traffic because Roger could see the cars as they were coming from the sides on the monitor which was not visible using the mirrors. The system was also beneficial in a
backing situation. As the trailer creates an angle with respect to the cab, the camera and monitor provided continuous viewing of the trailer throughout the turn.

Roger used the system for two weeks with the mount being placed both on the right and left side for one week each. Roger also suggests a split screen for the camera on the left and right side to accommodate the images from both sides of the truck.

In conclusion, Roger seemed to be very enthusiastic about the system and the great increase in safety the system provided. In the long run, he believes a system like this could be in most truck due to the increase in safety. With a payback period of 5 years, Roger could see himself paying $1200 dollars to have our system installed.

The images that follow show the elimination of the blind spots both in the truck while Roger was driving, as well as theoretical drawings considering the viewing angles in a turning situation.
Figure 21: View from Mirror While Turning

Figure 22: Diagram of Viewing Angles with Truck Turned
5. **Final Design**

5.1. **Design Decisions**

5.1.1. **Requirements**

The camera and monitor are the main components of the design. There are several specifications that must be met for the camera to ensure functionality in the proposed application. The monitor will be a direct replacement for the current mirror system, and has several important requirements to abide by as well. The monitor must be approximately the same size as current conventionally side mirrors. However, due to the fact that conventional blind spot mirrors are approximately ten feet from the driver, to provide a viewing surface perpectively the same size a monitor placed roughly 2 feet from the driver could be significantly smaller. In order to provide the most ease for viewing and functionality, a rough screen size of 4 inches high by 6 inches wide would be ideal. This size monitor would provide appropriate image size for camera images. The camera must be capable of operating on a low lighting mode. When driving at night, the monitor must not interfere with the truck driver’s concentration on the road, or produce any glare or bright light that can cause hazardous driving conditions. The screen must not be over reflective, or cause driver distraction during the day. The monitors will be mounted on either side of the dash in the cab of the trucks. The monitors must be located in places that coincide with existing driver habits. The monitor must also come with a simple interface for adjustment of brightness and camera angle.

A basic interface system will ensure the smooth adjustment of several key features of the cameras and monitors. Camera angle, night or day mode, and view angle should be quickly adjustable from a simple control panel. A light sensor will be placed on the dash by the windshield to allow a program to automatically adjust between daytime setting and nighttime settings, and will have an override the driver can activate to provide the best visibility. Some of these features will go beyond the scope of our design project and could be considered for future research or design projects.

5.1.2. **Camera & Camera Mounting**

The camera must be small. Reduction in size of the system monitoring space around trucks is essential for the design and increase of fuel savings in the application. Ideally the camera mounting will be roughly 0.5 inches to 2 inches diameter and between 0.5 inches and 3 inches in length. The camera should produce a medium to high resolution to the monitor to ensure distinction in driving situations. A low resolution camera, though less expensive, will produce poor quality images, on which the truck driver relies on to drive safely.

5.1.2.1. **Front Camera Mounting**

The front camera will be mounted on the top of the grill section of the semi truck cab. The diagram below shows the front camera mounting location. The location of the front camera will allow the driver to see in the entire front section of the truck allowing him or her to have a complete view of area around the truck (with the view provided by the side cameras). Figure 23 shows the mounting location of the front camera and Figure 24 shows CAD model of the final design. Figures 25 and 26 are the design options for the front mounting. The final design was selected taking into consideration the following factors: manufacturability, performance, and aesthetics.
Figure 23: Front Camera Mounting Location

Figure 24: Front Camera Mounting
5.1.2.2. *Side Camera Mounting*

The side camera will be located on the bottom bar of the mirror assembly. The mounting design allows the camera to be installed without the need of additional bars or brackets as it makes use of the already existing features of the truck. The wiring will be fed through into the cab alongside the existing wires for the CB radio.
Figure 27: Side Camera Mounting Location
Figure 28: Side Camera Mounting

Figure 29: Exploded View
Figure 30: Section View
5.1.3. Monitor & Monitor Mounting

For our final design, we will be using two monitors which will be placed according to the driver’s preference. The first monitor will have a split screen displaying the images of the two side cameras, while the second monitor will display the image of the front camera. Two LCD monitors will be used, and placed, in the cab. We want to place the monitor in a location so that with a quick glance down the driver could return his focus to the road. The best positions to place the two monitors would be at the left side of the driver close to the leftmost edge of the windshield for the front camera and the second monitor with a split screen to the right above the cab for the two side monitors. These monitors when placed can be moved based on the driver’s ease of use of preferred angles.

The monitor mount will be suction cup that can stick to the windshield and also have a screwed bracket at the end for the monitor. These mountings will be positioned on the windshield so that they do not interfere with driver’s field of view while driving. Figures 32 and 33 show the specified monitor and mounting assembly used for the final design.
5.1.4. Electronics Box

The electronics box is needed to send appropriate voltage to the cameras and monitors. The monitor requires DC 12V which is supplied by the electronics of the truck. The cameras require DC 6V which will be converted by the use of a LM7806 linear voltage regulator. Figure 19 on page 27 shows the basic schematics of the electronics box.
Figures 34 to 36 show CAD models of the outside of the electronics box. The box will contain a PCB for the voltage regulator and capacitors. The box will be made of HDPE and assembled using high strength adhesives. The PCB will be custom manufactured to suit the design requirements.
5.2. Obstacles

There are several obstacles that could hinder the production of our system on a large scale. Each obstacle will be analyzed individually with possible solution on how to overcome them.

