RoMow

A Project Proposal and Feasibility Study

Engineering 339

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Executive Summary

In this report, Team 3 discusses the feasibility and design of a remote-controlled platform to be used in conjunction with a push lawnmower. The project, aptly named RoMow, is the team’s capstone project for the engineering program at Calvin College. The goal of the RoMow is to create a rolling platform on which a mower can be placed and, by direction of the user, mow the lawn via a remote control transmitter. Through research, analysis and outside consultation, the team has determined that this project is indeed feasible. In-depth design and construction will begin once school re-convenes and Engineering 340 begins in the February 2015.
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1. Introduction

1.1 The Project

Team 3 was approached by Yoon Kim, an electrical engineering professor at Calvin College, with the idea for a design project which would benefit those who seek to live independently, but lack the ability to do ordinary tasks around the house. In order to make mowing the lawn possible for such people, he proposed that Team 3 design a remote controlled lawnmower. The method he proposed involves building a platform that can be attached to an existing push lawnmower. The platform would control the direction and speed of the mower by means of a control system and a set of electric motors. This platform should be removable from the original mower and should not require major modifications to the original design of the mower. A lawnmower is a dangerous piece of equipment and removing the manual controls (i.e. the handle and throttle) makes it potentially even more dangerous. Team 3 intends to design safeguards to make the RoMow safe to use, even remotely.

1.2 Design Norms

As aspiring engineers at Calvin College, Team 3 believes that responsible design should be at the heart of the project. The design of the RoMow should represent a functional product but should also express the following qualities, which are characteristic of a responsible design.

1.2.1 Transparency

One of the goals for this project is for it to be usable on any mower of similar make and model. For this to occur, the design must be done in such a way that makes the product easy for the general public to understand and use. The product should be flexible to various applications for which a customer might use a lawnmower. The customer should know what the RoMow is capable of and how to use it in a safe and effective way. The mechanical design should be sturdy and have the necessary safety factors built in so that the system does not fail prematurely under operating conditions. Ensuring that this happens is the responsibility of the designer.
1.2.2 Caring
The RoMow is designed for those who cannot easily mow their lawn, so caring is a critical aspect to the design. The design must be sensitive to the customers who will be using it. It should make mowing the lawn a simple task requiring little to no physical work to accomplish. Along with being easy to use, it should also be safe. The platform should make the task of mowing the lawn no more dangerous than it was before, and if possible make it safer.

1.2.3 Integrity
The design process of the RoMow shall be guided by the principle of integrity. This means that the design will be a delightful combination of both form and function. Included in this idea is that the design of the RoMow will make operation by the user intuitive. There shouldn’t be any and will not be any difference between expectations and reality.

1.3 Project Management

1.3.1 Team Member Biographies
The team is composed of three mechanical engineering majors and one electrical engineering major. The team is shown on the following page in Figure 1. The team decided on producing a remote controlled lawnmower after Professor Kim, who is serving as client and mentor for the group, introduced the project. It gained attention through its challenging design work both mechanically and electrically.
Figure 1 - Team 3
(Nathan Terschak, Dustin Brouwer, Jordan Newhof, Andrew Frandsen)

Nathan Terschak
Nathan was born in Fort Wayne, IN, briefly lived near Toronto, Ontario at age 11, and now resides permanently west of St. Louis, MO. After graduating from Westminster Christian Academy, he began attending Calvin College where he now studies Electrical/Computer engineering and serves as a captain on the swim team. His career goals include finding a job where both hardware and software design skills are applicable.
Nathan is responsible for the electrical components of the system. That includes: RC transmitter and receiver, electric motors, motor control system, and motor drivers. The electrical system is an emphasized part of the project due to the elaborate control system. He is also responsible for managing the team website.

Dustin Brouwer
Dustin Brouwer is from Sheboygan, Wisconsin. He is a mechanical engineering student who has a particular interest in controls and electronics. After graduation he hopes to obtain a manufacturing engineering position in the automotive field.
He has been given the responsibility of frame design along with building and testing prototypes. Dustin will also aid in the design of the electrical control system, given his experience with electrical equipment.
Jordan Newhof

Jordan was born and raised in Grand Rapids, Michigan. He attended Covenant Christian High School in Standale, Michigan and then began the engineering program at Calvin College in the fall of 2011. He is a mechanical engineering student, who especially enjoys work in thermodynamics and fluid flow. He hopes to gain an engineering position in mechanical consulting in either the energy or HVAC sector, as well as obtain a graduate degree in either Business or Engineering.

