Rear View

Project Proposal & Feasibility Study

Team 7
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1. Introduction

1.1. Project

1.1.1. Context and Motivation

In 2008, millions semi-trucks traveled over 140 billion miles in the United States. These semi-trucks, averaging between 5 and 8 mpg, consumed over 26 billion gallons of fuel. Also in 2008 there were 380,000 reported accidents involving semi-trucks resulting in millions in damages and lawsuits. Motivation for this project comes from a need to increase fuel economy and driving safety to improve some of the situations previously described.

1.1.2. Description

The objective of this project is to remove the rear view blind spot mirrors on semi-trucks. These mirrors are mounted on the front fenders of semi-trucks and are used to add more visibility in the semi-trucks blind spots. These mirrors will be replaces with a system of cameras and monitors in a effort to reduce the drag force produced by the existing blind spot mirrors. This project will not only increase the fuel economy, but will also increase the safety of semi-trucks.

1.2. Team

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 sector but after a few classes I decided to apply for the mechanical program. I am also involved in some extracurricular activities. I am currently an active member of Engineers without Border (EWB), National Association of Black Engineers (NSBE) and the president of the International Student Association Committee. On 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.
2. Project Objectives and Design Norms

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. Project Objectives

2.1.1. Fuel economy:

By replacing blind spot mirrors with a system of cameras and monitors, it will be possible to eliminate the drag caused by these mirrors. A study done by Kettering University shows that the drag force due to mirrors can account for nearly 10% of the total drag force produced. Since this project will only be concentrating on the blind spot mirrors, the expected reduction in drag force produced will be less than half of the total 10%.

2.1.2. Safety:

A system of cameras and monitors can increase the driver’s angle of vision. The placement of 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.

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.

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 a 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
focus on the profitable part but rather the care and attention to detail. We would pay
close attention to detail in producing our camera and monitoring system. 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. It would be terrible if we do not care for our equipments. We have to follow the
example 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 certain 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 our
drivers. We plan to care for the opinion of the drivers before we produce our system and
also after 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

In 2008 there were 9 million semi and combination trucks on the highway that traveled about 9 trillion miles that year (Appendix B). These trucks operate at an average of 6.2 mpg and consumed about 36.7 billion gallons of fuel in 2008 alone (Appendix B). Due to the shortage of cruel oil, the government has imposed some regulations to reduce the use of fuel in vehicles. These regulations have caused a lot of automobiles companies to reconsider the structure of their automobiles.

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 reconsidered and better solutions must be developed. One part of the truck that is being restructured to reduce the total amount of fuel consumed on fully loaded trucks is the side view mirrors. Most automobile companies have tried to reshape their side view mirrors to improve their fuel efficiency.

As stated previously, researchers at Kettering University have shown that exterior side view mirrors account for about 10% of the drag on semi-trucks. This percentage has come down from 10% to 8.5% in the last five years due to reconstruction of the side view mirrors. The reduction in the percent of drag on 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, a more aerodynamic side view mirror was developed.

One further solution to this illustrious problem is to replace the blind spot mirrors with a more aerodynamic camera and monitoring system. The camera and monitoring system would reduce the percentage of drag applied if properly implemented. It would also increase the safety of the driver by reducing the amount of accidents that occur on the highway. A typical driver is used to having long nights on the highway. It would be beneficial, and safer, for the driver to have a camera and monitoring system because the location of the monitors would create an easier view than a normal side view mirror. Along with the increase in safety on our roads, there is also the reduction of total CO2 emissions into the environment.

3.1. Aerodynamics

Aerodynamic is the study of the motion of air moving past a body. There have been considerable efforts to study the aerodynamics computationally. 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. Most of the aerodynamic testing on trucks is performed on a wind tunnel that can produce air at close to 60mph. Our project would utilize the Calvin College wind tunnel with a miniature model to compare our results with the data gathered from the preliminary road test. We will study the drag implications on the truck side mirrors.