5.2.1. Intellectual Properties

These properties include patents, trademarks, industrial design rights and copyrights that are already inexistence with similar or the same technology that we are trying to develop. Based on our patent search, there have been numerous systems similar to our system. These patents are briefly explained in Appendix D of this report. These exclusive rights have allowed the owners of the individual intellectual property to benefit from the design they have created for 19 years before any other person can replicate the technology. In fact in 1993, James Secor received a patent for a technology that uses three cameras and a LCD monitor to help the driver view traffic condition rearward. The only difference is that his aim was not to reduce fuel consumption but rather improve safety. We are just left to wonder why the technology never went into production. With all the patents found trying to improve the viewing angle of trucks, only the reversing camera and monitor system are presently in production. To overcome this obstacle, we plan to keep doing our research and development on making our system more aerodynamic while the years on the patent run out. By pitching the ideas to truck manufacturing companies, we are positive that the idea will be picked up sooner than later and be ready for production at the end of the patent years. With the combined better fuel savings annually, safer trips on the highway, and reduction in CO₂ emissions, our system is bound to reduce the total cost on fuel with a payback period of 4.5 years.

5.2.2. Human Factors

We are quick to accept technology that alters our normal standard of living. Most people have a route the use to go to church, for instance. Every Sunday, we wake up, get dressed and follow our normal route to church. Now there is a new road that was just built that your GPS is directing you...
towards to get to church in less time. At first, most people will be skeptical to take that route eventually that route will become part of your routine to church replacing the older and longer trip. That’s the same thing is will take for our system to be implemented. It has to be tested by numerous truck drivers and accepted that it makes driving these semi-trucks safer on the road. The issue with this system is the focal length, distance between monitor and driver, and driver acceptance to the system. First of all for the focal length, the newer system provides a larger viewing angle which is at a more comfortable distance for the driver. The truck driver is used to looking through the windshield or windows to locate his mirrors. The new system should improve his alertness to obstacles on the road improving his viewing of his sides. Driver acceptance might take time but with more use of the system in place of the mirrors, there will eventually be a shift and acceptance of our camera and monitor system because of its ease of use and wider viewing angle which for truck drivers is substantially important.

5.2.3. Marketing

If our system is so good, why is not in the market? How do we put this in place? And also what will it take to make sure it is successful. Based on the patents, there were very few designs that actually ran fuel saving data. These designs were based mainly on safety. Safety is a big issue, but why do we narrow our mind to just one aspect of the design.

The economy is not what it used to be several years ago. Due to the high fuel prices, there is a push for trucking companies to reduce their fuel consumption by 2017. With this push, designs like ours are being reconsidered at this point. Trucking companies have reached a point where they are desperate for more aerodynamic systems on their fleets. To put the design in place, we have to run tests to confirm what kind of fuel savings percentage our system produces. These numbers are what will make our design fail or succeed form a financial view. After successful testing, the idea can be pitched to trucking companies or sold to a truck manufacturing firm. All these we are currently performing to make sure that our design is successful and reliable for all that we have written and said about the system. At the end of the day, it’s a decision that requires a lot of convincing. With a payback period of 4.5 years on the system, and improved safety limiting lawsuits, most companies will jump at the chance to be the pioneers of the technology and make maximum profit for the 19 years the patent is in place.

5.2.4. Weather Conditions

Our camera is built to withstand any weather conditions that might affect the driver’s view. The camera is enclosed in a casing that protects it from most weather conditions. In fact, our system has a smaller surface area, making the effect of blurry images to be reduced. In a snow storm, if the mirrors are covered in snow, the driver has to come out and wipe each mirror before he can proceed. With our system, the camera is harder affected so much that the driver can’t seem to see. Therefore even in a snow storm, the truck driver can maintain a constant speed and still be safe. In the first few years of installation, we plan to have regular testing of wires and connections to make sure there is reduced power failure on the road.
6. Financial Calculations

6.1. Payback Calculations

One of the main goals for this project was that the savings produced by the system would allow for a payback period of 5 years. With the data we collected and the cost of the system that was estimated this goal was achieved. Using the calculations shown in the following figure, a cost for the rear view camera monitoring system, and the payback it provides were calculated.

![Figure 37: Financial Calculations Model](image)

While the numbers calculated in this spreadsheet seem to represent reality, there are a few other questions that need to be answered with respect to how closely to reality these numbers actually come. Several factors that affect the fuel savings are as follows: horsepower being used by engine during operation, the fuel economy, fuel costs, and the number of miles traveled per year.