Jordan is primarily responsible for communication with the client. Client communication is crucial in meeting all the design specifications provided by the client. Jordan is a major contributor in editing and writing the PPFS as well as assisting in the frame design.

Andrew Frandsen

Andrew is from Naperville, IL. He is a mechanical engineering major that thoroughly enjoys designing real world applications with sustainability in mind. Upon graduation, he hopes to obtain a job in renewable energy and to eventually pursue a master’s degree in Business Administration.

Andrew has the responsibility of frame design using computer-assisted design (CAD). Andrew assists in writing and editing the PPFS. Building and testing prototypes also falls under Andrew’s list of responsibilities.

1.3.2 Budget

Teams in the Engineering 339/340 class were originally given $500 for the completion of the senior design project. The proposed budget of the RoMow is shown below.

<table>
<thead>
<tr>
<th>Purchase</th>
<th>Project Use</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toro GTS Recycler</td>
<td>Lawnmower for proof of concept</td>
<td>$80</td>
</tr>
<tr>
<td>Hoveround MPV5</td>
<td>Motors, motor drivers, wheels</td>
<td>$350</td>
</tr>
<tr>
<td>12V Batteries</td>
<td>To power motors, electronics</td>
<td>$105</td>
</tr>
<tr>
<td>Transmitter / Reciever Pair</td>
<td>To control platform motion</td>
<td>$40</td>
</tr>
<tr>
<td>Arduino</td>
<td>Interface btw receiver and motors</td>
<td>$25</td>
</tr>
<tr>
<td>Misc. Items</td>
<td>----</td>
<td>$35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Estimated Budget</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$635</td>
</tr>
</tbody>
</table>

Table 1 - Proposed Project Budget
1.3.3 Schedule

Microsoft Project was used by the team to document all the necessary tasks for the project, as well as to record the amount of team hours spent on the task. The schedule has only been developed through the fall semester of 2014. The Gantt chart found in Figure 2 below shows a graphical breakdown of the time allotted to various tasks. This schedule is current as of December 3, 2014. Table 2 gives a breakdown of the hours spent on each task so far.

One of the first tasks for the team next semester is to reassess the schedule and determine the tasks which need to be accomplished.

![Figure 2 - Gantt chart of Semester Tasks](image-url)
Table 2 - Timesheet of Progress

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calculate Platform Performance Requirements</td>
<td>3 hrs</td>
</tr>
<tr>
<td>Shop for electric motors</td>
<td>3 hrs</td>
</tr>
<tr>
<td>Research Mower Dimensions</td>
<td>1 hr</td>
</tr>
<tr>
<td>Shop for Compatible Mower</td>
<td>2 hrs</td>
</tr>
<tr>
<td>Design Preliminary Frame</td>
<td>9 hrs</td>
</tr>
<tr>
<td>Determine Commens System</td>
<td>6 hrs</td>
</tr>
<tr>
<td>Write PPFS</td>
<td>0 hrs</td>
</tr>
<tr>
<td>Intro</td>
<td>1 hr</td>
</tr>
<tr>
<td>Background</td>
<td>4 hrs</td>
</tr>
<tr>
<td>Scope and Objectives</td>
<td>6 hrs</td>
</tr>
<tr>
<td>Client Specs and Design Options</td>
<td>10 hrs</td>
</tr>
<tr>
<td>Areas of Attention</td>
<td>5 hrs</td>
</tr>
<tr>
<td>Feasibility and Design Options Revisited</td>
<td>4 hrs</td>
</tr>
<tr>
<td>Cost Budget</td>
<td>2 hrs</td>
</tr>
<tr>
<td>Meeting with Industrial Consultant</td>
<td>4 hrs</td>
</tr>
<tr>
<td>Revise PPFS</td>
<td>15 hrs</td>
</tr>
<tr>
<td>Conclusion and Exec. Summary</td>
<td>1 hr</td>
</tr>
<tr>
<td>Appendices</td>
<td>2 hrs</td>
</tr>
</tbody>
</table>