3.1.1. Drag

The shape of a semi-truck is driven by cargo space. Most trucks are designed with specific criteria. The drag force that acts on the side view mirrors is calculated below:

\[ FD = \frac{(CD \times A \times p \times V^2)}{2} \]

Where

\[ CD -> \text{drag coefficient} \]
\[ A \Rightarrow \text{surface area of mirrors} \]
\[ \rho \Rightarrow \text{density of air} \]
\[ V \Rightarrow \text{average velocity} \]
\[ D \Rightarrow \text{diameter of mirror} \]
\[ \mu \Rightarrow \text{dynamic viscosity} \]

The amount of work done to overcome this drag force and the required energy input for a certain distance is shown below:

\[ W_{\text{drag}} = FD \times L \]
\[ E_{\text{in}} = \frac{W_{\text{drag}}}{\eta_{\text{truck}}} \]

Where
\[ W_{\text{drag}} \Rightarrow \text{work to overcome drag} \]
\[ FD \Rightarrow \text{force of drag} \]
\[ L \Rightarrow \text{distance traveled by truck} \]
\[ E_{\text{in}} \Rightarrow \text{required energy input} \]
\[ \eta_{\text{truck}} \Rightarrow \text{overall efficiency of truck} \]

3.1.2. Fuel Economy

The fuel consumption of the truck is calculated to see how much more fuel is being saved for the camera and monitoring system compared to the extruding side view mirrors. The fuel consumed by a diesel-engine powered truck is:

\[ L_{100} = 0.008051 \times FD \]

The amount of fuel and the cost of fuel that supplies energy are shown below:

\[ \text{Amount of Fuel} = \frac{m_{\text{fuel}}}{\rho_{\text{fuel}}} \]
\[ \text{Cost of Fuel} = \text{Amount of Fuel} \times \text{Unit Cost of Fuel} \]

The drag force and work done to overcome it are directly proportional to the drag coefficient. Then the percentage reduction in fuel consumption due to replacing the extruding side view mirrors with a camera and monitoring system is equal to the percent reduction in the drag coefficient:

\[ \text{Reduction Ratio} = \left( \frac{CD_{\text{extd.mirror}} - CD_{\text{camera sys}}}{CD_{\text{extd.mirror}}} \right) \]
\[ \text{Fuel Reduction} = \text{Reduction in Fuel} \times \text{Amount of Fuel} \]
\[ \text{Cost Reduction} = \text{Reduction in Fuel} \times \left( \frac{\text{Cost of Fuel}}{\text{year}} \right) \]
Since a truck has four sided mirrors and two front mirrors, the cost reduction would be multiplied by four to account for all mirrors.

3.2. Government Regulations

Government safety regulations can be an obstacle in implementing a camera-monitor system. However, regulations related to fuel economy and emissions do allow for improvements to be implemented.

3.2.1. Fuel Economy Standards

In a recent release, the government proposed plans to regulate fuel consumption of commercial trucks. This type of regulation would create incentives for products and research reducing aerodynamic drag.

3.2.2. Mirror Regulations

The Department of Transportation – Federal Motor Carrier Safety Administration has a standard for rear view mirrors that specifies requirements for rear view mirrors. The purpose of this standard is to reduce the number of deaths and injuries. The standard includes specification of performance and location of rear view mirrors (Appendix A).
4. Prototype and Testing

4.1. Prototype

In an effort to reduce fuel consumption and increase driver safety for semi-trucks on the road, there are several considerations that need to be made when looking at the mounting of the camera to the truck. The camera should be in a location where the view angle is sufficiently wide, as well as be in a place where the risk of braking off is minimized. The viewing angle is the amount of road the camera can see to either side of the truck, and can be varied by how far the center of the truck the camera is mounted. The housing the camera will be mounted in should be weather proof to maintain the full functionality of the camera and wired connections. Three different options will considered for the mounting of the camera that fit into the predefined specifications. Since several cameras will be mounted on different locations on front of the truck and on the cab, two different design options may be required to maximize the effectiveness of the camera.

4.1.1. Option 1

The first prototype option for mounting the cameras to the fenders would be a surface mounted unit. A small housing for the camera with aerodynamic design will be mounted to the front of the trucks and will allow the camera to be aimed at a desired angle to maximize the view for the driver. Adjustment of the camera angle will be limited based on the size and shape of the surface mounted housing and the viewing angle will also be limited due to the truck cab location. This option has a much smaller chance at being taken off when passing other objects while the truck is moving but has a more limited viewing angle and adjustment.

**Figure 1: Prototype Option 1**

4.1.2. Option 2

An option that has potential for a greater viewing angle and more adjustment would be option 2. The second prototype option for mounting the cameras to the front fenders would be an extending arm with a ball joint connection at the base of the unit and a fixed housing on the end. The arm would have a housing attached to the end for the camera that would be aerodynamically sound. The arm will also be hollow to allow for running wires in a closed space to conserve the integrity of the electrical connections. The arm should be long enough to extend the camera out close to the edge of the fender but should be should not extend past the edge of the truck. Moving the camera further from the fender will give a wider viewing angle and will as so allow for better adjustment of the
camera direction. Keeping the camera from hanging over the edge of the truck will ensure the housing and extension arm remain attached to the truck when the truck is in motion.

