Semi Pro

Project Proposal and Feasibility Study

Semi Pro - Team 16
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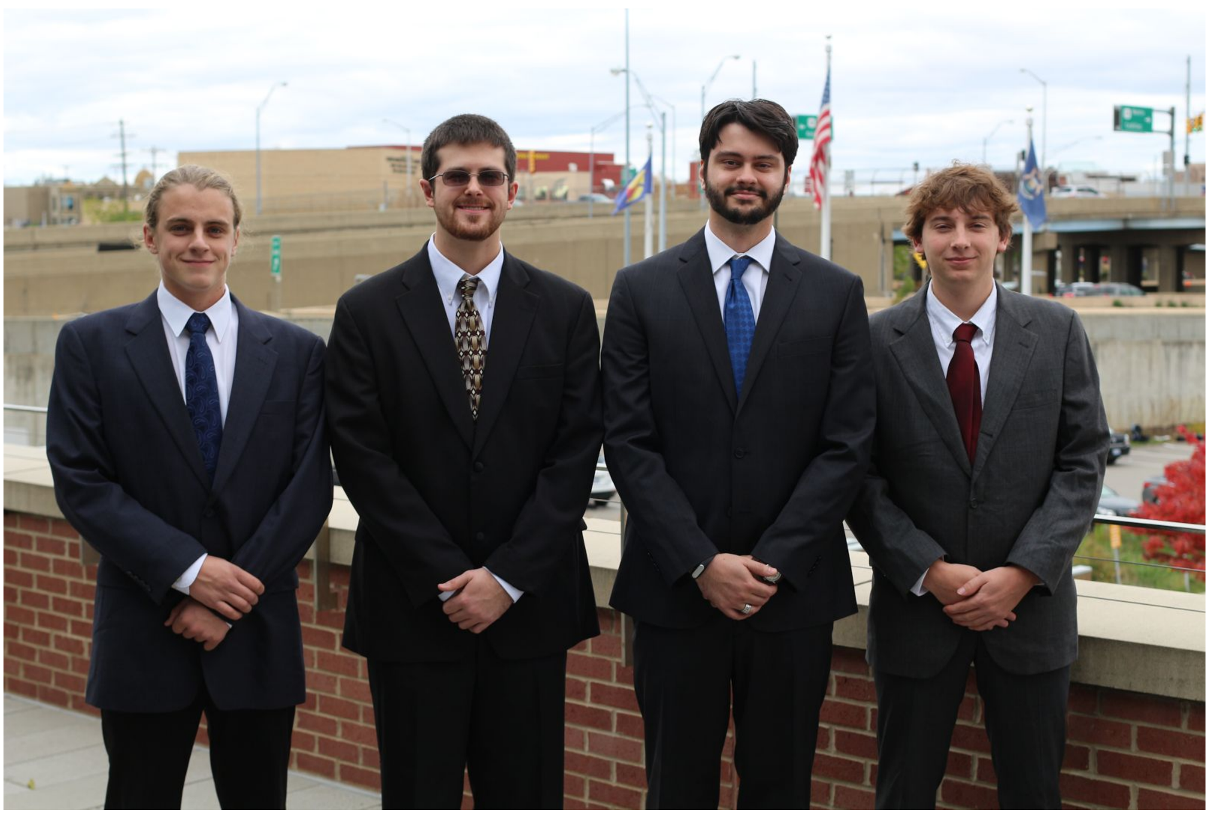
Engr Senior Design 339/340



Executive Summary

This project includes the development and production of a camera system to replace the convex mirrors on the front of semi-trucks. This system will reduce drag on the vehicle, improve visibility around the vehicle and increase driver accountability. With the help of our mentor, Eric Walstra of Gentex Corporation, Team 16 - Semi-Pro has created a proposal for a camera system than can be integrated into any existing truck. Using two 2 cameras mounted on the fender of the cab, and a removable, wireless, and self powered rear-view camera, the camera system will increase safety and reduce drag on the semi truck. In this design we take into consideration our christian design norms to promote caring, stewardship, and justice on the road. The camera feeds will be displayed aesthetically in the cab to assist the driver while simultaneously being recorded to enhance driver accountability. The target audience of truck drivers is key in our design and a sample group will be consulted for design consideration. With a budget of $500, the team can effectively order parts for this project at just over $300. If this product were produced full scale out of the parts we selected, the estimated sell price would be $700. Overall this project is feasible and worth pursuing.