1.4 Engineering 339/340

The Senior Design Project is the deliverable for the capstone class of the Engineering program at Calvin College. Senior capstone consists of the Engineering 339 and 340 classes. Engineering 339 is taken in the fall of senior year and focuses on many skills developing engineers need to enter the working world. Some of these skills include project management, effective presentation techniques, safety assessment, time management and group communication. The skills discussed in lecture are then reinforced in the design process, with deliverables that focus on time management, identification of roles and skills, and group communication. The skills are also showcased by various presentations throughout the semester, with faculty and employers, and with the Project Proposal Feasibility Study (PPFS). These are not the only items focused on in Engineering 339/340. Many resources are given to the students to assist them in searching for a job and in preparation for the interviewing process. Most importantly, faith, ethics and how they relate to the Christian engineer are focal points in each discussion. This directs the teams to design projects that are focused on helping people, making the world a better place, and glorifying God.
2. Background

2.1 Historical

Currently, there are no remote control platforms being produced. There are remote control lawnmowers and autonomous lawnmowers being made but each of these costs upwards of $2,000. One company that produces remote control mowers is Evatech. The design for the Evatech mower is a fully assembled lawnmower which operates via remote control\(^1\). The wheels are driven by two electric motors and are controlled via radio frequency (RF) signals from a handheld remote. Another option is to buy a do-it-yourself kit which when built allows the customer to control the mower via remote control\(^2\). This product also requires major modifications to the original mower. Both of these options require the removal of the existing wheels on the mower, making it dedicated to being remote-controlled all the time.

Although there are not very many remote control lawnmowers on the market, the market for robotic lawnmowers has been around for about fifteen years. Many of the major lawnmower companies have produced some sort of robotic lawnmower, but have encountered very little success in the American market. However the market in Europe has been friendlier to the idea of a robotic Lawnmower. Historically the prices for these mowers have been very high with most of the offerings being more than a thousand euros (approx. $1300). Below is a table showing some of the market offerings in terms of robotic mowers, along with their prices\(^3\). RoMow’s design offers a remote control lawnmower with no modifications to the original mower. This means the wheels will remain and no pieces will need to be added to the mower to make it adaptable to the platform. This provides the user with both a remote control and manual push mower at any point.

\(^1\) http://evatech.net/RCLM.php
\(^2\) http://www.superdroidrobots.com/shop/
\(^3\) http://www.telegraph.co.uk/gardening/gardeningequipment/
2.2 Current Market

Currently there is a small market in the United States for remote control lawnmowers. Generally these types of lawn mowers are used for applications such as mowing on extreme slopes where it would be dangerous for humans to mow. One such example is the mower produced by Summit Mowers\(^4\). This organization produces mowers strictly for sloped applications. There are also a few other models of remote control lawnmowers on the market that have seen moderate success. To be able to succeed in the market, the cost of the system must be kept low in order to entice customers to buy.

The current market for a remote control lawnmower platform includes people incapable of using a manual push mower, but who still want to live independently. This product can also be marketed to those who do not wish to mow their own lawn, or those who would enjoy mowing their lawn without actually physically walking behind their mower.

3. Need and Objective

3.1 Problem Statement

The identification of a problem or need in the market is one of the first things a company needs to do before they begin the process of designing a product. A new product will not be successful if there is no need for it in the market. So before the project is started, Team 3 identified a couple of market and customer needs that it can address with the design of the Ro-Mow.

3.1.1 Identification of a Need
People who are incapable of or find difficulty in using a standard push lawnmower would benefit from a product that allows their property to be taken care of without help from a third party. Another customer base that is in need of this product is business owners who have rather small areas of grass that need weekly mowing. They currently pay a large sum of money to have a small area of grass mowed. The RoMow would allow them to mow that grass quickly and without much effort. This product can also be marketed towards people who are tech-savvy and would prefer to control a mower remotely.

3.1.2 Objective
A platform system capable of remote control mowing would address both of the needs described above. The platform can be attached and removed from a push mower. When attached, the mower can be driven remotely with a hand-held controller. The mower can also be rolled off the platform and used in a typical manner with no changes, besides changing the wheel height and removing the emergency stop plug. With some added work, automation is also attainable but is currently outside the scope of the project.