![Figure 2: Prototype Option 2](image)

4.1.3. Option 3

A third prototype option is similar to the second option with a small variation. The third camera mounting option will be to attach a fixed arm to the front of the truck and add ball joint adjustment to the housing. This small adjustment will provide greater support at the end of the arm, while maintaining the functionality previously described in option 2.

![Figure 3: Prototype Option 3](image)

4.2. Testing

In order to gain accurate fuel savings information and project payback information, some testing is required. Testing for this project will occur in three steps. A preliminary testing phase will give ball park force numbers produced by conventional mirrors while traveling at 60 mph. A secondary testing phase will happen in Calvin College’s wind tunnel, and will allow for more accurate force reduction data. And finally the third stage of testing will be real world testing on an actual truck traveling at 60 mph. A more detailed description of testing, and equipment required is as follows. After all of the testing is completed, it will be presented on graphs and tables for the final report. This data will also play a large role in the final calculations for fuel savings and payback period.
4.2.1. Preliminary Testing

Conducting preliminary tests in order to calculate rough fuel cost savings is essential in determining the feasibility of this project. In order to measure the force produced by a conventional blind spot mirror going down the freeway at 60 miles per hour will require several pieces of equipment. First, a standard conventional blind spot mirror is required to ensure accuracy of wind displacement and force production. A force gauge will then be 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 will be taken at several different speeds allowing for cost savings calculations at several different speeds.

Preliminary testing is the first step used in acquiring the raw data required. In order to collect this raw data, a mirror must first be purchased. With the acquisition of a new mirror, a push force gage was attached to the mirror with a horse clamp. The mirror was then taken out on the highway and used to test the drag force produced by the air at different speeds. Results from the test are shown below.

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Force (N)</th>
<th>Force (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*average</td>
<td>*average</td>
</tr>
<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>

At the end of the test the force, in pounds force (lbf), is used to calculate the amount of fuel that would be consumed by a truck annually and also the fuel savings. Fuel and cost savings calculations can be seen in Appendix E.

4.2.2. Wind Tunnel Testing

Testing of the force produced by the conventional mirror and the new camera mounting system can also be measured using Calvin College’s new wind tunnel. Use of the wind tunnel will allow for more accurate data collection and relation to a more accurate wind speed. Using a strain gauge we can measure force based on the bending of a piece of metal and get much more accurate data. With more accurate data, the economic models and cost saving numbers can be updated. The wind tunnel will also allow for testing and wind resistance measurements of the camera mounting prototypes.

The wind tunnel test would be the next test performed on our extruding rear view mirrors and our more aerodynamic camera and monitoring system. To acquire some data on the wind tunnel, we as a group would need to build a miniature model or place a mirror with a strain gage on the mirror and pass air through it at the required speed. From
the wind tunnel test, we should be able to verify the drag force difference between the old extruding side view mirrors and our new camera and monitoring system. The wind tunnel is able to run at speed of up to 200mph. The model would be mounted also on a scale able to measure forces. From the acquired data, the Reynolds’s number would now be calculated.

4.2.3. Real World Testing

For the last stage of testing and data collection, test will be completed on actual trucks traveling down the road. There are several aspects of desired testing that cannot be completed on a small scale or in a lab setting. The mirrors this design project will replace are supported by a system of three bars that also produce wind resistance. In order for our fuel savings calculations to be as accurate as possible, these rods must also be taken into account. To collect data on the entire conventional mirror hardware strain gauges will be attached to several locations on the support structure. These strain gauges will then give us several strain measurements that can be combined to find the total wind resistance produced. The force measured in this test will give us the final number for our fuel savings.

To verify our results from the wind tunnel and preliminary test, actual data has to be taken on a semi truck to compare with the results from our wind tunnel testing. We will also be looking inside the trucks to verify where exactly to place our monitoring system. Also from the field test, we would be able to get some actual data by attaching a strain gage on the side view mirror and testing for the deflection at 60mph on the highway. At the end of our field test, we would recalculate the drag force, and also our fuel consumption analysis (formulas in the research section).
5. **Camera – Monitor**

5.1. **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 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 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. The camera will also require a low light setting, like night vision or infrared capabilities. This capability is important for trucks to drive when it is dark out and when external light is limited. Cameras will be mounted in four locations on the front of the truck. Two cameras will be mounted on the front most section of the truck, and two cameras will be mounted on the outside of the cab in a similar orientation to existing mirror installation. This addition of 1-2 cameras on the trucks will improve safety and visibility for the large vehicles. The camera must also be capable of linking with a monitor placed in the cab of the truck. This connection can be either a wired connection or a wireless connection.