6.1.1. Horsepower

When looking at the amount of power the engine is using, we initially input the maximum horsepower of the engine. But in actuality, the power needed to input into these equations to accurately represent this situation can be found by determining the revolutions per minute (rpm) of the engine while under normal operating conditions. These rpm values can then be converted into horsepower by using the power curve for the Detroit Diesel 16 engine that the trucks at Equity have in their trucks. The power curve for this DD16 engine can be seen below. This curve was found on Detroit Diesel's website (http://www.detroitdiesel.com/engines/dd16/default.aspx).
After consulting Roger, our driver, about the normal engine operating conditions, the normal rpm range is between 1,200 and 1,500 rpm. When we then read the horsepower values from the power curve we see that during normal conditions, the trucks are using between 470 and 580 hp. When we input that range of power into our analysis of economic and fuel savings the following graphs are produced. Due to the strong relation between the velocity of the truck and the power required to overcome the drag force produced, the relationship between horsepower and savings was calculated at three different speeds, 58, 59, and 60 mph. This speed range was determined from an estimated average velocity of a normal truck at Equity. The first graph below shows the relationship between horsepower and total percent savings.
When looking at the relationship between the horsepower and the percent savings, it makes sense that the more horsepower that is being used, the smaller the percentage effect the reduction of force, and power, will have on the engine. The next graph compares horsepower to the total fuel savings for Equity’s 250 truck fleet.

### 6.1.2. Fuel Economy and Miles per Year

Another number that greatly affects the fuel savings is the fuel economy. Equity provided us with their average miles per gallon for all four quarters of 2010. These values were then averaged for an annual fuel efficiency of 6.725 mpg. As the fuel efficiency changes the total annual savings provided increases, and that is the main purpose of increasing fuel economy. Below is a figure that shows the
relationship between the fuel efficiency and the total annual savings for Equity at several different speeds.

![Figure 41: Fuel Efficiency vs. Total Annual Savings](image)

One way to check the power required to keep the truck moving down the road is to look at the fuel economy in relation to the force produced and the velocity traveled. In order to do this calculation, an overall look at power consumption is required. The following calculations show the amount of power required to overcome normal drag force, the rolling friction, and other components of inefficiency that affect the movement of the truck.

\[
P = \left( \frac{1}{\text{mpg}_{\text{avg}}} \right) \times E \times V_{\text{avg}}
\]

Equation 4: Secondary Power Consumption Calculation

Where...
- \( P \) = Power used by engine
- \( \text{mpg}_{\text{avg}} = 6.725 \text{mpg} \) (average fuel economy)
- \( E = 138,700 \text{ Btu/gallon} \) (energy (Btu) per gallon diesel fuel)
- \( V_{\text{avg}} = 58 \text{ mph} \) (average velocity of truck)

This calculation takes a look at the actual energy used from a fuel efficiency standard. When the value for fuel efficiency, energy per gallon, and average velocity of the truck are input into the equations, the result is a power of 123747 Btu/hr. When this number is converted to horsepower so we can directly compare the horsepower read from the DD16 power curve, we get a value of 470.1 hp. This, coincidentally, is the lower value we read based on our rpm’s obtained from the driver. So when we input this value into our cost savings we find that, based on 470.1 hp at 58 mph we find that we are on the higher end of the overall percent fuel savings with a value of 44% savings.
6.1.3. Fuel Costs

Fuel costs directly affect the amount of savings that a trucking company experiences when implementing cost savings measures. The following graph shows the relation between the fuel cost per gallon and the payback period of the system.

![Fuel Cost vs. Payback Period](image)

When considering the distance traveled per year per truck, Equity has many different trucks, traveling many different distances. The miles used for this analysis was 100,000 miles per year. This number is an approximate average for the company. If a company has a higher average the savings can easily be scaled to find the appropriate savings values.

6.2. Budget

One of the requirements for this project was the creation of a budget that we would use to estimate and purchase parts. The following spreadsheet shows the budget for our team. The initial amount estimated for budgeted funds was $300.00. This value did not include any of our donated cameras or the donated monitor.
6.3. **Business Plan**

6.3.1. **Vision and Mission Statement**

Our vision as a team is to produce a product that shows our stewardship and care for our society. As stewards of the earth, we desire our product to reflect our position as Christian engineers. As engineers, we have certain codes of ethics that we are forced to abide by. From these codes of ethics, we have to produce a product that is good for our environment. As it says in the scriptures, “You shall not pollute the land in which you live.... You shall not defile the land in which you live, in which I also dwell; for I the LORD dwell among the Israelites” (Numbers 35:33-34). And also, "You must keep my decrees and my laws.... And if you defile the land, it will vomit you out as it vomited out the nations that were before you” (Leviticus 18:26, 28).

6.3.2. **Business Strategy**

The company hopes to achieve a system that will be fully operational in a couple of months. Hopefully with our system fully functional we would be able to reduce wind resistance on fully loaded trucks by approximately 0.48% leading to fuel savings and less CO2 emissions.

The company also desires to make a lot of revenue within a couple of years. The level of profit that this company can achieved all depends on the effort and dedication that is being put into its design. With the current market looking for ways to reduce total fuel usage and our company proving a solution to their problem, the sky is the limit to what our system can do for the trucking companies. The international market could also be tapped into to make profit.

Our desire of a company is to make safer trucks. With the amount of accidents involving semi trucks slowly increasing, our system could be the answer to safer trips down the highway. Our company will also help the country save a potential of 100 million gallons of fuel if our system is implemented nationwide.

Our company plans to successfully implements a cost leadership strategy can earn above-average returns even when the five competitive forces are strong.