4. Specifications and Design Alternatives

4.1 Client Specifications
The design of the Ro-Mow shall be governed by a set of specifications as outlined by the customer, Professor Yoon Kim. The specifications have given the team a clear direction in which to proceed during the design process. Having customer specifications also presents Team 3 with a specific set of issues that must be designed around.
The following specifications given by the client ensure that the design will be both safe and flexible for multiple applications. They are as follows:

- The mower can be attached and detached from the platform without modification
- There shall be a clamp for the mower blade to continually spin
- Must not remove wheels or modify the mower
- The platform must carry the mower and be driven by electric motor
- The platform must have 2 driven wheels minimum
- The control of the platform should be via wireless remote control (radio frequency) with a half mile range
- Design must have an emergency stop switch from the controller

4.2 Performance Specifications

Separate from the customer specifications are the team-imposed performance specifications that the carrying platform shall meet. These specifications include:

- Traveling on “flat” ground at a minimum speed of 3 mph
- Traversing a slope of at least 30 degrees
- Travel a minimum of 90 minutes on a full battery charge
- Must be able to cut grass to a length of 2 inches

4.3 Design Alternatives

In the process of coming up with a design for a carrying platform, Team 3 has processed a number of different design options for the various systems and components of the design. Some important decisions are outlined below.

4.3.1 Frame Design

One of the most significant design alternatives lies in choosing between a over-top design and a platform design. An over the top design could provide a blade height that is closer to the grass. The nominal blade height is the distance the blade is from the ground. This is important because the height of the blade determines the amount of grass being cut. The platform adds height to the nominal blade height being able to cut less grass than the over the top design.
The downside to an over-the-top design is the ease of conversion. The frame, battery (or batteries), and controls of the device would have to be placed over the mower, which would require a lot of physical exertion. Also, problems may arise with securely fastening the mower without modifying it.

Another factor which influenced our decision was input from the customer. He preferred a product onto which he could roll his lawnmower. For these reasons, the team’s design will utilize a platform design.

For this design, the team decided to use a Toro GTS (Figure 3) recycler as a representative mower to use for dimensioning the frame. The dimensions of the mower were used to design an AutoCad file (Figure 4) containing the dimensions of the mower, in inches, which shall be used to begin the frame design during the second semester.

4.3.2 Receiver to Motors Electronics

The team is faced with several hardware options for how to analyze the wireless signals being interpreted by the receiver on the platform and produce output signals that drive the two electric motors. The main question lies in whether to use a microcontroller or custom design hardware to have the receiver outputs interface with the motors. The logic required may be simple enough to implement via a custom design at lower cost. However, a microcontroller would allow for much more flexibility in the logic design. The decision process for this module is outlined in section 6.4.
4.3.3 Implementation of Transmitter/Receiver Pair

Choosing a frequency band along with a protocol for wireless communication between the controller and the platform is another design decision which must be made. The bandwidth and protocol can be used to search for a transmitter and a receiver integrated circuit pair where the transmitter chip will be integrated into the controller electronics and the receiver chip will interface with the platform electronics that drive
the motors. Alternately, an RC transmitter can be purchased along with a compatible receiver to eliminate having to design wireless technology, which might be too much of a challenge for this project.

### 4.3.4 Motor Selection

The team is faced with determining the amount of power needed to move the platform. By doing calculations based on the performance requirements, it was determined that the amount of power needed is a total of a 1 horsepower. However, this was reduced to 0.6 horsepower after the slope requirements were brought down to 30 degrees after looking at some of the mowers in this industry. These calculations can be found in Appendix A. Motors as well as a frame were donated to us by Prof. Tubergen of the Engineering Department at Calvin. These motors were tested for their power potential and were determined to be suitable for use based on the weight they could carry.

Another option for obtaining electric motors is by obtaining an electric wheelchair and removing the motors from it. They will be able to carry the weight of the lawnmower and operate at different speeds. The downside to this option is that these motors are expensive (around $250 for a set of two). The motors off of a wheelchair such as a Hoveround MPV5 are direct drive. This means that the motors are connected directly to the wheel and need no additional gearing to reach an appropriate speed.

The team decided to pursue the purchase of an electric wheelchair for several different reasons. The first reason has to do with the electric motors on the chair. These motors are capable of carrying a person of up to 300 pounds not including the weight of the chair itself. Also the wheel chair can travel a maximum of fifteen miles on a full battery charge. The weight that can be carried and the range of these motors with provided batteries insure that the performance requirements can be met. The customer also believed that pursuing this would make the design much easier by removing the need for additional gearing and motor drivers.

The wheelchair purchased was the aforementioned Hoveround MPV5, and it can be seen in Figure 5. The performance specifications of the motors are found in Appendix B.

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4.3.5 Motor Power Sourcing

The team is faced with choosing a single speed output or a variable speed output. The conclusion of the team is that variable speed is not necessary. If time allows, we will pursue assuming the initial design criterion have been met.

4.3.6 Slope Requirement

The required slope for the platform to be able to traverse is 30 degrees. The team is confident the vehicle will be able to do this but as the frame design is furthered along precaution will be taken to make sure the weights of the components are distributed in such a way that the vehicle can travel up and down a slope without stopping or tipping over.

4.4 Scope

Initially the team had a wide range of features that they desired to be incorporated in the RoMow. With the help of industrial consultant Eric Walstra, the team was able to separate needs from desires in the design. He helped identify some key design criteria, and also where bottlenecks could occur in the process. His direction helped keep the RoMow on track and determine a suitable scope for its design.
The initial scope of this design is going to be limited to meeting the requirements posed in Client and Performance Specifications (Section 4.1 & 4.2). The scope is limited to these so that the primary objectives of the project can be achieved. Once the primary objectives are met then the team can consider other ways to improve upon the original design. Widening the scope has infinite possibilities. However, budget and time constraints will limit the amount of scope expansions the group can consider and work on. Some possible scope expansion options are listed below.

4.4.1 Push Bar Obstruction Sensor
This sensor would be attached to the front of the platform and would signal an obstruction in the platforms path. It would be rather simple and be triggered upon being depressed towards the frame. The controller would then prohibit motion in that direction preventing the frame from continually crashing into something.

4.4.2 Thermal Sensor
A thermal sensor would be used to detect living things in the path of the platform. This would keep cats, dogs, or even small children from being run over by the platform.

4.4.3 Video Feed
A video feed would allow a person to drive the platform when it is out of sight. This would use either one or two cameras positioned above the cutting edge of the mower. This would allow the driver to make straight line cuts in the grass and add another measure of safety to assist the operator to avoid dangerous situations.

4.4.4 Variable Speed Motors
The variable speed motors would allow for the motors to go at different speeds giving more control to the driver. This would make the inputs of the controller work more as a “throttle” versus an on and off switch. This would be ideal but will take extra time and effort from the team.
4.4.5 Frame Adjustability
An adjustable frame would allow different size push mowers to be used on the proposed platform. The frame would be modified to adjust both in length and width to allow for a wide range of mower sizes.

4.4.6 Automation
Automation would allow the platform to run in a pre-programmed way. By recording commands of a previous cut, the platform would remember the locations it was in and follow the coordinates. This could be accomplished in one of two ways: GPS or Wi-Fi signal pinging. The GPS would be a challenge in that differential GPS would be needed to eliminate the inaccuracy of the GPS system. The Wi-Fi signal ping system would need multiple transmitters to triangulate the position of the vehicle based upon the pings from each of the transmitters. Another option for automation is controlling the direction of the mower by magnetism. This could be done by running a wire underground which is carrying a current. This creates a magnetic field which could direct the path of the mower with some processing and programming.

5. Feasibility

5.1 Frame Material Options
The two feasible material options for the frame are: steel and aluminum.

5.1.1 Steel
A steel frame provides high formability and durability, good tensile and yield strength. This provides an advantage because the design can be easily manipulated while still providing a high strength. The cost of steel is generally cheaper (per pound) than aluminum. Table 4, presented below, shows the material properties for steel.
### Table 4 - ASTM A36 Steel Properties\(^6\)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (1000 kg/m³)</td>
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<tr>
<td>Tensile Strength (MPa)</td>
<td>400–550</td>
</tr>
<tr>
<td>Yield Strength (MPa)</td>
<td>250</td>
</tr>
<tr>
<td>Brinell Hardness</td>
<td>150-180</td>
</tr>
</tbody>
</table>

#### 5.1.2 Aluminum

An aluminum frame provides more malleability and elasticity than steel. Aluminum can form shapes that steel is not able to achieve. The most significant advantage of using aluminum is the weight. Aluminum is about 2.5 times less dense than steel which can contribute to achieving the performance requirements of the system. Table 4, provided below, shows aluminum material properties.

### Table 5 - Aluminum 6061-T6 Properties\(^6\)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (1000 kg/m³)</td>
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</tr>
<tr>
<td>Tensile Strength (MPa)</td>
<td>300</td>
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<tr>
<td>Yield Strength (MPa)</td>
<td>241</td>
</tr>
<tr>
<td>Brinell Hardness</td>
<td>95</td>
</tr>
</tbody>
</table>

#### 5.2 Frame Material Structure Options

The two possible frame material structures that were analyzed were that of extruded pipe and sheet metal.

##### 5.2.1 Extruded Pipe

Extruded pipe provides lightweight yet durable design which can be easily welded together to create a frame. The frame does not need to be manipulated (bent or cut) in order to reach the required blade height.

##### 5.2.2 Sheet Metal

Sheet metal provides a design that does not need to be welded, but rather manipulated in order to produce the necessary frame requirements. A cut out in the frame needs to be made in order for the frame to reach the blade height necessary to cut grass.

5.3 Material Availability
Due to material availability at Calvin College, the design will be based off of steel extruded pipe. This ensures a strong, yet lightweight design which will achieve all design requirements, including the most important requirement of having the lawnmower blade as close to the ground as possible.

5.4 Design Concerns
The team identified a number of different concerns which need to be addressed during the design process and these are recorded in the following sections.

5.4.1 Communications
The team is faced with determining the form and range of a wireless communications system. A remote control transmitter that can send signals to a receiver on the platform will need to be designed or obtained off the shelf. It would be possible to design circuits for both the transmitter and receiver. However, with only one electrical student in the group, designing the wireless communication system would be beyond the scope of the Engineering 339/340 project, especially since it would also require the team to design the remote controller. Because of this, it has been decided that a standard hobbyist RC transmitter and compatible receiver will be used to allow for communication between the controller and the platform.

5.4.2 Propulsion
The team is faced with determining the power, gearing, and speed of the propulsion for the platform. To determine what will be necessary in terms of gearing to obtain a target speed, the electric motors must be tested for the actual weight of the whole platform.

5.4.3 Safety Considerations
The team has noticed a need for safety and precaution in this product. The team has discussed three forms of safety systems: emergency, loss of communication, and obstruction.
In the case of an emergency there are two possible forms of stopping the mower that have been discussed by the group. The first emergency stop (E-Stop) mechanism suggested would be an electrical relay that
would be placed in between the spark plug and the mower’s electrical cord. If a signal is sent to the relay, the relay would prohibit the spark plug from igniting the gas and stop the mower and the blade. The second would consist of a mechanical device that would hold the handle bar down unless given the signal to release the bar which would in turn stop the blade. In the case of loss of communication between the controller and the mower the on board control system will stop the platform from moving. In the case that the mower comes up against an obstruction, sensors on the front of the vehicle will stop the platform from continuing to move in a given direction.

The decision was made that the initial safety mechanism will be the electrical relay which will interact with the spark plug of the mower’s engine, as described above. The relay would be activated when communication between the transmitter and receiver is lost. It can also be activated when the E-stop button is depressed. The second option was dismissed because it would require significant modification to the body of the mower, which would disagree with the client specifications. At this point the safety mechanism that would incorporate the obstruction sensors will not be implemented. The team’s expectation is that the operator will always be in view of the mower, making this addition trivial. Safety is a high priority and will be constantly tested and revisited throughout the design process.

5.4.4 Mower Height

One source of concern for the design team is insuring that the height of the mowing deck is not higher than 2 inches at the lowest wheel height. To accomplish this, the design will have to allow the wheels to be suspended just off of the ground (approximately 1 inch or less) so that the maximum height of the deck from the ground is 2 inches. This is one of the first tasks the team will take on in the spring semester.

6. Electrical System Architecture

This section will outline, in a moderately detailed manner, the various electrical components that will be required in the system design.

6.1 Top Level System Design
6.1.1 Research

The team began by researching various DIY remote control vehicle projects on the Internet in order to obtain a rough idea of what components would be needed. One such project that was studied was the Lawnbot400\(^7\). This robot used an Arduino-based microcontroller board to translate pulse-position modulation signals from an RC receiver to pulse-width modulation signals that can be fed into the motor drivers. Another project called DIY Radio Controlled Lawnmower was found online\(^8\). The website for this project describes several options for implementing the electronic components in a robotic lawn mower. The project author used an electric wheelchair’s motors and controller, and then created his own module to add onto the wheelchair controller and replace the joystick. This module includes the radio receiver and a custom board to generate the signals that the controller will recognize. These two example projects gave the team a good idea of what components will be needed for the project and the different options for choosing them.

6.1.2 Subsystems Overview

It was determined that the set of main electrical modules that will be needed includes an RC transmitter and compatible receiver, electric motor drivers, DC motors, and an electronic module to interface between the receiver and the motor drivers. Figure 6 shows a Level 0 block diagram of this system.

\(^7\) http://makezine.com/projects/lawnbot400/
\(^8\) http://members.iinet.net.au/~tnpshow/RCLM/intro.htm
6.2 RC Transmitter and Receiver

6.2.1 Custom Controller and Radio System
The team briefly considered designing a custom radio frequency system, which would also require a custom made remote controller. However, it was quickly realized that this would extend beyond the scope of the senior design project.

6.2.2 Standard RC Transmitter
The team searched online for standard RC transmitters that would meet the requirements of this system. Two viable options were found and compared.
**Tactic TTX403 4-Channel Transmitter**

This transmitter offers 4 channels in the 2.4 GHz frequency range and a 6-channel compatible receiver can be purchased in addition. This system is generally used for an RC airplane which suggests the range will be suitable for this application. The price for this product is around thirty-five dollars\(^9\).

**2.4G CT6B 6-Channel Transmitter + Receiver**

This product is very similar to the Tactic TTX403, but it offers a 6-channel transmission and includes the receiver as part of the package. This package can be purchased for about forty dollars\(^10\) which is comparable to the Tactic Transmitter.

**6.2.3 Decision**

The team has decided to use the CT6B transmitter/receiver pair due to the fact that it is cheaper than the Tactic TTX403 and still offers all the features that will be needed for the project.

**6.3 Electric Motors**

As was described in section 4.3, the electric motors that will be used for the platform will be the ones taken from the Hoveround electric wheelchair. These motors are rated to 24 volts direct current and are produced by Shihlin. These motors are internally geared to 180 rpm, and are intended to directly drive the wheel without any additional gearing.

**6.4 Motor Control Electronics**

There will likely be a need for an electronic module that interfaces the receiver outputs to the inputs of the motor drivers. This will offer more flexibility for how the RC transmitter affects how the platform is driven.

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\(^9\) [http://www.rcuniverse.com/magazine/article_display.cfm?article_id=1545](http://www.rcuniverse.com/magazine/article_display.cfm?article_id=1545)

6.4.1 Definition of Motor Behavior Based on Transmitter Controls
This module will need to be designed in a way that allows the transmitter controls to activate the motors in the correct way according to the type of steering desired by the user. This module will allow for tank steering, standard remote control vehicle steering, or the ability to select between the two.

6.4.2 Custom Circuit Implementation
One potential way to implement this module is through a custom hardware circuit that allows a pre-defined interfacing scheme to control how the motors are driven.

6.4.3 Microprocessor Implementation
Another solution to this design problem would be using a microcontroller to accept the digital inputs from the receiver and send signals to the motor drivers based on a written program. The ATMega328 chip can be used along with the Arduino IDE to do this.

6.4.4 Decision
The team has decided to use an Arduino Uno microcontroller to implement this electronic module for several reasons. The Arduino board contains 6 digital I/O pins that can be used for pulse-width modulation signals. Additionally, the team has experience working with this product and the development environments for it. This will reduce the amount of time needed to implement a program to translate the receiver signals. Lastly, the Arduino Uno only costs $25, so it is very affordable considering the capabilities it provides. Designing a custom board would require many smaller costs that would likely add up to at least the same amount as simply purchasing an Arduino board. Also, the Arduino board offers flexibility in the initial design. Once a working Arduino-based implementation has been established, it might then be feasible to design and build a custom board that is cheaper per unit and accomplishes the specific task that is needed for this part of the project.