The monitor will be the 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 perceptively 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.
6. Financial
6.1. Budget

A preliminary budget for the project is shown below.

- Purchase rear view mirrors: ($80 for fender mirror, $120 for west coast mirror assembly)
- Camera dims and functionality (FREE? Gentex)
- Camera mounting system ($100)

6.2. Business Plan

I) Executive Summary:

With the new laws on fuel regulations which proposing that trucking companies reduce total fuel consumption by 15-20% before 2018, replacement of the two front mirrors would be a stepping stone to improving fuel efficiency on trucks per year. In our project hopefully, we would be able to increase the safety on our roads especially on the highway. With our new system in place, most trucking companies would save a sufficient amount of fuel consumption each year. Our system would also help to increase the safety on our roads by providing the drivers with a much easier, wider and comfortable area of focus. The ultimate goal of this project is to replace the front blind spot mirrors on a semi truck with a camera and monitoring system. This project will not only increase the fuel economy, but also increase the safety on our roads.

Although it might cost more to produce the camera and monitoring system, we believe that one of the best strategies to fuel efficient trucks is replacing the front mirrors. This project can be successful if it implies this newer monitoring system. The payback period for the car will be achieved during the lifetime of the semi truck.

We are currently in contact with managerial and technical personnel to ensure our product meets all the new requirements desired by the firm. Eric Walstra from Gentex is providing our team with a camera and monitor for testing of our prototype. Also with the help of Professor Rich DeJong (expertise of aerodynamics) we have been able to tackle some of the constraints that our project might face and now have more confidence to produce the best monitoring system. Professor Ned Nielsen is also an integral part of the project. He remains our main instructor throughout the project and a key resource in achieving success. Last and not the least our industrial consultant Ren Tubergen has challenged us as a team to make sure that we consider all aspects of this project. He also has provided us with a lot of resources on our subject matter and a lot of suggestion on how best to carry out some of our preliminary tests.
II) 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. Just like 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 "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).

With the millions of trucks striving to meet government regulation, there is a big market if we push for our product. With a big market on a lookout for new ideas to improve their fuel efficiency, we as a team could be the first group to try and help those companies reach their mark. We could be the pioneers and possibly have a patent for our invention so that we can make maximum profit. By applying our resources to a better camera and monitoring system we should be able to make a lot of profit from our system.

III) Industry Profile and Overview:

Due to the shortage of cruel oil, the government has imposed some regulations to reduce the use of fuel in vehicles. These regulations have caused a lot of automobiles companies to reconsider the structure of their automobiles. Our major customers would be the companies that shape the mirrors for the semi trucks. Hopefully with the push for better fuel efficient trucks our system will provide an acceptable alternative to the conventional blind spot mirrors.

There has been a lot of progress in the design and production of semi trucks. Unlike the older truck models, there is a significant trend in the newer trucks that are on the highways. The mirror accounts for about 8.5% of the total drag on the truck. Replacing the front two mirrors with a camera and monitoring system will eliminate most of the drag on the truck. In the design of our system, we have taken the initiative to review the government regulation on the mirrors. The side view mirrors are a standard and can’t be replaced while the front two mirrors are to be maneuvered in anyway necessary. In fact, some of the recent trucks have completely eliminated the front two mirrors.

The growth rate of different mirror shapes is very high. Through the years and with the recent rush to improve fuel economy, this large market is just waiting for someone to tap into it. If we are successful in the launch of our system, we could be the pioneers to a very big market and thereby make a lot of money.

The barriers to the market of mirrors are very large. For our system, we have the option to stay or leave at which ever point we want. While are product is in circulation we can be working on other trends to improve fuel economy. As a team we can both sell the technology to a truck company and not worry about the distribution and marketing making the maximum profit for a few years. Another option that would keep us in the market is to individually find companies that are willing to implement our new system. The issue with that option is that we would have to distribute the camera and monitoring system by ourselves. We can start locally and if we achieve a good enough profit possible expanding to a domestic or even internationally level. With our new system in place, the sky is the limit to the amount
of sales that we could achieve. If we scale down our system, we might also be able to tap into the automobile industries. The future looks bright for the team if we take initiative right now and who knows what other new systems we could come up with to reduce fuel usage on trucks.

IV) Business Strategy
A) Desired image and market position =>
   The position in the market looks really looks great right now. Our plan is to get into a market that no company has really got a strong hold off. The most camera and monitoring system used in vehicles are the ones for reversing. Well our system would not only be profitable but has a byproduct of making an environment safer. They image of our product will be viewed and desired by every trucking company because it will show that that they are concerned about their society.