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1 Introduction

This Project Proposal and Feasibility Study document contains information pertaining to the Calvin College senior design team Semi-Pro.

1.1 Problem Definition

The Problems team Semi-Pro is trying to solve with our project are: Semi-truck visibility, drag on a semi-truck and accountability. Current semi trucks use two flat side view mirrors which are required by law, and optional convex mirrors for enhanced visibility, as seen in Figure 1 in the Appendix. These convex mirrors increase the wind resistance on the truck which requires more work to move the semi-truck, resulting in a lower fuel efficiency. Our team seeks to decrease the drag on the truck while increasing the visibility, by modifying or removing the convex mirrors.

http://www.m-cna.com/construction_industry
Figure 1: Semi-Truck with Convex Blind-Spot Mirror

The other problem our team seeks to solve is visibility when backing a semi trailer into a dock. Currently Semi drivers rely solely on sideview and rearview mirrors to back up. While it is a skill than many seasoned truck drivers have mastered, backing a semi-trailer up can still be very difficult and dangerous. There is almost no way to see if there is something directly behind the truck. Team Semi-Pro seeks to make a way for semi-truck drivers to have a convenient back-up system with more visibility and a way for to see if there are people or things in the way when backing up a trailer. An issue that arises with this concept is that each truck connects to multiple trailers, and any backup cameras must be removable from every truck or they would need to be attached to the truck itself.

If semi truck drivers get into an accident there is not a way to tell who is at fault rather than word of mouth and after crash analysis. Based on data from the Federal Motor Carrier Safety Administration, There are on average more than 90,000 injury accidents per year on large trucks and busses, more than 4,600 of which are fatal accidents.[1]

With our design we both hope to lower these numbers, and provide accurate data when a crash does occur. Some type of recording system would aid law enforcement with crash data holding drivers, and trucking companies accountable for the problems caused by crashes in semi-trucks.

1.2 Design considerations

To solve the problems listed in section 1.1, team Semi-Pro primarily focused on a camera system.
It was originally considered to remove all of the sideview mirrors (flat mirrors, and convex). This idea was rejected because of legal obligations. If the flat side mirrors were removed and a camera system put in its place, the camera system would always have to be on, even when the semi-truck was off. This would be a challenge to keep the system powered without draining the battery.

The team considered mounting the camera to the top of the truck on a mechanism that would make the camera pop up when backing up, but eventually decided on a detachable backup camera for better visibility of obstructions behind the trailer.

Team Semi-Pro decided to only eliminate the convex mirrors, replacing them with a camera. This would reduce drag in the truck and provide similar or enhanced visibility when compared with the convex mirrors.

1.3 Team

The team consists of two electrical and two mechanical engineering students. Taylor Mulder and Isaac Embertson are the electrical engineers of the team. Robert Lanser and Adam Christensen are the mechanical engineers on this project. All members of the team are in the fourth year of the engineering program at Calvin.

Adam Christensen is a mechanical engineering student pursuing a sustainability designation. Adam has interned at Farnsworth Inc., an architectural-engineering firm, as an HVAC and plumbing design engineer, and with Masonite Corp., an internationally leading residential door manufacturer, in their codes and compliance department at their research and development center.

Isaac Embertson is an electrical engineering student in his fourth year of the engineering program at Calvin. He has one year of internship experience at BorgWarner, working with the assembly systems of an automotive plant.

Taylor Mulder is an electrical engineering student in his fourth year at Calvin College. He also has a minor in Computer Science. He has two years of internship experience at Cadillac Castings, Inc. He has accepted a job with Cadillac Castings, Inc as an Electrical Engineer.

Robert Lanser is a mechanical engineering student with an international designation, and four years of internship experience at Innotec, working with the production of automotive components.