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### Table 4: Project Budget

<table>
<thead>
<tr>
<th>Item</th>
<th>Estimated Cost</th>
<th>Actual Cost</th>
<th>Purchaser</th>
</tr>
</thead>
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<tr>
<td>Mirrors</td>
<td>$21.20</td>
<td>$21.20</td>
<td>JB</td>
</tr>
<tr>
<td>Support System</td>
<td>$60.00</td>
<td>$58.61</td>
<td>JB</td>
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<tr>
<td>Camera &amp; Monitor Mounting</td>
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<td>$9.07</td>
<td>JB</td>
</tr>
<tr>
<td>Power Source</td>
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<td>$67.00</td>
<td>JL</td>
</tr>
<tr>
<td>Strain Gauges</td>
<td>$60.00</td>
<td>$57.00</td>
<td>YG</td>
</tr>
<tr>
<td>Strain Gauge Adhesive</td>
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<td>$0.00</td>
<td>YG</td>
</tr>
<tr>
<td>Voltage Regulator &amp; Capacitors</td>
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<td>$2.50</td>
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<tr>
<td>Hardware</td>
<td>$20.00</td>
<td>$0.00</td>
<td>ALL</td>
</tr>
<tr>
<td>Car Power Adapter</td>
<td>$9.00</td>
<td>$8.47</td>
<td>JL</td>
</tr>
<tr>
<td>4 Pin Connectors</td>
<td>$20.00</td>
<td>$19.96</td>
<td>JL</td>
</tr>
<tr>
<td>Acrylic Sheet &amp; Adhesive</td>
<td>$6.80</td>
<td>$6.80</td>
<td>JL</td>
</tr>
<tr>
<td>PCB</td>
<td>$3.00</td>
<td>$2.98</td>
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</tr>
<tr>
<td>Wire</td>
<td>$20.00</td>
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<td>JL</td>
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<tr>
<td><strong>Total:</strong></td>
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<td><strong>$274.58</strong></td>
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<tr>
<td><strong>Budget</strong></td>
<td><strong>$300.00</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• Rivalry with Existing Competitors: Achieving the lowest cost position means that a company’s competitors will hesitate to compete on the basis of price because, in the event of a price war, our low cost will continue to earn profits after its competitors compete away their profits.

• Bargaining Power of Suppliers: Because we have achieved the lowest cost position in the industry, our cost leadership strategy enables our company to absorb a greater amount of cost increases from powerful suppliers before it must raise prices charged to customers. This may enable our company to be alone among its competitors in earning above-average returns. In addition, a low-cost leader that also has a dominant market share may be in a position to force suppliers to lower prices or to hold down the level of price increases, and thus reduce the power of suppliers.

• Potential Entrants: Our companies successfully following cost leadership strategies generally must produce and sell in large volumes to earn above-average returns. And, with a continuous focus on efficiency and reducing costs, low-cost leadership companies create barriers to entry. New entrants must either enter the industry at a large scale (large enough to achieve the same economies of scale as the next lowest cost company) or be satisfied with average profits until they move sufficiently far down the experience curve to match the efficiencies of the low-cost leader.

• Product Substitutes: The low-cost leader (our company) is in a more attractive position relative to substitute products than are other companies in the industry. To retain customers, we, the low-cost leader can more easily reduce prices to maintain the price-value relationship and retain customers.

By using a camera and monitoring system instead of the usual blind spot mirrors, our company would stand out as possibly the monopolist distributor of the technology if we decide to acquire a patent on our system. However, fairly quickly, our competitors will copy, or even improve upon, our unique values or advantages, and therefore the advantage is soon lost. These are the attributes we considered in order for our product to be different.

• The size, the shape and the components of the product must stand out from that of our competition.
• The features of the product must be able to function with any weather change.
• The product performance or product quality should reflect to the customers anytime they are using the system.
• The product performance consistency should be of high quality in any location in the US.
• The life cycle of the product should be consistent for a very long time.
• The reliability of the product will be noticed in its day to day use. The reliability of the product would not be based on its warranty but rather on a life time of the truck. The system should be fully functional for 10+ years without major repairs.
• Is the product easily repairable? The product would be easily repairable or fully replaced if a warranty has been placed.
• The style and design of the product should be attractive and appealing to the customers.

The focus of the company will remain to produce a fully functional camera and monitor system that would appeal to our customers for years to come. Hopefully with a reliable system our customers will remain loyal to our brand for years to come due to the relationship and business we would have done together. Our company also wishes to focus on producing the system at the minimum cost.
possible. Our product might someday make its way to the European or Asian market, and it should be able to function on a consistent basis.

6.3.3. Marketing Strategy
The recent push for greater fuel efficiency has lead to a push by trucking companies to redesign the vehicles used to increase fuel economy. There are many different ways to increase the fuel economy in the trucking industry but there are very few people producing any real solutions. CO₂ emissions are at their highest rates in history and the fuel supply is beginning to run thin. Change is necessary and our product is the first step to a cleaner future. Our product with increase fuel economy by reducing the total drag produced by semi-trucks and will reduce carbon dioxide emissions. This rear view camera monitoring system will increase the safety for all drivers on the road.

Customers in our target market include truck drivers and any companies that have fleets of trucks. Many different people drive trucks and it is important to appeal to every one of them. This product will be able to satisfy the needs of both large and small companies because of its low cost and ease of use.