B) Company Goals and Objectives
   These are some of the goals and objectives that we believe that our camera system would provide.

   Goals
   • Reduce wind resistance by approximately 2% leading to fuel saving and CO2 emissions.
   • Keep cost per unit such that the pay-off period through the life of the truck.

   Other Considerations
   • Obtain wind resistance data from actual trucks.
   • Perform scale model experiments in Calvin wind tunnel.
   • Evaluation mass production options and marketability.
   • Adaptability for drivers to the new system.
   • Research other fuel efficiency systems.

   Approximate Estimations of Fuel Savings
   • Assume linear relationship between wind resistance and fuel economy.
   • Total cross sectional area of truck: 57 sq. in.
   • 2% reduction in wind resistance.
   • 150,000 miles per truck per year @ 8 mpg.
   • Annual fuel savings of 175 gallons per year on a truck.
   • Annual savings of $525/yr assuming $3/gal.

   Recent Financial Data
   • Tractor trailers logged 143.6 billion miles in the United States alone at an average of 5.9 miles per gallon.
   • 24.3 billion gallons of diesel fuel or 600 million barrels or oil
• At $100 per barrel of crude oil, the direct economic impact is 57 billion dollars per year

• 2% of wind resistance => 1% reduction in fuel savings
• Potential fuel savings of 500 million gallons per year
7. Conclusion

Replacement of the blind spot mirrors on semi trucks has several added benefits. Increased safety, fuel savings, and CO2 emission reduction are just some of the desired outcomes for this project. Fuel savings of roughly 2% or more will help the economy push toward a more sustainable future and stimulate economic growth. Use of cameras in place of conventional mirrors allows for wider viewing angles and greater visibility for drivers. Overall this project is one that could have a great impact on safety for truckers as well as provide an avenue to a brighter future for our country and world.
Appendix A. Government Regulations for Rear View Mirrors

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 and less than 11,340 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.
### ANNUAL VEHICLE DISTANCE TRaveled IN MILES AND RELATED DATA - 2008 1/  
BY HIGHWAY CATEGORY AND VEHICLE TYPE  