1.4 Course & College information

Calvin College is a liberal arts college with an engineering program. For the engineering program, seniors are required to work on a final capstone project in the last year of the program. This capstone class is split up in two semester long classes called Engr 339, and Engr 340. ENGR 339 is a two credit semester portion of the class. This section is focussed on defining the project and determining feasibility of the project. The second section of the class ENGR 340 is a four credit class that is more focused on implementing and developing the final project.

2 Project Management

2.1 Team Organization

The team will be split into two primary parts. The Mechanical Engineers (Adam and Robert) will focus on the physical components of the system. This includes the cameras, displays and mounting equipment supporting the cameras. The Electrical Engineers (Taylor and Isaac) will work primarily on the software and communication aspects of the camera system.

Team meetings are run on a weekly basis and are scheduled when it is most beneficial for the group to meet together, generally on non-lecture days. Team meetings typically begin with updates and a brief informational introduction to get the group up-to-date, then work is assigned and the group carries out the assigned work. At the conclusion of the meeting, the group assigns work and sets a date for the next group meeting.

The following figure shows the current organization of the group, including advisors, course instructors and consultants associated with the project.

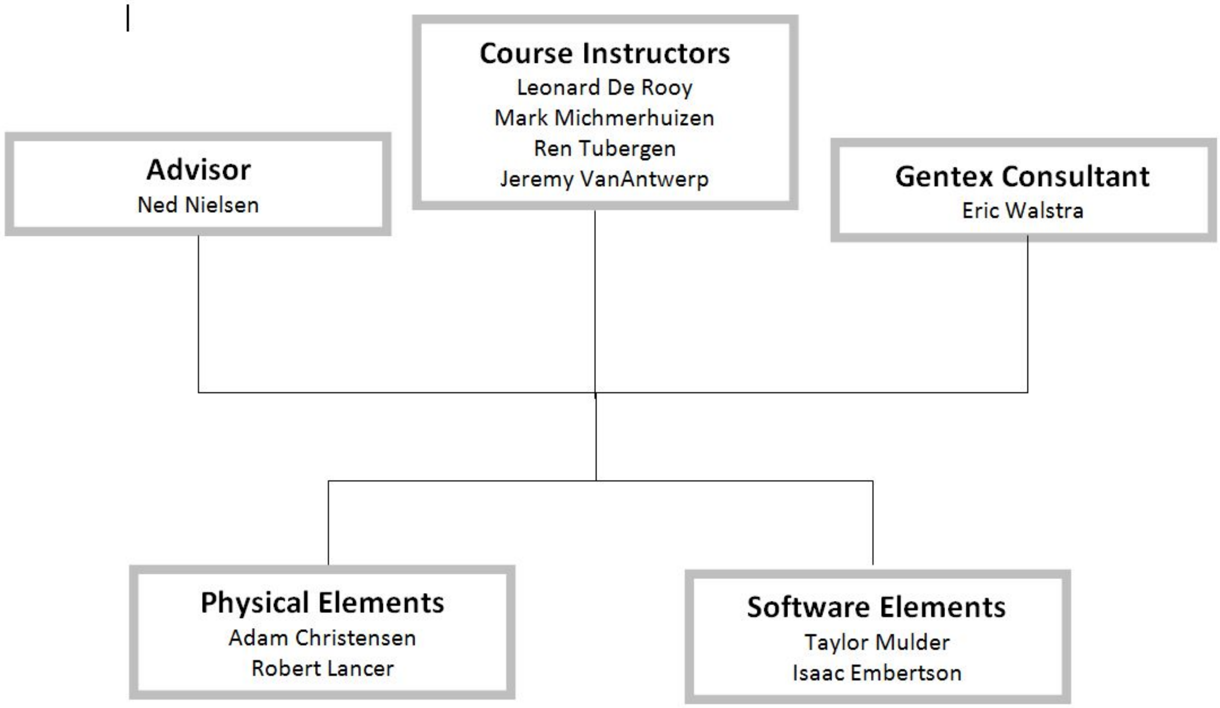

Figure 2: Team Organization Chart

For further information, all relevant documents can be found at:
http://engr.calvinblogs.org/16-17/srdesign16/

2.2 Schedule

The group handles scheduling in several ways. A Gantt Chart was created to schedule tasks for the project. The group generally meets on a weekly basis to discuss relevant parts of the project. The schedule is updated if necessary when the group meets and is changed according to the consensus of the group. If any issues arise, they are discussed within the group and resolved in a way that takes each member of the group into consideration. For further information, see Task Specifications and Schedule.