6.3.3.1. Motivation to Buy
Customers who purchase our rearview camera monitoring system will be very pleased with the increased functionality of the new blind spot monitoring system. Customers will desire the increased fuel savings provided by the unit and the greatly increased safety that this new system will provide.

Market size and trends
The market for our product starts with the companies and businesses that are local to our area. As the company expands and grows so will the market. There are over 2 million trucks on the road in the U.S. at any given time and our product can be marketed to all of them. There is also potential for marketing to international customers. As our economy continues to grow and develop, trucks will become increasingly important in providing food and other necessities around the country. While the trucking market continues to grow, our target market will continue to grow as well.

6.3.3.2. Advertising and Promotion
While advertising for our new rear view camera monitoring system will be based on the increased safety potential for the truckers on the road currently, as well as the increased fuel savings from the reduction in drag resulting from the increased aerodynamics of the camera unit. These two points will provide savings in both fuel costs as well as less cost in legal battles brought on due to semi-truck accidents. We plan to use several types of media to share the message of better fuel economy and increased safety. A majority of the sales to larger truck producers and trucking companies will be done through direct presentation and sales pitches. Our product is not for consumption by the general public so we will not be making use of TV, but we will be making use of internet websites. Ads focused on a specific group of people who search particular websites will allow us to reach smaller companies with fewer trucks.

When the product starts to gain popularity and demand increases, we will expand our market and bump up the advertising budget. Publicity for the rear view camera monitoring system will be achieved through word of mouth and will hopefully become standard for all semi-trucks.

6.3.3.3. Pricing
When our product is compared to others on the market we want to be able to say that the price for our system is comparable to others. The camera monitoring system will pay for itself over time and that feature will provide steep competition to other competitors in the same market. We would like this product to be viewed of as a high quality, reasonably priced, cost savings device that greatly increases safety.
6.3.4. Competitor Analysis

Based on our recent, there are no major competitors in this market. A lot of research has been done on replacing the extruding blind spot mirrors with a camera and monitoring system, but no company is actually producing the system. There has been a monopoly of restructuring the design of the blind spot mirrors in recent years.

Our main competitor in the American market is United Truck Center Ltd. United truck center is a group currently is producing blind spot mirrors for the trucking industries on a large scale and so it will difficult to get into the market. Listed are the strengths that they have on the market.

- Consistency in product for over 50 years
- Main suppliers of the blind spot system.
- Brand loyalty of major trucking companies
- Recent re-design of aerodynamic mirrors
- Low cost of mirrors

Although they have a consistency product, there are the weaknesses of their product compared to our newer and safer system.

- Recent re-design of mirrors does not improve safety.
- Total fuel savings per year not significantly high to make a difference
- CO₂ emissions still released at the same rate
- Number of accidents involving semi trucks have increased
- Repositioning of the blind spot mirrors does not improve fuel usage.
- With the new push by government to improve fuel efficiency of trucks by 20% before 2018, there is very little impact that the company can make.

With the promise of our product making a lot of revenue within the first few years, there are bound to be a lot of competitors in the market trying to produce a better camera and monitoring system at a lower cost than we do. These companies include Wenzhou Success Group in China, and Sony in Japan. Companies that produce blind spot mirrors could also change their strategy by also producing our system.

The push by other competitors to take some of our profit away from us will make the price of our product to drop. At the beginning, when our company has the monopolistic market, the customer had to buy our product because of the fuel savings that revenue being saved that the trucking companies were gaining. Now with alternative designs to our system, our customers have the right to neglect our system for a cheaper and also consistent system. A bad decision like that could end up killing our control of the market in a couple of years.

A solution to all these problems is to acquire for a patent towards our invention, but that can only last for 19 years before our competitors are back into the market again. With the patent in place, at least we will be able to make maximum profit from the US market for the 19 years that we have the patent.
7. References

8. Appendix

A. US DOT Regulations

Department of Transportation – Federal Motor Carrier Safety Administration
Modified to Include Only Relevant Regulations

Regulation Part 393.80: Rear-vision mirrors.

§393.80 Rear-vision mirrors.
(a) Every bus, truck, and truck tractor shall be equipped with two rear-vision mirrors, one at each side, firmly attached to the outside of the motor vehicle, and so located as to reflect to the driver a view of the highway to the rear, along both sides of the vehicle. All such regulated rear-vision mirrors and their replacements shall meet, as a minimum, the requirements of FMVSS No. 111 (49 CFR 571.111) in force at the time the vehicle was manufactured.

Regulation Part 571.111: Standard No. 111; Rearview mirrors.
§571.111 Standard No. 111; Rearview mirrors.