<table>
<thead>
<tr>
<th>YEAR</th>
<th>ITEM</th>
<th>PASSENGER CARS</th>
<th>MOTOR-CYCLES</th>
<th>BUSES</th>
<th>OTHER 2-AXLE 4-TIRE VEHICLES 3/</th>
<th>SINGLE UNIT 2-AXLE 6-TIRE OR MORE TRUCKS 4/</th>
<th>COMBINATION TRUCKS</th>
<th>SUBTOTALS</th>
<th>SINGLE UNIT 2-AXLE 6-TIRE OR MORE AND COMBINATION TRUCKS</th>
<th>ALL MOTOR VEHICLES 2/</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Motor-Vehicle Travel: (millions of vehicle-miles)</td>
<td>115,532</td>
<td>1,348</td>
<td>1,027</td>
<td>79,842</td>
<td>7,720</td>
<td>40,342</td>
<td>143,373</td>
<td>47,542</td>
<td>243,916</td>
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<tr>
<td>2007</td>
<td>Inerstate Rural</td>
<td>122,183</td>
<td>1,410</td>
<td>868</td>
<td>82,030</td>
<td>7,188</td>
<td>42,832</td>
<td>204,212</td>
<td>46,810</td>
<td>258,636</td>
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<td>2008</td>
<td>Other Arterial Rural</td>
<td>194,567</td>
<td>2,416</td>
<td>1,023</td>
<td>139,867</td>
<td>13,648</td>
<td>25,426</td>
<td>331,794</td>
<td>36,071</td>
<td>372,765</td>
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<tr>
<td>2007</td>
<td>Other Rural</td>
<td>204,123</td>
<td>2,305</td>
<td>1,015</td>
<td>145,685</td>
<td>13,877</td>
<td>28,193</td>
<td>350,108</td>
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<td>Other Rural</td>
<td>166,664</td>
<td>1,928</td>
<td>1,772</td>
<td>145,171</td>
<td>18,745</td>
<td>13,306</td>
<td>349,855</td>
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<tr>
<td>2007</td>
<td>All Rural</td>
<td>203,465</td>
<td>1,820</td>
<td>1,722</td>
<td>148,912</td>
<td>15,565</td>
<td>14,919</td>
<td>352,097</td>
<td>26,786</td>
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<tr>
<td>2008</td>
<td>Interstate Urban</td>
<td>203,412</td>
<td>5,655</td>
<td>3,194</td>
<td>381,883</td>
<td>34,423</td>
<td>79,496</td>
<td>854,463</td>
<td>115,911</td>
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<td>2007</td>
<td>Interstate Urban</td>
<td>353,761</td>
<td>5,486</td>
<td>1,725</td>
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<td>33,723</td>
<td>82,565</td>
<td>920,418</td>
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<td>2008</td>
<td>Other Urban</td>
<td>262,321</td>
<td>2,738</td>
<td>1,077</td>
<td>159,605</td>
<td>13,127</td>
<td>30,223</td>
<td>431,926</td>
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<td>2007</td>
<td>Other Urban</td>
<td>267,650</td>
<td>2,631</td>
<td>1,052</td>
<td>170,894</td>
<td>13,143</td>
<td>31,282</td>
<td>438,216</td>
<td>41,406</td>
<td>481,258</td>
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<tr>
<td>2008</td>
<td>All Urban</td>
<td>650,417</td>
<td>6,051</td>
<td>2,218</td>
<td>577,117</td>
<td>37,400</td>
<td>33,727</td>
<td>1,247,534</td>
<td>71,197</td>
<td>1,318,731</td>
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<tr>
<td>2007</td>
<td>Total Rural and Urban</td>
<td>710,118</td>
<td>5,444</td>
<td>2,205</td>
<td>504,575</td>
<td>35,147</td>
<td>30,882</td>
<td>1,440,063</td>
<td>66,038</td>
<td>1,506,101</td>
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<tr>
<td>2008</td>
<td>Total Rural and Urban</td>
<td>1,112,738</td>
<td>8,786</td>
<td>3,369</td>
<td>745,722</td>
<td>47,557</td>
<td>54,019</td>
<td>1,859,400</td>
<td>111,547</td>
<td>1,970,948</td>
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<td>2007</td>
<td>Total Rural and Urban</td>
<td>1,422,977</td>
<td>10,070</td>
<td>2,357</td>
<td>735,044</td>
<td>45,208</td>
<td>52,150</td>
<td>1,978,320</td>
<td>107,444</td>
<td>1,985,764</td>
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<tr>
<td>2008</td>
<td>Number of motor vehicles</td>
<td>1,419,462</td>
<td>14,204</td>
<td>7,114</td>
<td>1,138,033</td>
<td>83,581</td>
<td>143,507</td>
<td>2,723,463</td>
<td>227,458</td>
<td>2,950,921</td>
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<tr>
<td>2007</td>
<td>Registered 5/</td>
<td>1,390,123</td>
<td>7,752,926</td>
<td>843,310</td>
<td>101,234,949</td>
<td>78,032,882</td>
<td>2,210,859</td>
<td>238,314,959</td>
<td>9,006,738</td>
<td>245,315,694</td>
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<tr>
<td>2008</td>
<td>Average miles traveled 6/</td>
<td>11,788</td>
<td>1,896</td>
<td>9,890</td>
<td>10,981</td>
<td>12,962</td>
<td>54,743</td>
<td>111,432</td>
<td>25,256</td>
<td>136,688</td>
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<td>2007</td>
<td>Per vehicle 5/</td>
<td>12,304</td>
<td>1,068</td>
<td>9,835</td>
<td>10,962</td>
<td>12,540</td>
<td>85,937</td>
<td>117,300</td>
<td>25,152</td>
<td>142,452</td>
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<td>2008</td>
<td>Total miles traveled 6/</td>
<td>2,563,083</td>
<td>18,396</td>
<td>150,827</td>
<td>1,021,080</td>
<td>89,061</td>
<td>143,827</td>
<td>4,475,004</td>
<td>227,458</td>
<td>4,693,466</td>
</tr>
<tr>
<td>2007</td>
<td>(millions)</td>
<td>2,642,409</td>
<td>17,296</td>
<td>147,086</td>
<td>1,029,210</td>
<td>82,014</td>
<td>145,098</td>
<td>4,570,818</td>
<td>227,080</td>
<td>4,797,901</td>
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<tr>
<td>2008</td>
<td>Total fuel consumed 7/</td>
<td>71,467,204</td>
<td>286,365</td>
<td>1,120,639</td>
<td>61,193,934</td>
<td>9,099,726</td>
<td>28,014,441</td>
<td>132,858,130</td>
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<td>2008</td>
<td>Average fuel consumption per vehicle 8/</td>
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<td>3,030</td>
<td>1,310</td>
<td>650</td>
<td>1,456</td>
<td>12,101</td>
<td>557</td>
<td>4,075</td>
<td>607</td>
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<tr>
<td>2007</td>
<td>(gallons)</td>
<td>547</td>
<td>3,172</td>
<td>1,372</td>
<td>651</td>
<td>1,470</td>
<td>12,805</td>
<td>574</td>
<td>4,270</td>
<td>693</td>
</tr>
<tr>
<td>2008</td>
<td>Average miles traveled per gallon 7/</td>
<td>22.6</td>
<td>0.95</td>
<td>6.4</td>
<td>18.1</td>
<td>8.5</td>
<td>5.4</td>
<td>20.5</td>
<td>0.5</td>
<td>17.5</td>
</tr>
<tr>
<td>2007</td>
<td>(miles)</td>
<td>22.6</td>
<td>0.95</td>
<td>6.1</td>
<td>18.0</td>
<td>8.2</td>
<td>5.1</td>
<td>20.4</td>
<td>0.5</td>
<td>17.5</td>
</tr>
</tbody>
</table>