2.3 Budget

The budget is currently handled by the group as a whole. The budget is typically updated every time a major transaction occurs. This will serve as a tool for the project in that it will give the group an idea of the overall cost of the project as well as the costs for individual project components. This can be a useful factor for determining theoretical revenue for our project (if applicable) and estimate costs of mass production. If issues arise with the budget, the group meets and discusses the reasons behind the issue and any possible solutions that may be taken. For further information, see Business Plan. The provided budget from Calvin College is $500 for purchasing prototype components for the senior design project. Team Semi-Pro anticipates this budget to be sufficient for prototyping the camera system.

2.4 Method of Approach

The design approach for the project consists mainly of brainstorming sessions with the whole group. Each member submits solutions, whether to the larger problem or some smaller issue within the project. These ideas are evaluated by the group and the best idea is used. If there is a tie in the decision, the group enters an educated discussion where all sides of the issue are presented and the group re-evaluates the ideas present.

The research approach is similar to the design approach, in that each member of the group performs research for the project, with a concentration on the part of the project that corresponds the most with their Engineering concentration and experience. Useful research is evaluated at the group level and either used as a tool to work on the project or set aside for possible future use.

In terms of communication methods, each member of the group has an equal voice whenever the group needs to discuss a topic. The group members maintain good communication with each other, keeping the group tight and well-informed at all times. This communication is done primarily through social media and email.

In all approaches, Christian values are applied. Each team member is responsible for maintaining self-control and imitating Christ in their interactions with one another. Each team member is expected to act with integrity and positively represent Calvin College.

3 Requirements

For this project to be considered a success, the system must conform to the following requirements.

3.1 Interface Requirements

The interface of the camera system must be convenient for the truck operator to use. This convenience will mean that the camera system does not require the driver to turn it on, make adjustments, or modify the camera system in any way. The diver should be able to look at the side he wishes to change lanes in and see the camera that corresponds to the same side.

3.2 Functional Requirements

Some functional considerations of this project include the stability of the camera mounts, which must be able to hold up against wind, 70 MPH driving speeds, and occasional bumps/scuffs. The camera system must be durable; the camera system must be able to hold up in harsh conditions including freezing, muddy, and hot summer days. The cameras must withstand a temperature between -20 to 120 degrees Fahrenheit. The video must have sufficient quality; video must be wide angle of at least 120 degrees so drivers can clearly see what is behind them when driving. Finally, the system must be able to store at least 24 hours of footage and have sufficient viewing range. The connection between camera and display must be able to easily and reliably reach from a truck cab to the back of a 53’ trailer.

3.3 Performance Requirements

Some performance requirements taken into consideration that team Semi-Pro hopes to achieve through research and development include the following: An increase of 1% for Miles per Gallon (mpg), a 2% decrease of force acting on the front of the vehicle, a viewing angle that eliminates all blind spots and a depth increase to accurately see how far behind the trailer other vehicles are.

3.4 Environmental Requirements

The system shall satisfy all regulations regarding emissions and motor vehicles. If the the rear camera is a self-powered module, it should utilize a renewable energy source such as a photovoltaic panel to provide power to the module. For the camera elements powered by the semi-truck, the system should not waste electricity provided by the semi-truck.

4 Task Specifications and Schedule

These are the major tasks and subtasks for this project, as well as percentage of completion:
Assigned Project Tasks:

- PPFS Outline (100%)
- WBS (100%)
- Project Brief for Industrial Consultant (100%)
- Oral Presentations (100%)
- Website (100%)
- Poster (100%)
- PPFS Draft (100%)
- PPFS (100%)

Project Design Tasks:

- Mirror Testing (0%)
    - Test Guideline Generation (0%)
- Side Camera Design (28%)
    - Component Research (75%)
    - Case (0%)
    - Mounting Design (0%)
- Display Design (28%)
    - Layout Design (0%)
    - Communications (0%)
    - Component Research (75%)
- Rear Camera Design (28%)
    - Component Research (75%)
    - Case (0%)
    - Mounting Design (0%)
- DVR (38%)
    - Research (75%)
    - Mounting Design (0%)

The estimated total expected person-hours needed to complete the design is 400 hours. For further information regarding task choices, see System Architecture.
For further information and task schedules, visit http://engr.calvinblogs.org/16-17/srdesign16/.