6.5 Motor Drivers
There will need to be an implementation of an H-bridge circuit to allow power from the battery to be supplied to the motors based on a pulse-width-modulation (PWM) signal from the microcontroller. Since
there will be a high current draw, a simple H-bridge integrated circuit will not be suitable. The team initially decided to search for a low-priced DC motor speed controller that can handle the current draw from the battery. However, due to the fact that these are not cheap, the team has decided to use the speed controller from the electric wheelchair that has been purchased. This decision will allow the system to be built at a lower cost. The team will have to determine what types of electrical signals are needed for this specific controller so that the receiver-to-motor driver module can be designed accordingly.
Conclusion

In this report Team 3 has come to the conclusion that the design proposed is feasible and shall be built in the spring semester of 2015. At the moment the components needed for the design are known and will all be purchased in the near future. The frame design work will occur in the spring along with the implementation of the electronics hardware. The structural design will be done first in a 3D CAD package such as Inventor or SolidWorks, and will be analyzed by means of Finite Element Analysis before it is implemented, to insure safety and structural integrity.

Upcoming plans for the group involve taking apart the wheelchair for the needed components, designing of the module to interface between the receiver and motor drivers, and developing a series of tests to analyze the performance of the components, structural integrity of the frame, and the safety protocols.
Acknowledgements

Team 3 would like to acknowledge the efforts of several people who have assisted in the process of this project thus far. First, Prof. Kim of Calvin’s Engineering Department has served as the team’s client as well as mentor. Eric Walstra was the team’s industrial consultant and provided many helpful insights and helped to narrow the scope of the project. Finally the efforts of Professor Michmerhuizen need to be acknowledged. He served as the team’s advisor this semester and provided a good deal of guidance. Thank you all for your efforts!
Appendix A – Horsepower Calculations

Horse Power Calculations

\[
\text{Mass} = 100 \ [\text{kg}]
\]

\[
\text{gravity} = 9.81 \ [\text{m/s}^2]
\]

\[
\text{velocity} = 3 \ [\text{mph}] \cdot 0.44704 \cdot \frac{\text{m/s}}{\text{mph}}
\]

\[
\text{Force} = \text{Mass} \cdot \text{gravity} \cdot \sin \left( 30 \ [\text{deg}] \right)
\]

\[
\text{Power} = \text{Force} \cdot \text{velocity} \cdot 0.001341022 \cdot \frac{\text{hp}}{\text{W}}
\]

Force = 490.5 \ [\text{N}]

gravity = 9.81 \ [\text{m/s}^2]

Mass = 100 \ [\text{kg}]

Power = 0.8822 \ [\text{hp}]

velocity = 1.341 \ [\text{m/s}]

No unit problems were detected.

Calculation time = .0 \text{ sec.}

The necessary total horsepower required by the two motors will be 0.882 horsepower as seen above. This can be satisfied by two 0.5 horsepower electric motors.
Appendix B – Motor Specifications

MPV 5 Specifications

Performance
Maximum Speed* 5 mph
Range (per battery charge)* 15 miles
Capacity 300 lbs
Turning Radius 22.7”
Ground Clearance 2.5”
Maximum step climb 2”
Maximum grade climb 6”

Dimensions and weight (with 20” seat in lowest position)
Length 38”
Overall Width 24”
Top of seat cushion to floor 19.8”
Seat height adjustment 0”, 1.5”, or 2.5”
from lowest position
Total weight, with batteries 195 lbs
Base only 91 lbs
Base with batteries 143 lbs

Batteries
Two U-1 batteries, 33 amp hour capacity each, Sealed AGM

Tires and casters
Tire type and tread Pneumatic, non-marking
Tire diameter and width 9” x 3.5”
Caster type and tread Solid, non-marking
Caster diameter and width 8” x 2”

Seat

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<td>Right</td>
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* Speed and range will vary with respect to terrain and weight of rider.

Note: Specifications and equipment subject to change without notice.