FSU/FAMU College of Engineering
Departments of Electrical and Mechanical Engineering

Project Plans & Product Specifications Report

Robotic Weeding Harvester
Team Number: ECE#16 - ME#11

9/29/14

Submitted To:
Dr. Gupta
Dr. Helzer
Dr. Li
Dr.Frank
Dr.Clark
Jeff Phipps

Authors:
Ian Nowak (EE)
Coen Purvis (ME)
Amanda Richards (ME)
Grant Richter (ME)
Jeremy Rybicki (EE/CpE)
Nathan Walden (ME)

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Abstract

Jeff Phipps is a local organic farm owner who is in need of extra help in maintaining the weeds on his eight-acre organic farm. This report will outline the plan of action Team 11 desires to take in the design and implementation of a weeding robot that will provide this extra needed help on Mr. Phipps' farm. In addition to this, the report will summarize and explain the product specifications of which we will adhere to in order to develop the best product for our sponsor.

Thus far, taking background research into consideration, design ideas have been brainstormed and modeled. The product specifications provided to us by our sponsor in addition to specifications we thought as appropriate aided in the design of certain components that would be possible for our final designs. Proper scheduling and resource allocation have been assigned for tasks throughout the remainder of the semester to ensure our strict timeline is followed.

In the upcoming weeks, we hope to have our design ideas approved of by both our sponsor and advisors. At this stage we would like to request funds for the purpose of prototyping to test our preliminary ideas. The group plans to build individual components of these preliminary ideas in order to test their feasibility. By testing the individual key components of this project (locomotion, navigation and weeding methods), the group can unbiasedly determine the best idea for each of these components.

1.0 Introduction

The idea for this Senior Design project is to design and build a method for getting rid of weeds between the rows of crops on organic farms. Research tells us the idea of integrating robotic systems onto farms to reduce the labor and human dependency is not a new one. A lot of the existing technology will help guide us in the right directions for the purpose of our design.

Organic farms do not use traditional farming techniques such as herbicides and pesticides, so this robot will eliminate the need for a human to pull weeds from the farm plots. The robot will have to navigate between the rows of crops, remove weeds, keep itself charged and running 24/7, as well as follow other design constraints as outlined in this paper. Some of the challenges associated with these desired operations is the method of which the robot will be programmed to navigate through the plot. The team is composed of four mechanical engineers and two electrical engineers, and is sponsored by the mechanical engineering department. The project is sponsored by Jeff Phipps, of the Orchard Pond Organics farm, and is advised by Dr. Clark and Dr. Li.

2.0 Project Definition

2.1 Background research

The idea of integrating robotic systems onto farms to reduce the labor and human dependency is not a new one. This application has been researched extensively, especially in European countries like Denmark, the Netherlands and Italy. Many of these ideas are already prototyped and are being used on farmland on a day to day basis.

The majority of these prototypes require a single person to navigate through the crops and "typically use cameras or infrared sensors to spot the weeds, which they can differentiate from vegetables by using pattern recognition.[1]" The Steketee Machine Factory has developed an automatic hoeing machine that affects ten rows of crops at a time. While this does not remove the weeds, it does agitate the surface of the soil in preparation for planting and allows a consistent and uniform approach to farming. The Steketee IC Automatic Hoeing Machine is pictured below on the left.

One example of a working prototype that hits very close to home comes from a Danish engineering company, F. Poulsen Engineering. They focus directly on creating robots for use on organic and conventional farming that "provides efficient and economical weed control without the use of herbicides"[2]. This machine primarily focuses on cultivating and can affect at most, thirty six rows of crops at one time. It is capable of operating 24/7 and also uses infrared sensors to maintain position between the crops. Currently, the robot is not autonomous but work is continually being done to enable the machine to run on autopilot.