S1. Scope. This standard specifies requirements for the performance and location of rearview mirrors.
S2. Purpose. The purpose of this standard is to reduce the number of deaths and injuries that occur when the driver of a motor vehicle does not have a clear and reasonably unobstructed view to the rear.
S3. Application. This standard applies to passenger cars, multipurpose passenger vehicles, trucks, buses, school buses and motorcycles.
S4. Definitions.
Convex mirror means a mirror having a curved reflective surface whose shape is the same as that of the exterior surface of a section of a sphere.
Effective mirror surface means the portions of a mirror that reflect images, excluding the mirror rim or mounting brackets.
Unit magnification mirror means a plane or flat mirror with a reflective surface through which the angular height and width of the image of an object is equal to the angular height and width of the object when viewed directly at the same distance except for flaws that do not exceed normal manufacturing tolerances. For the purposes of this regulation a prismatic day-night adjustment rearview mirror one of whose positions provides unit magnification is considered a unit magnification mirror.
S7. Requirements for multipurpose passenger vehicles and trucks with a GVWR of more than 4,536 kg and less than 11,340 kg and buses, other than school buses, with a GVWR of more than 4,536 kg.
S7.1 Each multipurpose passenger vehicle and truck with a GVWR of more than 4,536 kg and less than 11,340 kg and each bus, other than a school bus, with a GVWR of more than 4,536 kg shall have outside mirrors of unit magnification, each with not less than 323 cm² of reflective surface, installed with stable supports on both sides of the vehicle. The mirrors shall be located so as to provide the driver a view to the rear along both sides of the vehicle and shall be adjustable both in the horizontal and vertical directions to view the rearward scene.
S8. Requirements for multipurpose passenger vehicles and trucks with a GVWR of 11,340 kg or more.
S8.1 Each multipurpose passenger vehicle and truck with a GVWR of 11,340 kg or more shall have outside mirrors of unit magnification, each with not less than 323 cm² of reflective surface, installed with stable supports on both sides of the vehicle. The mirrors shall be located so as to provide the driver a view to the rear along both sides of the vehicle and shall be adjustable both in the horizontal and vertical directions to view the rearward scene.
S11. Mirror Construction. The average reflectance of any mirror required by this standard shall be determined in accordance with SAE Recommended Practice J964, OCT84. All single reflectance mirrors shall have an average reflectance of at least 35 percent. If a mirror is capable of multiple reflectance levels, the minimum reflectance level in the day mode shall be at least 35 percent and the minimum reflectance level in the night mode shall be at least 4 percent. A multiple reflectance mirror shall either
be equipped with a means for the driver to adjust the mirror to a reflectance level of at least 35 percent in the event of electrical failure, or achieve such reflectance level automatically in the event of electrical failure.
### B. Annual Vehicle Distance Traveled

#### Department of Transportation – Federal Highway Administration

**Highway Statistics 2007 and 2008**

#### ANNUAL VEHICLE DISTANCE TRAVELED IN MILES AND RELATED DATA - 2008 1/1

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ITEM</th>
<th>PASSENGER CARS</th>
<th>MOTOR CYCLES</th>
<th>BUSES</th>
<th>OTHER SINGLE-AXLE TIRE OR MORE TRUCKS 4/</th>
<th>COMBINATION TRUCKS</th>
<th>PASSENGER CARS AND OTHER SINGLE-AXLE TIRE OR MORE COMBINATION TRUCKS</th>
<th>SUBTOTALS 2/</th>
<th>SINGLE-UNIT 2-AXLE TIRE OR MORE AND COMBINATION TRUCKS</th>
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<tr>
<td>2008</td>
<td>Interstate Rural</td>
<td>112,312</td>
<td>1,398</td>
<td>1,017</td>
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<td>Other Rural</td>
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<td>1,077</td>
<td>141,711</td>
<td>15,475</td>
<td>13,000</td>
<td>12,296</td>
<td>179,025</td>
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<tr>
<td>2006</td>
<td>Other Rural</td>
<td>210,802</td>
<td>2,059</td>
<td>1,077</td>
<td>141,711</td>
<td>15,475</td>
<td>13,000</td>
<td>12,296</td>
<td>179,025</td>
</tr>
<tr>
<td>2008</td>
<td>All Rural</td>
<td>203,495</td>
<td>1,823</td>
<td>1,722</td>
<td>141,812</td>
<td>15,559</td>
<td>14,101</td>
<td>12,976</td>
<td>183,987</td>
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<tr>
<td>2007</td>
<td>All Rural</td>
<td>203,495</td>
<td>1,823</td>
<td>1,722</td>
<td>141,812</td>
<td>15,559</td>
<td>14,101</td>
<td>12,976</td>
<td>183,987</td>
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<tr>
<td>2006</td>
<td>All Rural</td>
<td>203,495</td>
<td>1,823</td>
<td>1,722</td>
<td>141,812</td>
<td>15,559</td>
<td>14,101</td>
<td>12,976</td>
<td>183,987</td>
</tr>
<tr>
<td>2007</td>
<td>Intermediate Urban</td>
<td>290,750</td>
<td>2,761</td>
<td>1,952</td>
<td>160,570</td>
<td>10,143</td>
<td>31,292</td>
<td>14,101</td>
<td>243,822</td>
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<tr>
<td>2006</td>
<td>Intermediate Urban</td>
<td>290,750</td>
<td>2,761</td>
<td>1,952</td>
<td>160,570</td>
<td>10,143</td>
<td>31,292</td>
<td>14,101</td>
<td>243,822</td>
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<td>2008</td>
<td>Other Urban</td>
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<td>2,516</td>
<td>577,117</td>
<td>37,406</td>
<td>53,789</td>
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<td>519,975</td>
<td>35,814</td>
<td>50,392</td>
<td>2,889</td>
<td>1,494,090</td>
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<tr>
<td>2006</td>
<td>Other Urban</td>
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<td>7,444</td>
<td>2,205</td>
<td>519,975</td>
<td>35,814</td>
<td>50,392</td>
<td>2,889</td>
<td>1,494,090</td>
</tr>
<tr>
<td>2008</td>
<td>All Urban</td>
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<td>710,722</td>
<td>67,672</td>
<td>47,627</td>
<td>94,016</td>
<td>1,859,490</td>
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<tr>
<td>2007</td>
<td>All Urban</td>
<td>1,112,720</td>
<td>6,799</td>
<td>3,295</td>
<td>710,722</td>
<td>67,672</td>
<td>47,627</td>
<td>94,016</td>
<td>1,859,490</td>
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<tr>
<td>2006</td>
<td>All Urban</td>
<td>1,112,720</td>
<td>6,799</td>
<td>3,295</td>
<td>710,722</td>
<td>67,672</td>
<td>47,627</td>
<td>94,016</td>
<td>1,859,490</td>
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<tr>
<td>2008</td>
<td>Total Rural and Urban</td>
<td>1,891,060</td>
<td>14,484</td>
<td>7,114</td>
<td>1,109,603</td>
<td>83,661</td>
<td>143,567</td>
<td>7,246,452</td>
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<td>2007</td>
<td>Total Rural and Urban</td>
<td>1,891,060</td>
<td>14,484</td>
<td>7,114</td>
<td>1,109,603</td>
<td>83,661</td>
<td>143,567</td>
<td>7,246,452</td>
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<td>2006</td>
<td>Total Rural and Urban</td>
<td>1,891,060</td>
<td>14,484</td>
<td>7,114</td>
<td>1,109,603</td>
<td>83,661</td>
<td>143,567</td>
<td>7,246,452</td>
<td>227,886</td>
</tr>
</tbody>
</table>