5 System Architecture

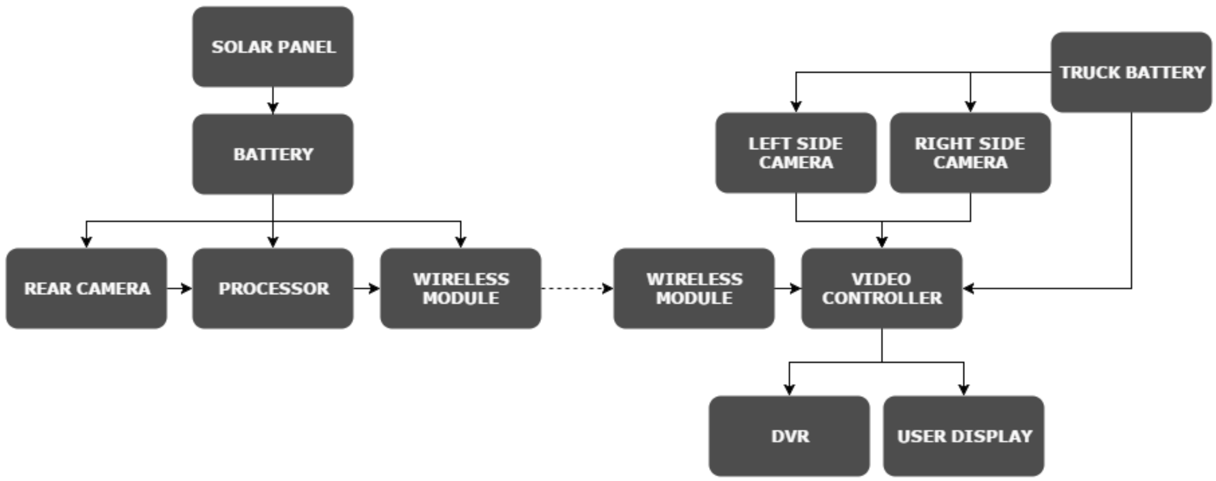

Figure 3: System Process Diagram

The system is separated into two modules that will communicate via a wireless module. Each component will be powered separately with no reliance upon the other module. The module that will be located on the trailer of the semi-truck is the left portion of Figure 3. This will hopefully be powered by a separate battery and renewable power source such as a solar panel. It will contain a camera facing backwards and will have a wireless module to communicate with the front module. The right portion of Figure 3 is the module that will be located in the tractor. This will run off of the truck battery and will contain two cameras, one for each side; a controller,a wireless module, a user display, and a dvr module. These two modules will encompass a total system that will enhance visibility and reduce drag.

6 Design

Pictured above in Figure 3 is the core build of the proposed system. The following sections will discuss the purpose and need of each block in the figure and proposed the ideal component for each function.

6.1 Design Criteria

All cameras will need to be free of any infrared (IR) filtering. This will improve night vision, especially when paired with IR LEDs. Their casing should protected them from the elements and debris kicked up by other vehicles as well as be streamlined to create as little drag as possible. The len’s need to remain clear with little to no maintenance.

The rear camera should be equipped with a processor and wireless communication module powerful enough to send a clear video stream to the driver with no interference from other devices. The primary limiting factors of wireless communication are the bandwidth and range. The power supplied should be enough to at least last an eleven hour shift, and ideally renewable from the addition of a solar panel. All of this needs to be packaged in a manageable container that can be easily attached the rear of trailer at a height high enough to give the driver a perceptive distance between the trailer and objects behind it.

Video from all cameras will be processed in the main cab and displayed clearly on one or more screens that are located within a driver's natural eye movement pattern without being a distraction. These video feeds should then be recorded to a digital video recording (DVR) device for driver accountability.