1/ The 50 states and the District of Columbia report travel by highway category, number of motor vehicles registered, and total fuel consumed. The travel 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 (VUID), and other sources.
2/ Totals by highway category are from table VM-2. Some changes between rural and urban roadways can be attributed to 2002 boundary changes.
3/ Other 2-Axle 4-Tire Vehicles which are not passenger cars. These include vans, pickup trucks, and sport utility vehicles.
4/ Single-Unit 2-Axle 6-Tire or More Trucks on a single frame with at least two axles and six tires.
5/ Truck registration figures are from tables M-1 and M-4 with truck distribution estimated by the FHWA.
6/ Vehicle occupancy is estimated by the FHWA from the 2001 National Household Travel Survey (NHTS). For heavy trucks, 1 motor vehicle miles traveled = 1 person-miles traveled.
7/ Total fuel consumption figures are from tables MF-21 and MF-27. 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 VUID, and other sources with nominal inputs for motorbikes and buses.
Appendix C: Government Fuel Consumption Regulation Proposal

Big trucks may face fuel consumption regulations

By James R. Healey, USA TODAY

The government on Monday proposed the first regulations limiting fuel consumption of work trucks — from big-rig trucks to concrete mixers, buses, even heavy-duty pickups — saying the rules finally address the thirstiest and most-polluting vehicles on the road.

The proposal, which would take effect with 2014 models and ratchet up through 2018 models, requires a public comment period and other procedures, and wouldn’t be final until next year.

The rules would raise the cost of trucks and the diesel engines most of them use, but the government says the payback in fuel-cost savings would be as fast as one year for heavily used over-the-road trucks. Even so, "We are concerned that this could price some buyers out of the market," says Kyle Treadway, chairman of the American Truck Dealers and owner of a Kenworth dealership in Salt Lake City. Lower fuel consumption is good, he agrees, but the federal proposal "is expected to add thousands of dollars to the cost per truck."

"We’re reviewing the proposed rules and approaching (them) with caution," says Norita Taylor of the Owner-Operator Independent Drivers Association, a trade group representing owners of one or two trucks or small fleets. Well-meaning initiatives sometimes place outsize cost burdens on small-scale truckers, she says.

A conservative group that opposes government involvement in the economy denounced the proposed rules as "energy rationing." Myron Ebell, director of the center for energy and environment at the Competitive Enterprise Institute, said, "The only way to increase fuel efficiency as quickly (as proposed) will be to move less freight," damaging the economy.

The complex proposal would cut fuel use 10% to 20%.

"We’ve been flatlined at 6 to 6.5 miles per gallon for years" for a loaded tractor-trailer rig, says Glen Kedzie, vice president at the American Trucking Associations, a major industry trade group. That translates to about 16 gallons of diesel fuel per 100 miles. A 20% gain would cut fuel use to about 14 gallons per 100 miles.

Major trucking and shipping interests endorsed the move for its potential cost savings. ATA noted that it has backed fuel-consumption regulations since 2008. "The proposal, using current technology, is achievable," spokesman Brandon Borgna says.

A consortium representing trucking, shipping and drivetrain companies says it recommended fuel-use regulations for commercial trucks as far back as 2006. Now called the Heavy-Duty Fuel Efficiency Leadership Group, it "devised a set of principles" for big-truck fuel use and proposed them to the Obama administration this year.