Notes:
1/ The 50 states and the District of Columbia reported by highway category, number of motor vehicles registered, and total fuel consumed. The total and fuel data by vehicle type and stratification of trucks are estimated by the Federal Highway Administration (FHWA). Estimation procedures include use of State supplied data, the 2002 Census of Transportation Vehicle Inventory and Use Survey (CVIUS), and other sources.
2/ Totals by highway category are from table 3.2d. Some changes between rural and urban roadway may be attributed to 2002 census boundary changes.
3/ Other Single-axle-Trucks which are not passenger cars. These include vans, pickup trucks, and sport utility vehicles.
4/ Single-longitudinal-tire or more trucks on a single axle, with at least two axles and no semi-trailer.
5/ Trunk-axle-truck categories are the same as table 3.2d. Some changes between rural and urban roadway may be attributed to 2002 census boundary changes.
6/ Vehicle occupancy is estimated by the FHWA from the 2002 National Household Travel Survey (NHATS). For heavy trucks, 1 motor vehicle miles traveled = 1 person-miles traveled.
7/ Total fuel consumption figures are from tables M-27 and M-28. Distribution by vehicle type is estimated by the FHWA based on miles per gallon for both diesel and gasoline powered vehicles using State-supplied data, the 2002 CVIUS, and other sources with national inputs for motorcycles and buses.
### C. Accident Statistics

Department of Transportation – National Highway Traffic Safety Administration

*Traffic Safety Facts 2008: Chapter 3. Vehicles: Large Trucks*

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#### Large Trucks Involved in Crashes by Initial Point of Impact, Crash Severity, and Crash Type

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<th>Crash Severity</th>
<th>Number</th>
<th>Percent</th>
<th>Number</th>
<th>Percent</th>
<th>Number</th>
<th>Percent</th>
<th>Total</th>
<th>Number</th>
<th>Percent</th>
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<tbody>
<tr>
<td></td>
<td>Fatal</td>
<td></td>
<td></td>
<td>Injury</td>
<td></td>
<td>Property Damage Only</td>
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<td></td>
<td>Total</td>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Number</td>
<td>Percent</td>
<td></td>
<td></td>
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<tr>
<td>Front</td>
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<td>Right Side</td>
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<td>9.0</td>
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<td>23,000</td>
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<td>25,000</td>
<td>24.6</td>
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</tr>
<tr>
<td>Rear</td>
<td>38</td>
<td>5.1</td>
<td>-</td>
<td>3.2</td>
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<td>Noncollision</td>
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<td><strong>Total</strong></td>
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<td><strong>100.0</strong></td>
<td><strong>1,100</strong></td>
<td><strong>100.0</strong></td>
<td><strong>88,000</strong></td>
<td><strong>100.0</strong></td>
<td><strong>100,000</strong></td>
<td><strong>100.0</strong></td>
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#### Single-Vehicle Crashes

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<th>Initial Point of Impact</th>
<th>Crash Severity</th>
<th>Number</th>
<th>Percent</th>
<th>Number</th>
<th>Percent</th>
<th>Number</th>
<th>Percent</th>
<th>Total</th>
<th>Number</th>
<th>Percent</th>
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<td>39.8</td>
<td>58,000</td>
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<td>82,000</td>
<td>29.3</td>
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<tr>
<td>Left Side</td>
<td>311</td>
<td>9.4</td>
<td>13,000</td>
<td>23.0</td>
<td>55,000</td>
<td>24.8</td>
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<td>9,000</td>
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<td>58,000</td>
<td>26.3</td>
<td>68,000</td>
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<td>18.9</td>
<td>38,000</td>
<td>17.4</td>
<td>49,000</td>
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<tr>
<td>Noncollision</td>
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<td>0.2</td>
<td>-</td>
<td>0.7</td>
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<td>8</td>
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<td>4.3</td>
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<tr>
<td><strong>Total</strong></td>
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#### Multiple-Vehicle Crashes

<table>
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<th>Initial Point of Impact</th>
<th>Crash Severity</th>
<th>Number</th>
<th>Percent</th>
<th>Number</th>
<th>Percent</th>
<th>Number</th>
<th>Percent</th>
<th>Total</th>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
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<td>38.2</td>
<td>92,000</td>
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<td>120,000</td>
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<td>7.3</td>
<td>11,000</td>
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</tr>
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<td>1.3</td>
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<td><strong>380,000</strong></td>
<td><strong>100.0</strong></td>
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</tr>
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</table>

*Less than 500.*
D. Related Patents

Inventor: Yamazaki, Shunpei (Tokyo, JP)  
Filed: November 1, 2001  
Abstract: A vehicle has a display device which widens the field of view (visible area) reflected by a side mirror or a back mirror mounted on the vehicle. To enable a driver driving the vehicle to confirm safety even when it is difficult for the driver to visually recognize some of the objects surrounding the vehicle, a liquid crystal display device or an EL display device is provided in the side mirror (door mirror), the back mirror (room mirror) or in an interior portion of the vehicle. A camera is mounted on the vehicle and an image from the camera is displayed on the display device. Further, information read from a sensor (distance measuring sensor) having the function of measuring the distance to another vehicle, and a sensor (impact sensor) having the function of sensing an externally applied impact force larger than a predetermined value is displayed on the display device.

Inventor: Belloso, Gregorio M  
Filed: April 23, 2004  
Abstract: A rear view monitoring system for motor vehicles employs three video assemblies, two of which view regions rearwardly at opposite sides of the vehicle, and the third views the region directly rearwardly of the vehicle. Each assembly has an optical lens which gathers light at a particular viewing angle to produce a focused image, and a camera body which converts the image to an electronic signal capable of adjustment and transmission by electrical conductors. The assemblies also have provision for reversing the image to a mirror-image format. The mirror images are of substantially equal magnification and are displayed on screens mounted within the vehicle at positions generally associated with conventional rear view mirrors.

Inventor: Robison, Elburn  
Filed: January 31, 1980  
Abstract: An undistorted view of regions rearward of a vehicle such as a tractor-trailer is provided by a closed circuit television system wherein a television camera having a wide angle viewing capability is positioned at the rear of the vehicle at an effective viewing elevation between about 20% and 70% of the total height of the vehicle. The camera is protected against debilitating factors by a protective enclosure which occupies minimal space and affords secure attachment to said vehicle by virtue of a mounting wherein the axis of said camera lens is horizontally disposed in a plane perpendicular to the longitudinal axis of said vehicle. A mirror associated with said camera lens at a 45 degree angle thereto serves the two-fold purpose of permitting the desired mode of mounting of said enclosure, and reversing the image presented to said camera. The camera is connected by means of electrical wires to a television receiver positioned within easy view of the driver of the vehicle.

Inventor: Secor, James O  
Filed: February 12, 1993  
Abstract: A rear viewing arrangement is provided for a motor vehicle to permit the operator to view traffic conditions to rearward from left and right sides of the vehicle, as well as directly behind the vehicle. Left and right video cameras are mounted on the left and right sides of the motor vehicle forwardly of the driver’s position. Each camera attachment has a miniature video camera viewing angle directed generally rearwards, and a housing or shroud that is in the form of an aerodynamic fairing disposed over the associated camera to protect the same and to minimize the amount of protuberance laterally from the side of the vehicle. The fairing also avoids unnecessary airflow turbulence, thereby
streamlining the vehicle. The images viewed from these camera assemblies reproduced on an LCD viewing screen, which is integrated with the instrument cluster on the vehicle dashboard. The operator can easily observe the conditions to rearward without having to divert his or her attention from the road ahead.

Inventor: Gutta; Srinivas (Buchanan, NY), Trajkovic; Miroslav (Ossining, NY), Colmenarez; Antonio (Peekskill, NY)

Filed: March 30, 2001

Abstract: A vehicular vision system to aid a driver of a vehicle to determine whether it is safe to change lanes includes a camera having a field of view such that the field of view corresponds to at least a portion of an area proximate the vehicle. The system also includes an object identifier electrically coupled to the camera, a distance determiner which determines a distance of the object which is in the field of the camera, and a display electrically coupled to the camera which displays an image generated by the camera and provides an indication of the type of object which is in the field of view of the camera and the distance of the object from the vehicle.
E. Component Drawings
The drawings in the following pages are not to scale.

Figure 43: Prototype Camera Holder

Figure 44: Prototype Arm Assembly
Figure 45: Front Mounting Assembly

Figure 46: Side Mounting Assembly (half)
Figure 47: Front Camera Shell

Figure 48: Side Mounting Spacer
Figure 49: Electronics Box Back

Figure 50: Electronics Box Bottom
Figure 51: Electronics Box Front

Figure 52: Electronics Box Left
Figure 53: Electronics Box Right

Figure 54: Electronics Box Top