6.1.1 Design Norms

The leading design norms for this project are integrity, delightful harmony, transparency and trust. Our product will show our integrity through the pursuit of safety for all drivers on the roads and pedestrians working around semi-trucks by providing the trucks with much needed visibility. By replacing the convex mirrors with low-profile cameras, our product will work in harmony by saving diesel fuel and avoiding interference with other systems similar to ours. By recording all of the drivers interactions on the road, our product will bring justice to those at fault in accidents. Our system will be transparent to the customer, with any limitations or defects clearly communicated to the user. Finally, our system will be trustworthy and reliable, which can be counted on to work in a variety of situations and environments.

Through the processes of creating our final design, our team will keep in mind all of the design norms. We intend our product to be culturally appropriate and serve its intended audience how they need it most. We will actively seek their valued input. We hope to work together with trust, integrity and transparency, building not only a quality product, but a reliable team that our sponsors and college will be proud to support.

6.2 Design Alternatives

The biggest decision was choosing a form of wireless communication to transfer the video stream from the rear camera. We knew we wanted as little interference as possible, so analog signals were ruled out and we inspected digital forms of wireless communication only. The big three we focused on were bluetooth, WiFi, and spread spectrum. The first two are commonly know. Spread spectrum is unique for instead of transmitting over a few frequencies at high power, it transmits over a large spread of frequencies at low power. This means it is less likely to run into interference since devices would only interfere over a few frequencies. While this might sound ideal, the technology is quite expensive (a typical transmitter would run a couple hundred dollars), so this idea was cast out. Next, bluetooth was rejected for it had significant limitations with bandwidth. And so, WiFi look like the best bet, but will have common problems with interference if introduced to highly residential areas (e.g. apartment complex, cities, subdivisions) since about 61% of Americans own WiFi routers.[2]

6.3 Design Decisions

Cameras, such as the one pictured in Figure 4 in the Appendix, are intended for security camera use and do not have an IR filter, making them perfect for low light. After testing both analog and USB cameras, the team decided to use ethernet cameras, as this choice provides the greatest bandwidth and reliability. This exact camera was tested by the group and when subjected to IR light from LEDs, objects could be clearly defined in complete darkness. These cameras with IR LEDs will be mounted in prototype 3D printed cases that will mount to the fenders of a semi cab. A hydrophobic lens will seal in the camera and prevent dew from forming on the lens. All components will be completely sealed from the weather inside the case. This case can be 3M taped to the fender and wired under the fender and into the engine housing, where it will get power from the battery and continue to run up into the cab.

The rear camera will have a similar design yet it will come with its own power and wireless communication. A Raspberry Pi will be used to process the video and transmit it through a WiFi antenna to the cab. This is estimated to draw an average of .5 Amps at 5 Volts, so it is estimated that the rear camera system will need 6 Amp-hours of power. Lithium-ion batteries are lightweight and hold a charge well. About eight of the cells shown in Figure 5 in the Appendix would hold enough charge for an 11 hour trip and are roughly the size of a AA battery each. Paired with a monocrystalline solar panel and well programmed stand-by mode, the camera system will be able to be left on the truck longer before having to be removed and recharged.

Another Raspberry Pi will be used in the cab to receive the wired and wireless video feeds and process them to displays mounted on the dashboard. These displays will have a photocell that will adjust the brightness depending on the amount of light inside the cab so that the screens will still be visible with sun glare. The Pi will be set up as a host for the WiFi and the rear camera will bind to it. If there is still processing power available, the Pi will be programmed to also save all the video feeds to an external hard drive. If there isn't, an external DVR will be purchased and the Pi will output all video feeds to it.

7 Integration, Test, Debug

Small scale testing for specific components can be done on a workbench or assembled on one of the team member's vehicles. In addition, a wind tunnel will be used to evaluate the drag force on the exposed camera modules to determine the total reduction in drag force due to replacing the mirrors. For a full system test, a fully functional semi-truck rig will be used. One of the team members has a contact in a trucking company and we are currently communicating with them for their interest in testing. We hope to have a full scale test of the system over at least one shipment with feedback from the driver.

8 Business Plan

The business plan is divided into two separate parts, the marketing study and the cost estimate. The marketing study describes the current market for a camera system for industrial trucking. The cost estimate describes the specifics of starting production of such a product.

8.1 Marketing Study

The marketing study for the industrial trucking camera system includes a comprehensive study of both the completion of our product and a market survey to determine the potential of our product.

8.1.1 Competition

There are current systems that are available on the market. Most of them are built around a backup camera and use that as the main focus in their design. Single systems that only include a backup camera are around $300 the base system. Larger systems that can have multiple cameras, similar to our system, range from $600-$900.

8.1.2 Market Survey

An appointment with Inontime will be arranged. This will allow us to talk with a company that is built around the trucking industry. We will be able to present ideas to drivers and get their opinion on what they would like to see. In addition, we will also be able to talk with company representatives and find out the value that they would place in a system like what we are designing.

8.2 Cost Estimate

The cost estimate includes both the summary of the development costs during the project for the school year and the production costs of a system in an industrial setting.

8.2.1 Development

The budget of the project is $500 which was what Calvin College provides each team. Prototype parts include two Raspberry Pi 3s, three cameras, an external battery pack, 3-D printed cases, 1-3 LCD displays and cabling to connect the parts. Our total parts cost comes in around $400. Our parts list is as follows: two Raspberry Pi 3s, three cameras, one to three LCD displays, an external battery pack and miscellaneous cabling. This cost includes shipping with room for any miscellaneous parts that we have are not aware of yet.

8.2.2 Production

The product would be a mass produced item that could be used on trucks currently on the road and also be able to be incorporated in trucks that will be produced in the future.

8.2.2.1 Fixed Costs

The complete cost of parts is expected to be around $400. The costs of design time is expected to be around $100,000. That equates to 250 hours of work time for each member of the design team.

8.2.2.2 Variable Costs

In the U.S., it is estimated that there are over 15.5 million trucks with 2 million being tractor trailers [8]. We are estimating the sale of 100,000 units for our product. For the final product, the cases would not be 3D printed as it would be more cost effective and time efficient to have the cases mass produced using injection molding. The cost of the parts are shown in Table 1.

Table 1: Parts Cost for Single System

Quantity	Part	Price per Unit	Total
2	Raspberry Pi 3	$39.95 [4]	$79.90
3	Camera	$16.99 [6]	$50.97
3	5” LCD Display	$29.95 [5]	$89.85
8	Lithium-Ion Battery	$5.49 [7]	$43.92
2	RCA Cable	$10.49 [9]	$20.98
1	3D Printed Camera Enclosure	$30.00 (Material Estimate)	$30.00

The cost of these parts does not include shipping or ports loss so an extra 10% is added to the parts price as overhead for a total of $350. Over 100,000 systems sold in 5 years, the initial research and development cost recovery is 5$ per system. The company overhead covers for the everyday costs of running a business and is estimated at 40%.

Table 2: Cost of a Single System

Parts	$315
Parts Overhead	$31.5
Total	$346.5
Total plus Company Overhead	$485.1

8.2.2.3 Summary Financials

The costs of the system, along with an estimated sales price and profit are shown in Table 3. The sales tax applied is 35%.

Table 3: Profit of a Single System

Cost of one System with Overhead	$485.10
Amortized Startup Costs	$5
Total Costs	$490.1
Sales Price	$700
Profit before Tax	$209.9
Profit after Tax	$136.43

Using a sales price of $700 per system, the resulting profit of $136.43 produces a profit margin of 19.5% which is within our specifications.

9 Conclusion

This project is definitely feasible. The system can be developed in a timely manner and will be able to compete in the market because it has both more features, and will be easier to install than current systems. There are many parts of this project that could be added on if time allows. The more additional features, the better the project will be able to compete in the marketplace. Our solution is not the only possible solution for reducing drag on convex mirror on semi trucks, but it is what the team believes to be the best and most viable solution.

10 Acknowledgements

Team 16, Semi-Pro, would like to thank the following people, companies, and organizations with their assistance in the process of this project, past and future. This report was made more complete with their assistance and advice.

- Eric Walstra, Engineering Manager - Gentex Corp.
- Ned Nielsen, Engineering Professor - Calvin College

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