Figure 1. The Steketee IC Automatic Hoeing Machine[4]

Figure 2. ROBOVATOR from F. Poulsen Engineering[2]

There are a few noticeable differences between the prototypes previously mentioned and the focus of our project. These examples do not include complete autonomous motion, one of the main objectives we hope to accomplish. The ROBOVATOR from F. Paulsen Engineering is close to success in autonomous motion but in the majority of the testing, the machine does not always maintain linear motion down the rows of crops. This is a huge issue, especially with such large, damaging equipment. This is something we hope to stay away from in our own design. An additional discrepancy seen between the existing technology and what we hope to accomplish is a robot that has very minimal ground pressure. In the previous examples the machines are able to affect a larger amount of rows at once but largely affects the ground pressure and the soil at the far end of the machine where there is contact with the wheels.

Figure 3. Hortibot in action

According to an article in the Ludington Daily News, Michigan, "Danish agricultural engineers have built a robot to help farmers with weeds. The Hortibot is about 3-foot-by-3-foot, is self-propelled, and uses global positioning system (GPS). It can recognize 25 different kinds of weeds and eliminate them by using its weed-removing attachments. It's also very environmentally friendly because it can reduce herbicide usage by 75 percent. But so far, it's only a prototype and the Danish engineers need to find a manufacturer for distribution.[3]" Hortibot is an excellent example of what we wish to accomplish in our design and is pictured to the left.

There is a significant amount of literature published on the potential applications and development of cooperative robots for sustainable broad-acre agriculture. Most of this literature aims to redefine the methods of agriculture and guide people in thinking of broader and more efficient ways to maintain sustainable agriculture. There has also been numerous proceedings on the topic of field robots. In 2007, the Wageningen University Farm Technology Group from the Netherlands hosted a prototype competition on field robots. The competition involved the prototyped robots competing with each other in Olympic-style competition in rough terrain. With a total of 8 competing robots, each one was capable of robust and advanced navigation, weed control, load-sensitive engine regulation, and spray control and suspension stabilizers, to name a few[4]. Another proceeding worth mention took place in Pisa, Italy in 2012. The Robotics and Associated High-Technologies and Equipment for Agriculture (RHEA) hosted this event to focus on 'Applications of automated systems and robotics for crop protection in sustainable precision agriculture'[7]. The proceedings main goal was to join experienced researchers to develop ways in which the use of 'agricultural and forestry chemical inputs are diminished'. They aim to 'improve crop quality, health and safety for humans, and reduce production costs by means of sustainable crop management using a fleet of heterogeneous robots-ground and aerial-equipped with advanced perception systems, enhanced end-effectors and improved decision control algorithms'.[5] One of the prototypes presented at this proceeding is pictured below. These are only a few examples of the literature that already exists

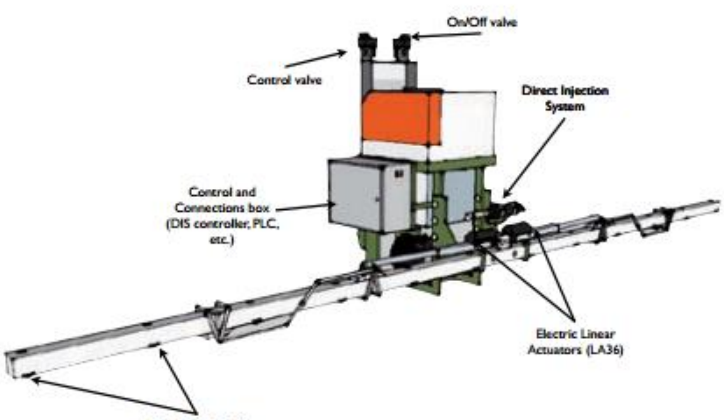

Figure 4. Prototype weed control system from RHEA Proceeding

for this exciting new advancement in agriculture.

It can be noted that some of the existing technology, excluding Hortibot, does not completely focus on weed removal but instead on the cultivation and soil preparation aspects of farming. One of the gaps in this technology we would like to fill and improve upon would be the actual weed removal. Instead of merely sifting the top layer of soil we want to focus on affecting and removing the actual root of the weed.

A tool that was developed to make manual labor easier is the Ergonica Weed Twister. "The Ergonica Weed Twister was designed to more efficiently penetrate the soil with a minimum of soil disturbance and extract both new seedlings and deep roots of various shapes and sizes more precisely and efficiently than other hand tools and weeders[6]." The device is pictured to the right and shows the way in which the root of the weed is directly affected. This is something we would like to integrate in to our design that would be an improvement in comparison to existing designs in which the actual weed removal aspect was not completely satisfied.

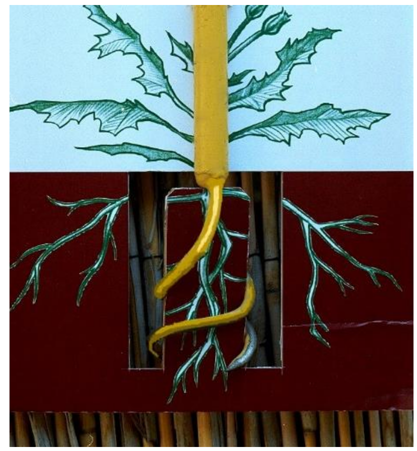

Figure 5. Ergonica Weed Twister

It is imperative that a new technology be developed to assist in this large-scale production of food to balance the ever-increasing population. As with any push in new advancements or technology, not everyone is going to support it or believe it will actually improve mankind. We experienced some of this opposition directly when speaking with the master farmhand at Orchard Pond Organics. The master farmer expressed his concern that with the integration of robots on the farm, people would feel less and less inclined to educate themselves on how to correctly harvest and maintain a farm. He believes it will put many people like himself out of work and result in an ignorant and uneducated group of people relying on technology to feed themselves.

2.2 Need Statement

The Robotic Weed Harvester Team is sponsored by tinkerer and inventor Jeff Phipps. He owns a plot of land spanning 10,000 acres of which 8 acres is set aside for an organic farm. At present Jeff is struggling to make the organic farm viable for the remaining property. The main issue is that organic farming on such a large scale requires a large amount of manpower, that of which Jeff does not have. With the use of modern machines, herbicides, and pesticides a more traditional farm, of a much larger size could be run by a single person. The capability for Jeff to do the same with organic farming does not exist. Without the use of herbicides and tilling to control weeds they become a major issue. Jeff wants to change this by commissioning the DeepDivers (Team 11) to build him a 24/7 autonomous weeding robot to alleviate the workload synonymous with organic farming.

As the world's population increases, farmers have had to produce larger crops yields. This continual need to ramp up yield has led to a farming industry where bigger is king. With large scale farming comes more aggressive farming practices. Farmers employ tilling to control weeds, shape the soil, and create furrows to aid in irrigation. This method is extremely invasive to the soil. Tilling destroys the biodiversity in the soil, microbes in the top layers of soils are killed along with beneficial insects such a worms. Having a large microbe biodiversity in the soil makes food such as nitrogen, carbon, oxygen, hydrogen, potassium and other trace minerals available to the plants. As microbes eat they produce waste which is in the form of plant food. The worms that are destroyed loosen the soil in a way that allows a plants roots to more easily take hold and grow toward the area where large concentrations of food lies. It also causes material in the soil to aerate and decompose faster than normal which releases carbon into the atmosphere. This an environmental issue which is at the forefront of public thought. If a no till method was adopted then farms would act more as a "carbon sink" then an annual carbon release.

The main issue with a no-till organic farm is that it require a large amount of manpower to maintain. This makes them costly to run in the market saturated by high yield farms using traditional techniques. With no till organic farms the main consumer of manpower is the weeding of fields. A solution to this is to build a low impact 24/7 weeding robot that can perform the task of weeding without human input. This would be a tool no till organic farmers can use to achieve all the benefits of this type of farming while driving prices down an enabling competition with more traditional farms.

"Organic Farms require too much manpower to run because the weeds cannot be controlled without continuous care by the farmer in the absence of tilling and herbicide."

2.3 Goal Statement & Objectives

Goal Statement: "Design a robot capable of weeding a farm."

Objectives

- Navigate an appropriate set farm plot
- Be able to properly avoid the crops on each row
- Remove weeds within the rows of crops

3.0 Constraints

Since this project is about satisfying the customer's needs, it is imperative that the constraints are carefully outlined. The customer hopes that this robot will be advanced in capabilities, but these constraints will encompass the requirements that the senior design team believes can be satisfied within the allotted time and budget.

The following are primary goals, and these goals will be a measure of success for the finalized product. With all of the equipment on the robot, it should not compact the dirt in the plot by more than $3/8^{th}$ of an inch. Additionally, it must be able to navigate successfully through the plot by avoiding the crops and staying within the allotted area in between them. Most importantly, it must be able to remove weeds from the plot (meaning that the weeding mechanism should affect 100% of the dirt, but needs to at least remove 60-70% of the weeds). Also, this weeding mechanism should not disturb more than an inch of soil. As mentioned before, there is a wealth of biodiversity in the soil and deep disturbances will hurt the health of the client's organic farm. As stretch goals, the robot should be able to run 24/7, operate in any weather, and be waterproof. These stretch goals will be attempted if the primary requirements of the project are satisfied.

Table 2 Requirement ranking from 0-5 (least to most)

Requirement	Priority
Movement/Navigation	5
Ground Pressure	5
24/7 Operability	3
Charging Station	3
Waterproof	4
Weeding Capabilities	5

3.1 Design Specifications

The design specifications for this project are in large part a product of the constraints given by our sponsor Jeff Phipps. The design specifications that are most important to our sponsor are the following.

- The robot cannot exceed 36 inches in width
- The robot cannot compact soil more than ⅜ inches
- Only the top inch of soil can be disturbed
- Robot must be able to operate between rows of 36-72 inches in width
- Be able operate 24/7

The robot has to under 3 feet due to the fact that if the robot exceeds 3 feet it will affect the crops while weeding in between the row. The robot must be light enough and have a ground pressure of about 1 psi in order to compact the soil to specifications required by the sponsor. In order to be able to have the robot operate at any time of day a charging station must be made this is a secondary goal for the team and will be dealt with after the design has been made and all other specifications are met. All design specifications will be taken into account when designing and prototyping the robot.

3.2 Performance Specification

24/7 operation

The robotic weed harvester needs to be in operation. 24/7. This method is possible through two methods. The robot can return itself to a charging station that is connected to the grid. This will allow the robot to continue working with minimal delays. However this method will put limitations on the robots range. An alternative method would be to use a large solar cells. The robot could be fitted with rechargeable batteries and periodically go into a “Charge” mode where the primary function becomes maximizing sun exposure. The issue with solar power is it does not work during the nighttime. Batteries of a sufficient size would need to carry operations into the night. A combination of the two would be the most effective approach to achieving 24/7 operation.

- Charging statin connected to grid
- Solar cells for increased runtime

80% weed removal

In a given patch of land 80% of the weeds in that are must be either uprooted or clear cut. The method of seek and uproot would increase the longevity of the field. A weed taken from the root will soon dry out and die, and the chances of regrowth are slim to none. To achieve the desired 80% effect on a pass a more robust clear cut method will also be employed. Whatever the robot misses to individually pick will be cut. Cutting will reduce the effect of the weed but if left unchecked the weed will grow back very quickly.

- “Find and Pick” as Primary
- “Clear cut” as Secondary

Differentiate crops from weeds

The robot must be able to differentiate a weed from a crop. Plants have many different stages of growth and at times crops look like weeds. In order to avoid crop destructions a method of image processing and pattern recognition will be used to determine what areas are “ok” to weed and what areas the robot must actively check through sight if it’s a crop or not.

Navigate through fields

The robotic weed harvester must be able to navigate with minor disturbance through the crops. Crop damage must be avoid at all costs. The fields will also be full of rough terrain that must be navigated while maintaining logs of areas in the field that have been covered. The robot must keep track of its progress though the field to prevent wasted energy and over compacting of the soil. To achieve this an assortment of sensors will be utilized to interact with the field.

- Possible Methods - Multiple methods will be used in unison
    - GPS
    - Ultrasonic Range finder
    - Whiskers
        - keep robot centered in the row
    - Pattern recognition
        - Rely on certain grow pattern to navigate from a designated starting point.

Avoid Soil Disturbance

Soil compaction must be avoided because it impedes root growth. Impeded root growth leads to stressed and stunted plants. The robot must have a small soil impact by keeping weight to a minimum and choosing a tire configuration that distributes weight effectively. Not only does navigation have to be low impact but also the weeding method chosen. The soil must not be tilled or dug up when weeding.

Possibility for Attachments/Adaptability

Allow for design to be built upon for future features and improvements. As the methods of navigating and weeding become more refined the robot should be able to take on extra works such as handling the preparing of the field, watering, bug control, and crop harvesting.

- New features to be added in the future.
    - Planting capabilities
    - Bug Control
    - Crop Harvesting
    - Field Preparation

4.0 Design Ideas

Based on our research efforts and advice taken from the sponsor, we have devised several preliminary ideas for each of the key components for the project.

4.1 Locomotion

Based on the four methods of locomotion, a design matrix was constructed to determine the most favorable design method to get the robot successfully through the plot without disrupting the soil significantly. A design with wheels was the most favorable with treads coming in a close second.

Table 3 – Design Matrix for Locomotion Design Ideas
Scale from 1 – 3 (One being the most negative, three being the most positive)

Criteria	Wheels	Treads	Legs	Wires
Complexity	3	2	1	1
Ground Pressure	2	3	2	3
Stability	3	3	2	2
Navigability	3	2	1	1
Speed	2	2	1	2
Cost	3	2	1	1
Total	16	14	8	10

The most favorable design ideas to model are pictured below.

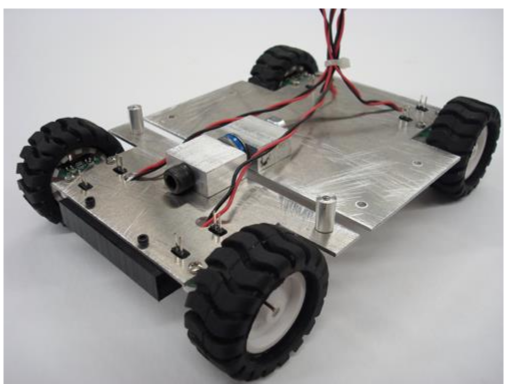

Figure 6 – Prototype Platform with Wheels[8]

Figure 7 – Treaded Robot[9]

4.2 Navigation

The following table presents the design matrix constructed with navigational design ideas. As shows, the idea of using ultrasonic technology as well as whiskers was the most favorable ideas in regards to the criteria.

Table 4 – Design Matrix for Navigation Design Ideas
Scale from 1 – 3 (One being the most negative, three being the most positive)

Criteria	**GPS**	**Ultrasonic**	**Whiskers**	**Computer Vision**
Complexity	1	3	3	2
Reliability	1	2	2	2
Resolution	1	2	2	2
Speed of Response	2	3	3	3
Cost	1	3	3	2
Total	6	13	13	11

4.3 Weeding Mechanism

The following table presents the design matrix to determine the best possible mechanism for the purpose of weed removal.

Table 5 – Design Matrix for Weeding Mechanism Design Ideas
Scale from 1 – 3 (One being the most negative, three being the most positive)

Criteria	**Find and Pluck**	**General Area**
Complexity	1	3
Reliability	3	1
Speed	1	2
Effectiveness	2	3
Cost	1	2
Total	8	11

Pictures presented below show ideas for designing the mechanism for weed removal.

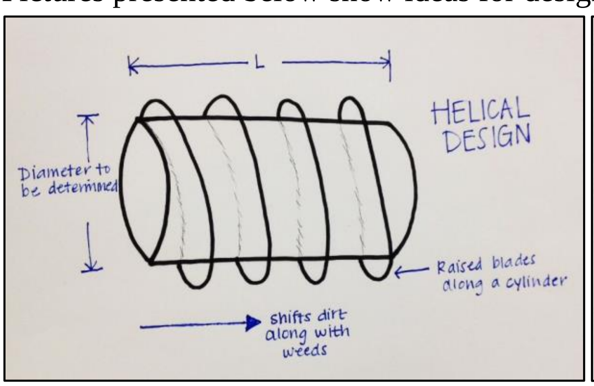

Figure 8 – Helical Design

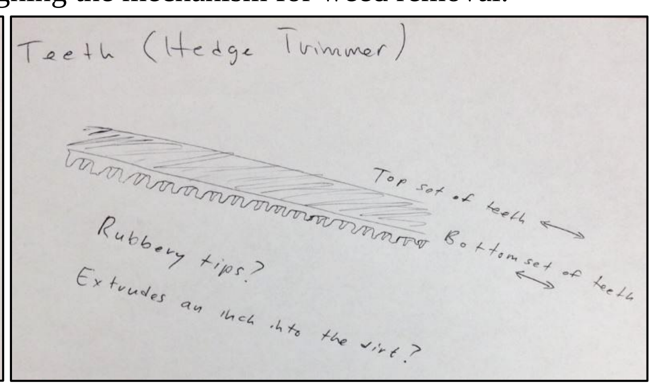

Figure 9 – Teeth Design for Weed Removal

5.0 Methodology

To accomplish this project the robot will have to be constructed in separate Subdivisions. The robot will be broken up into locomotion, navigation-localization, and weeding. Locomotion will focus on how to move the robot through rough and possible muddy terrain, while maintaining low ground pressure. Navigation-localization will deal with how to get to and through each plot of crops and deal with separating plant from weed. The weeding subdivision will determine the most efficient form of weeding without disturbing the crops or causing large amounts of damage to the soil.

5.1 Schedule

The Gantt chart is broken down into three parts. The first part is understanding the project. This part includes sections that revolve about getting to know the project better. From getting a better understanding of the needs of the sponsor to identifying the resources and finally elaborating on the specifications as the project continues. The second part is developing solutions. This part takes information that is being learned from the first part and applies it to creating solutions that meets the needs of the sponsor. This section includes coming up with strategies for the robot, prototyping those strategies, selecting the concept that works the best, and finally breaking that concept down into something manageable and delivering a solution. The final section is a summary of how our time is being spent on the different components of the project. Locomotion, navigation, and weeding are the different modules that the weeding robot will be broken up. These parts will each go through background research, design specification, generation of ideas, concept selection, and reviewing with the sponsor. These are a summary of what is being shown in the first two parts of the Gantt chart and are just used to help understand how everything is connected.

5.2 Resource Allocation

Since this senior design project is multidisciplinary and has students from both the Electrical and Computer Engineering department and the Mechanical Engineering department, the project tasks will be assigned so that they best fit each member’s major. Microsoft Project will be utilized as well to ensure that each member has a fair level of work to complete in regards to everyone else.

Mechanical Engineers

<u>Team Leader</u> - Responsible for administrative tasks as well as being spokesperson for the team. The team lead will be responsible for the continued contact with the sponsor as well as for the scheduling of all events. The team lead will also focus on ensuring microprocessor technology works with the mechanical side of the robot.

Primary - Grant Richter
Secondary – Nathan Walden

Lead Mechanical Engineer - In charge of mechanical design work, specifically making sure drawings are consistent. The lead mechanical engineer will also assist with work associated with the electrical design. The lead mechanical engineer will also make sure all design proposals are reviewed by both our advisor and the sponsor and make sure to properly and completely explain all mechanical aspects of design to others. Mechanical design focus on drive system of the robot.

Primary - Nathan Walden
Secondary – Coen Purvis

Financial Advisor - Tasked with allocation of the budget and managing purchase requests. The financial advisor will ensure the allocated budget is properly Design tasks focus on the actual weeding mechanism for the robot.

Primary - Amanda Richards
Secondary – Grant Richter

Specifications Leader - Tasked with designing body of robot and making sure that weight and size are applicable to specifications given by the project sponsor.

Primary - Coen Purvis
Secondary – Amanda Richards

Electrical and Computer Engineers

Lead Electrical Engineer - Responsible for electrical design, making sure all systems work with mechanical design. Focus on electrical hardware design systems such as embedded systems on robot and charging station.

Primary - Ian Nowak
Secondary – Jeremy Rybicki

Webmaster - Responsible for the website which will grow as team progresses through the project. Focus on software design such as robots autonomy to drive itself down rows as well as location charging station, crops and weeds.

Primary - Jeremy Rybicki
Secondary – Ian Nowak

6.0 Conclusion

Through the use of the project planning document, the DeepDivers have constructed a well thought out time line and approach for delivering on the project goals that were set forward. In order to satisfy the sponsor, Jeff, the group has devised a compromise between his desired goals, and the scope of the project that can be accomplished in the limited budget and time frame. The team plans to approach design and construction by splitting up the project into key components. These key components are locomotion, navigation and weeding methods. While there are more desires for the project, such as 24/7 operability and waterproofing, the primary components of the project will be accomplished first. By splitting up the responsibility of the project between the group members, the team has ensured that each task has a primary and secondary accountability for each task. Through the construction of this document, the team has learned some valuable lessons. When the customer presents a set of goals, there is a tough compromise between the idea that the customer has and the product which the team can deliver. Another lesson learned was that it is difficult to plan a project into the future, and so to make an accurate estimate, the tasks must be broken up into small enough chunks to set reasonable deadlines. Finally, it is necessary to allocate time to each and every task, no matter how small, in order to ensure that it is accomplished.

7.0 References

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8.0 Appendix

Fig. 10: Gantt Chart

	Task Name	WBS	Duration	Start	Finish
1	**Understanding Project**	**1**	**50 days**	**Mon 8/25/14**	**Fri 10/31/14**
2	Identifying Need	1.1	15 days	Mon 8/25/14	Fri 9/12/14
3	Code of Conduct	1.2	0 days	Fri 9/5/14	Fri 9/5/14
4	Design Specifications	1.3	15 days	Mon 9/15/14	Fri 10/3/14
5	Identifying Resources	1.4	15 days	Mon 9/22/14	Fri 10/10/14
6	Needs Assessment Deliverable	1.5	0 days	Fri 9/26/14	Fri 9/26/14
7	Elaborate Specifications	1.6	15 days	Mon 10/13/14	Fri 10/31/14
8	**Develop Solutions**	**2**	**61 days**	**Mon 9/15/14**	**Fri 12/5/14**
9	Background Research	2.1	10 days	Mon 9/15/14	Fri 9/26/14
10	Strategies	2.2	15 days	Mon 9/15/14	Fri 10/3/14
11	Prototyping	2.3	15 days	Mon 9/22/14	Fri 10/10/14
12	Project Plans Deliverable	2.4	0 days	Fri 10/10/14	Fri 10/10/14
13	Concept Selection	2.5	10 days	Mon 10/13/14	Fri 10/24/14
14	Midterm Presentation 1	2.6	0 days	Tue 10/14/14	Tue 10/14/14
15	Concept Breakdown	2.7	25 days	Mon 10/27/14	Thu 11/27/14
16	Midterm Presentation 2	2.8	0 days	Tue 11/18/14	Tue 11/18/14
17	Design Solution	2.9	21 days	Fri 11/7/14	Fri 12/5/14
18	Final Presentation	2.10	0 days	Tue 12/2/14	Tue 12/2/14
19	**Locomotion/Navigation/Weeding**	**3**	**76 days**	**Mon 9/15/14**	**Fri 12/26/14**
20	Background Research	3.1	10 days	Mon 9/15/14	Fri 9/26/14
21	Design Specifications	3.2	10 days	Mon 9/15/14	Fri 9/26/14
22	Generate Ideas	3.3	30 days	Mon 9/22/14	Fri 10/31/14
23	Concept Selection	3.4	25 days	Sat 11/1/14	Thu 12/4/14
24	Review With Sponsor	3.5	39 days	Tue 11/4/14	Fri 12/26/14