Though the emphasis is on semi-tractor rigs and other big trucks, the regulations would apply to vehicles as small as those with an 8,500-pound gross vehicle weight rating (the safe weight of the truck and cargo combined) — a Ford F-250 pickup or equivalent.
The heavy-truck rules would join fuel-economy rules for passenger vehicles that require automakers to average 35.5 miles per gallon in 2016. A recent proposal would push that to as much as 62 mpg in 2025. The government forecast the truck rules would cost the industry $7.7 billion, but save $35 billion in fuel. The standards would apply to the manufacturers of both engines and trucks, not to the companies that use them. In the heavy-duty world, buyers often choose engines separately from trucks.

Navistar, which builds both big trucks and the engines that power them at its International Truck and Engine unit, says it's too soon to determine the precise effect of the proposed rules, but hopes the government will "properly incentivize" advanced technologies. Navistar makes fuel-saving diesel-electric hybrid systems for buses and commercial trucks.

The regulations don't address the trailers that semis pull — requiring them to be more aerodynamic, for example — though they dramatically affect fuel use.

Critics say the standards might not be high enough and should "do more to draw advanced technologies into the market" by giving added credit for hybrid drivetrains or advanced transmissions, says Therese Langer, head of transportation issues at the American Council for an Energy-Efficient Economy, an advocacy group.

The rules are a joint product of the Environmental Protection Agency and the National Highway Traffic Safety Administration. EPA specifies fuel-use limits in grams of carbon dioxide emitted per ton-mile. NHTSA specifies gallons of fuel used per 1,000 ton-miles. They say their approaches complement each other.

They both are intended to take into account that a truck hauling steel will burn more fuel, and thus emit more CO₂, than a similar truck hauling feather-bedding. "With just five years of new vehicles sold under this program, America will eliminate the same amount of oil that we import from Russia and Nigeria in a year," says Rep. Edward Markey, D-Mass., member of several energy-related House committees.
Appendix D: Accident Statistics

Department of Transportation – National Highway Traffic Safety Administration


<table>
<thead>
<tr>
<th>Initial Point of Impact</th>
<th>Crash Severity</th>
<th>Single-Vehicle Crashes</th>
<th>Multiple-Vehicle Crashes</th>
<th>All Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatal</td>
<td>Injury</td>
<td>Property Damage Only</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
<td>Number</td>
<td>Percent</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Front</td>
<td>441</td>
<td>59.5</td>
<td>3,000</td>
<td>29.9</td>
</tr>
<tr>
<td>Left Side</td>
<td>38</td>
<td>5.1</td>
<td>1,000</td>
<td>6.2</td>
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<tr>
<td>Right Side</td>
<td>67</td>
<td>9.0</td>
<td>2,000</td>
<td>17.1</td>
</tr>
<tr>
<td>Rear</td>
<td>38</td>
<td>5.1</td>
<td>*</td>
<td>3.2</td>
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<tr>
<td>Noncollision</td>
<td>94</td>
<td>12.7</td>
<td>4,000</td>
<td>40.6</td>
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<tr>
<td>Other/Unknown</td>
<td>63</td>
<td>8.5</td>
<td>*</td>
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<tr>
<td>Total</td>
<td>741</td>
<td>100.0</td>
<td>11,000</td>
<td>100.0</td>
</tr>
</tbody>
</table>

*Less than 500.
Appendix E: Fuel and Cost Savings Calculations

Calculations done in Engineering Equation Solver (EES) Program

Equations:

Disc Force Calculation and Cost analysis.
1 December 2010
Team 7: Rear-View

Assumptions:

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

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

Calculations:

\[ V_{\text{ft/s}} = V_{mph} \cdot \left( \frac{1.457 \text{ ft/s}}{\text{mph}} \right) \]

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

\[ h_{\text{Saved}} = \frac{\text{TotalForce} \cdot V_{\text{ft/s}}}{550 \text{ [lbf-ft/s-hp]}} \]

\[ h_{\text{NowRequired}} = h_{\text{truck}} - h_{\text{Saved}} \]

\[ h_{\text{Percent}} = \frac{h_{\text{NowRequired}}}{h_{\text{truck}}} \]

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

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

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

**Unit Settings: SI kPa kJ mass deg**

- CostOfFuel = 3 [$/gal]  
- hpNowRequired = 198.9 [hp]  
- hpSaved = 1.056 [hp]  
- MirrorNumber = 2  
- mpgtruck = 10 [miles/gal]  
- TotalGallonsUsed = 50000 [gal]  
- \( V_{ft/s} = 88 \) [ft/s]

- FuelSaved = 264 [gal]  
- hpPercent = 0.9947  
- hptruck = 200 [hp]  
- MoneySaved = 792 [$$]  
- TotalForce = 6.6 [bf]  
- TravelDistance = 500000 [miles]  
- \( V_{mph} = 60 \) [mph]
References: